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Jordan Journal of Natural History

Editorial Preface

It is a pleasure to present issue 8 of Jordan Journal of Natural History (JJNH), a journal published by the Conservation Monitoring Centre, The Royal Society for the Conservation of Nature (RSCN). The Jordan Journal of Natural History (JJNH) is an open access international scientific journal publishing original research and reviews in nature history in its broadest sense. This is taken to include conservation biology, botany, geology, paleontology, zoology, and ecology, including a broad range of systematics papers encompassing traditional taxonomic revisions and descriptions, cladistics analyses and molecular phylogenetic. The editorial policy of JJNH will follow the lines of most international journals. All manuscripts received by the editor will be examined by referees, who will be instructed to judge the papers by the significance and novelty of the results reported and to favour briefness of presentation.

The editorial board will make every effort to ensure prompt processing of the manuscripts received and to widen the circulation of the journal as far as possible. A group of distinguished scholars have agreed to serve on the editorial board. Without the service and dedication of these eminent scholars, JJNH would have never existed. Now, the editorial board is encouraged by the continuous growth of the journal and its formation into a true multidisciplinary publication. We are also honored to have the privilege of working with all members of the international advisory board served by a team of highly reputable researchers from different countries across the globe. We are also delighted with our team of national and international reviewers who are actively involved in research in different natural history fields and who provide authors with high quality reviews and helpful comments to improve their manuscripts.

We would like to reaffirm that the success of the journal depends on the quality of reviewing and, equally, the quality of the research papers published. In addition to being a hard-copy journal, JJNH is an open access journal which means that all contents are freely available for the users and their institutions free of charge. Users are allowed to read, download, copy, distribute, print, search, or link to the full texts of the articles in this journal without asking for prior permission from the publisher or the author. This is in accordance with the BOAI definition of open access.

At the end of this preface, would like to thank our readers and authors for their continuing interest in JJNH, and each member of our editorial and review boards for their continued hard work, support and dedication, which made it possible to bring another new issue of JJNH to the multidisciplinary international audience. We very much appreciate your support as we strive to make JJNH one of the most leading and authoritative journals in the field of Natural History Sciences.

December, 2021

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Hamidan, NA, Geiger, MF and Freyhof, J. 2014. *Garra jordanica*, a new species from the Dead Sea basin with remarks on the relationship of *G. ghorensis, G. tibanica* and *G. rufa* (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwaters*, 25(3): 223-236.

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Table of Contents

Jordan Journal of Natural History, 8 (2), 2021 Pages: 11-19

New Records for the Native Flora of the West Bank, the Occupied Palestinian Territories

Banan Al-Sheikh [1,2] and Mazin B. Qumsiyeh[2*]

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Abstract: Thirteen species which belong to eight families of vascular plants are hereby reported as new and noteworthy records from the Occupied Palestinian Territories in the West Bank. While reported elsewhere in Palestine, many provide range extensions southwards and it is relevant to report them here especially that Palestine is now recognized as a state within the 1967 borders (West Bank and Gaza) and as this can be helpful for planning purposes. These include *Alisma plantago-aquatica* L., *Damasonium alisma* Miller, *Butomus umbellatus* L., *Lactuca aculeata* Boiss. & Kotschy ex Boiss, *Scorzonera phaeopappa* (Boiss.) Boiss., *Convolvulus scammonia* L.., *Convolvulus coelesyriacus* Boiss., *Stachys distans* Benth., *Salvia sclarea* L., *Securigera parviflora* (Desv.) Lassen, *Crypsis acuminata* Trin., *Crypsis alopecuroides* (Piller et Mitterpol) Schrader, and *Pteris vittata* L. Much more work remains to be done to add to the growing list of the flora of this region.

Keywords: Geographic distribution, Palestine, Flora, Range extension, Biodiversity.

Introduction

The small geographic area of Palestine enjoys diverse climates because of its geologic history (African and Arabian plate movements that resulted in high mountains in addition to hosting the lowest point on earth at the Dead Sea). This history and its presence at the nexus of the Eurasian and African continents allow this area to have diverse habitats with floristic elements ranging from Mediterranean, Irano-Turanian, Saharo-Aindian, Coastal, Ethiopian and Sudanese flora and fauna (Soto-Berelov *et al.*, 2015). The local flora has been subject to various investigations, yet much remains to be explored including updating its presence, ecology, and the conservation status of many families and groups (Post, 1933; Zohary, 1966, 1972; Feinburn-Dothan, 1978; Zohary and Feinbrun-Dothan, 1986; Danin, 1992; Fragman *et al.*, 1999; Taifour and El-Oqlah 2017; Xu *et al.* 2020; Pahl and Qumsiyeh 2021).

More importantly, there are also many areas rarely visited by botanists in the Occupied Palestinian Territories (OPTs) such as the northern West Bank (see maps in Levin & Shmida, 2007 that show lack of data for these areas). There is an urgency for conducting similar studies because of the threats of urbanization, the intensification of agriculture, changes in land use (military zones, firing zones), changes in water management, intensified tourism, and climate change (Qumsiyeh *et al.*, 2014; Qumsiyeh and Amr, 2017; Al-Shaikh and Qumsiyeh in press).

The authors strongly believe that listing species in the West Bank and Gaza (even those previously reported in other parts of historic Palestine) is important for two reasons: 1) A more thorough geographic distribution is produced (many species for example will reach their southernmost distribution in the West Bank). 2) Palestine

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*Corresponding author: mazin@qumsiyeh.org is now recognized as a state within the 1967 borders (West Bank and Gaza) and hence this can be very helpful for planning purposes and for preparing national reports for the Convention on Biological Diversity which Palestine had signed. Recent studies by (Al-Sheikh 2019) shed light on the flora of the occupied West Bank which is considered a rich biodiversity hotspot with many endemic (Cuttelod *et al.*, 2009) and rare species (Al-Shaikh and Qumsiyeh, in press). The current study is extended to report new data on some species from the West Bank to build a better knowledge base for this rich flora.

Methods

Al-Sheikh has been documenting and photographing plants in the area for the past twenty years. Data were collected via trips to the locations cited below usually in the spring over the past few years. Coordinates provided are based on the longitude and latitude based on the Global Positioning System (GPS) mapping. Altitudes are given in meters above sea level. For each species, the localities are reported and are followed by comments on status. Photographs were taken by the senior author and are from the new localities mentioned unless stated otherwise. The species were identified from literature (e.g., Feinbrun-Dothan 1978; Feinbrun-Dothan and Danin 1991) including certain monographs referring to particular groups (e.g., for *Convolvulus*, see Scotland *et al*. 2015). Locality data were compared with data from Danin (2015), flora.org.il and GBIF (Horvitz and Danin 2015).However, the latter include many amateur reports not confirmed by botanists; also some of the coordinates did not match. Comparisons are also noted with the nearby Jordan (Al-Eisawi 2013; Taifour and El-Oqlah 2017; though the number and status of the taxa are not certain). Original herbarium specimens were deposited at the National Agricultural Research Center (NARC)/Ministry of Agriculture. Also, duplicate specimens that are listed under each species are preserved in the Palestine Institute for Biodiversity and Sustainability, Bethlehem University, and are labeled as PMNH-Hxxxx (which refers to Palestine Museum of Natural History-Herbarium). Unless otherwise indicated, one specimen of each species is preserved at NARC and one at PMNH-H.

Results

The results of this survey confirm that thirteen taxa in eight families are hereby recorded in the area of the West Bank which were either not reported earlier or were dubious and now confirmed as present in this contested part of Palestine.

Alisamataceae

Alisma plantago-aquatica L., Figure 1A
PMNH-H00244, Arraneh, Jenin Governorate, N: 32° 30.606/ E: 35° 20.155; Alt 199 m; 27 March 2017

An aquatic or semi-aquatic perennial ,40-80 cm. Leaves long petiolate with blade elliptical-ovate, subcordate at base. Flowers disposed on a pyramid-shape inflorescence, taller than the rest of the plant, white flowers, up to 15 mm in diameter. Petals and sepals are in threes; there are six stamens and numerous Fl. March-September. Hab. small rock Ponds filled with rainwater.
This species is listed on the local red list (Sapir *et al.*, 2003) and is found in the extreme north in Lake Hula, Upper Galilee and Jabal Alshaikh (Mt. Hermon) (https://flora.org.il/en/plants/ALIPLA/). The record provided through this study is far to the south of these localities and is the first record in the West Bank.

PMNH-H00257; Sanour Plain, Jenin Governorate; N: 32° 21.944/ E: 35° 16.054; Alt. 356 m; 24 July 2020

Annual,10-40 cm. Leaves long petiolate 3-8 cm. ovate-oblong, cuneate at the base. Scapes longer than leaves, whorls few, 5-7 flowers. Petals white, yellow at base. Fl. April-June. Habitat site of inundated in winter.

Figure 1. **A**. *Alisma plantago-aquatica* L., **B**. *Damasonium alisma* Miller; **C**. *Butomus umbellatus* L; **D**. *Scorzonera phaeopappa* (Boiss.) Boiss.

Damasonium alisma Miller, Figure 1B

This species is noted to be spread in the Mediterranean Zone and has been reported as rare in the Samaritan mountains (Danin 2004) but no specific localities were given. Its ecology here like elsewhere is in moist areas that get flooded in winter but dry fairly quickly, and once semi-dry, the plants grow quickly and usually are not seen by August.

Butomaceae

Butomus umbellatus L, Figure 1C

PMNH-H00252; Sanour, Jenin Governorate; N: 32° 21.944/ E: 35° 16.054; Alt. 356 m; 24 July2020.

Aquatic perennial, 40-150 cm. Thick creeping rhizome. Scape terete longer than leaves. Leaves basal rosette, erect, linear, 3-10 mm broad. Inflorescence, terminal, umbel-like with many flowers. Flowers showy, 2-2.5 cm in diameter. Petals obovate, pinkish-white. Sepals smaller than petals. Fl. April-June. Habitat site inundated in winter as a temporary pond.
Reported in the Hula Basin and the Sharon Plain, and very rarely in the Marj Ibn Amer area (Esdraelon) (Danon 2004). The species prefers moist habitats; perhaps, this is why the researchers found it in the area of Sanour (a valley that gets flooded in winter).

Asteraceae (Compositae)

Lactuca aculeata Boiss. &Kotschy ex Boiss.

PMNH-H00246; Mikhmas intersection (roadside) from the road of Jaba’-Nablus, Ramallah Governorate; N: 31°87.550 /E: 35°26.692; Alt 588 m; 20 Aug 2019

Annual up to 100 cm tall. Stem whitish, glabrous or hispid. Stem leaves 3-9 cm long, 1.5-3.5 cm wide, entire, sinuate-dentate, attenuate or auriculate, glaucous on both surfaces. Inflorescence paniculate, with many heads. Peduncle hispid or glandular below heads, covered with bracts. Corolla ligulate yellow. Achenes 7.5 mm long, pilose, brown, ribbed, with a filiform beak. Pappus of simple bristles, white, at least 3.5 mm long. Fl. May-August. Hab. disturbed habitat.

It was reported by Danin (2004 and https://flora.org.il/en/plants/LACACU/) in the Hula and the Golan (Occupied Syrian Territory) and Baharav et al. (2018) added detailed distribution maps in northern Palestine and the occupied Golan Heights. It is also recorded in Jordan (Kik *et al.* 2017; Taifour and El-Oqlah2017). This is the southernmost record of the species in historic Palestine and the first in the West Bank, Occupied Palestinian Territories (OPTs). *Lactuna tuberosa* Jacq., and *L. viminea* are more common (Al-Sheikh and Mahasna, 2016).

Scorzonera phaeopappa (Boiss.) Boiss., Figure 1D

PMNH-H00256; Faqoua', Jenin Governorate; 32° 29.763 /E: 35° 24.410, ALT 388 m,20 March 2018 North facing hillside, mixed plants with olive groves.

Perennial herb, 20-45 cm. Stems erect, scape-like. Radical leaves erect linear, 2-5 mm broad. Peduncles one-headed. Flowering heads 3-4.5 cm in diameter. Involucre densely ciliate near apex. Florets pink, longer than involucre. Achenes glabrous, striate in the lower third. Pappus long as achene. Fl. April-May. Habitat characterized by Terra Rosa soil between limestone outcrops.
It was recorded by Danin (2004) and in https://flora.org.il/en/plants/SCOMUL/ as *S. multiscapa.*Zaika et al.(2020) providedtaxonomic revisions. It is foundin the Upper Galilee where it is more common than the nearby area of Mount Gilboa (Jebal Jalboun) and Esdraelon Plain (Marj Ibn Amer). The species occurs in similar habitats of hedges near olive groves in Jordan (Al-Eisawi 2013). This is its southernmost record and the first in the OPTs. *Pseudopodospermum (Scorzorena) paposa* is more common and was reported in places such as Wadi Quff (Al-Sheikh and Mahasna, 2016)

Convolvulaceae

*Convolvulus scammonia*L.,Figure 2A

PMNH-H00251; Wadi Balat, Nablus-Ramallah Road, Ramallah Governorate; 1 km West Wadi Haramiya spring;N: 31° 59.889/ E: 35° 14.367;Alt 601 m;17 May 2016 Roadside.

Glabrous perennial herb. Stems 30-100 cm. Leaves petiolate, entire, triangular, hastate at base, upper leaves sometimes linear, petiole about as long as blade or shorter. Flowers axillary. Sepals glabrous, unequal, inner sepals longer than outer sepals. Corolla pale yellow, 25-40 mm, purplish stripes on outside. Fl. April-June. Hab. hedgerows with Terra Rosa soil.

Convolvulus scammonia is found in Jordan where it is also used as a medicinal plant (Al-Eisawi 2013; Oran and Al-Eisawi 2014; Taifour and El-Oqlah 2017).This species was documented by Danin (2004 and https://flora.org.il/en/plants/CONSCA/) as common in upper Galilee and Mt. Carmel but more rarely encountered elsewhere in the north of the country (Feinburn-Dothan 1978). Danin (2004) mentions "Samaria" (northern mountains north of the West Bank) but does not give specific locality records. *C. siculus* L. is more common than *C. scammonia* and *C. coielesyriacus* and was earlier reported in places like Wadi Quff (Al-Sheikh and Mahasna, 2016).

*Convolvulus coelesyriacus*Boiss., Figure 2C

PMNH-H00245, Bardeiba, Yasseed, Nablus Governorate,32° 17.454 /E: 35° 17.533, Alt 571 m, 3 April 2015, south facing slope, grazing area.

Annual herb,15-40 cm, branched from base. Stems decumbent or ascending. Leaves petiolate, lower ones are cordate at base. Flowers solitary in leaf axils. Sepals covered with spreading hairs. Corolla 15-20 mm, pink. Fl. March-May. Hab. phrygana and in olive groves.

It is reported in Jordan (Al-Eisawi 2013; Taifour and El-Oqlah 2017) and in the studied area as common in upper Galilee and Mt. Carmel, but more rarely encountered elsewhere in the north of the country (Danin 2004 andhttps://flora.org.il/en/plants/CONCOE/). This is also the southernmost record in Palestine.

Lamiaceae (Labiatae)

Salvia sclarea L Figure 2B

PMNH-H00247, Jaba', Jenin Governorate, N 32° 19.032'/E 35° 15.071', Alt 456 m; 30 June 2020.PMNH-H00248, Burqa, Alqosour, Nablus Governorate, N 32° 18.410'/ E 35° 12.142', Alt. 654 m; 30 April 2012.

Perennial aromatic herb, 40-100 cm, covered with long hairs. Stems erect ending with narrow panicle. Leaves rugose, 8-15 cm, broadly ovate, cordate at base, cauline leaves long petiolate, the upper most sessile. Corolla purplish-pink or pale blue, 2-3 times as long as calyx. Verticillasters 2-6 flowers. Calyx campanulate, about 10 mm, Fl. May-June. Habitat: high sunny mountains.

Salvia sclarea was reported from the upper Galilee and the Golan (occupied Syrian territories) in batha among rocks (Danin 2004 and https://flora.org.il/ en/plants/SALSCL/). Many species of *Salvia* were reported in the study region, but for this species, it is the southernmost distribution noted in historic Palestine. The species was not reported in Jordan in the checklist of Al-Eisawi (2013), but was reported by Oran and Al-Eisawi (2014) and by Taifour and El-Oqlah (2017).

*Stachys distans*Benth.Figure 2E

PMNH-H00249, Deir Ibzi', Ain Bubein, Ramallah Governorate, N: 31° 55.146/ E: 35° 07.743,Alt 551 m, 10 July 2012.

Perennial herb, 30-100 cm, branched above base, flowering stems with long internodes. Leaves 2-4 cm, oblong-lanceolate, dentate, lower leaves petiolate, upper leaves sessile , Verticillasters few to many flowers. Corolla about 10 mm, white. Fl. May-June. Hab. rocky places in garigue.

Danin (2004https://flora.org.il/en/plants/STADIS/) reported this species in the north of Historic Palestine especially found in higher frequency in Upper and coastal Galilee in garigue and maquis rocky habitats. He noted it as rare in the Judean Mountains. This is the first record in the northern West Bank of the species. The species was not reported from Jordan in the checklist of Al-Eisawi (2013) but was reported in the checklist of Taifour and El-Oqlah (2017).

Papilionaceae

Securigera parviflora (Desv.) Lassen, Figure 2D

PMNH-H00250, Um Al-Tut Nature Reserve, Jenin Governorate; N: 32° 26.03/ E: 35° 20.34;Alt 257 m, 18 March 2018.
Annual glabrous herb, 10-40 cm. Stems erect or procumbent, branching from base. Leaves 3-12 cm, leaflets 7-13 pairs, oblong-obovate, mucronulate at apex. Racemes 4-7 flowers. Calyx minute, Corolla 3-4 times as long as calyx, yellow. Pod 4-7 cm, narrow linear, semicircular, thickened at joints. Fl.March-April. Hab. degraded phrygana.

Securigera parviflora was reported in the Galilee and northwestern and western (coastal) areas of historic Palestine in Mediterranean woodland and shrub lands (Danin 2004 and https://flora.org.il/en/plants/SECPAR/). These specimens were observed in Batha habitats in the north facing the slope of Um Al-Tut protected area. The species was not reported from Jordan yet, but is believed to occur there based on habitat availability.

Poaceae (Gramineae)
Crypsis acuminata Trin.
PMNH-H00254, Sanour, Jenin Governorate, N 32° 21.709' E 35° 15.398', Alt. 357 m, 24 June 2018.

Annual herb, 15-30 cm, branched at base, sheaths narrowly membranous-margined, sometimes fringed with hairs. Panical terminal spike-like, narrowly cylindrical, dense, bristly, remote from uppermost leaves after flowering. Glumes membranous, slightly hairy margins, lower glume narrower than the upper glume. Palea, two-veined, shorter than lemma. Fl. May-August. Hab. sites inundated in winter.

According to Danin (2004 and https://flora.org.il/en/plants/CRYACM/), this species is "rare in Samaria," but no actual records are given, so the researchers think this record is worth-noting from Sanour, an area that gets flooded after the rains, and dries into mud flats in the summer.

Crypsis alopecuroides (Piller et Mitterpol) Schrader

PMNH-H00253, Sanour. Jenin Governorate, N: 32° 21.709 /E: 35° 15. 398; Alt. 357 m; 24 June 2018.

Annual herb, 3-20 cm, branched at base. Leaves flat, with cylindrical sheaths narrowly membranous-margined, terminal spike-like, narrowly cylindrical, several times longer than broad, very dense, enveloped

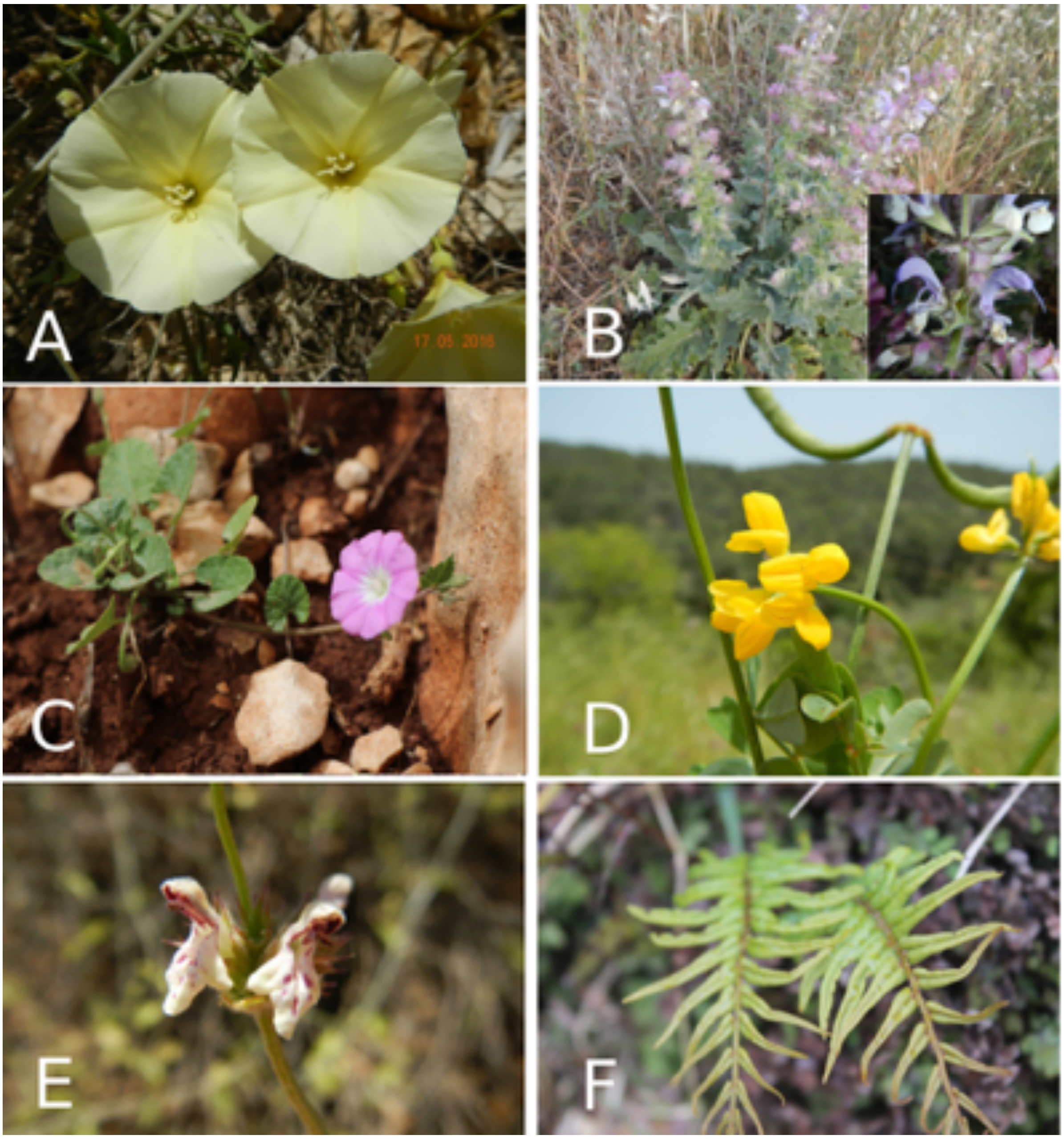

Figure 2 **A**. *Convolvulus scammonia* L.; **B**. *Salvia sclarea* L.; **C**. *Convolvulus coelesyriacus* Boiss.; **D**. *Securigera parviflora* (Desv.) Lassen; **E**.*Stachys distans* Benth; **F**.*Pteris vittata* L.

in uppermost sheath only at the beginning of flowering. Glumes hispidulous at keel. Upper glume longer and broader than the lower. Pelea two-veined. Fl. May-Oct. Hab. sites inundated in winter.

According to Danin (2004 and https://flora.org.il/en/plants/CRYALO/), this species is found in the occupied Golan heights and Mt. Hermon, butis rare in “Judean hills”. However, no actual records are noted in the latter area, so the researchers believe this record is worth mentioning from Sanour in the northern part of the West Bank (an area that gets flooded after the rains and dries into mud flats in the summer).The researchers doubt the species’ presence in the southern areas.

Pteridaceae

Pteris vittata L., Figure 2F

PMNH-H00255, Ain ‘Oleim, Beita Al-Fouqa, Nablus Governorate, 32^0 26’ N $25^0$49’ E; Alt 762 m, 29 March 2019.

A terrestrial perennial fern, 30-100 cm. Rhizome creeping, covered with brown scales. Leaves densely tufted, pinnate 3-10 cm, opposite, linear, subsessile, all pinnately nerved with simple veins. Sporangia surrounded by sterile filaments. Fl. March-August.

According to Danin (2004, andhttps://flora.org.il/en/plants/ptevit/), this species is reported in the far north of Palestine (upper Galilee, Hula area, and Kinrot Valley near Lake Tiberias). The current record for the species is the furthest southwards to be reported and is the first in the West Bank.

Discussion

The latest checklist of the species of vascular plants in the West Bank listed 1612 species which belong to 117 families (Al-Sheikh 2019). Here in, this study reported thirteen more species to add to this list and many of those represent significant range extension to the south and are the first records in the West Bank. The nearby Kingdom of Jordan has 2543 species (Al-Eisawi 2013; 2531 species per Taifour and El-Oqlah 2017), but this number is debated and needs updating. Historic Palestine has 2750 species in 138 families (Danin 2004). Both sides of the Jordan valley thus have a rich floral assemblage due to the region’s geologic history that created a varied topography and climate, including having the lowest point on earth at the Dead Sea, some elevated mountains on both sides of the Jordan Valley, and a diversity of arid and moist regions. Furthermore, the geographic location allows for the penetration of the Ethiopian/Sudanese flora through the Great Rift Valley. This paper and others published show that much remains to be explored. This becomes more urgent especially that diversity is unfortunately threatened by anthropogenic effects in the region of Palestine by the colonial Israeli activities (Qumsiyeh and Abusarhan, 2020; Qumsiyeh and Albardeya, in press).The current study shows rare plants (found in single localities (twelve species in the West Bank) or at best two localities (*Salvia sclarea*). A recent study actually shows that even though about a third of the plant species of the West Bank is quite rare, and is found in very few localities, it is subject to damaging human impacts (Al-Shaikh and Qumsiyeh in press).

Conclusion

Such studies of the extension of ranges and notes on the ecology and habitats of plants are highly needed for a better planning and conservation measures. Much more can be done and is being done to protect the fauna and flora of this historic land (EQA 2015; Qumsiyeh *et al.* 2017). The researchers also encourage more studies similar to this one to understand the fauna and flora of the OPTs which have been neglected in light of political and social challenges. Palestine as a nascent state should first revise the key plant areas (KPAs) based on most up-to-date data, and then incorporate the most recent data for a more proper management especially in nature reserves and other KPAs where the researchers found many of the above-mentioned taxa.

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The Consumption of Dead *Incilius luetkenii* (Anura: Buffonidae) by *Ctenosaura similis* (Squamata: Iguanidae)

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Abstract: The Ctenosaur or Black Iguana (*Ctenosaura similis*) occupies xeric habitats in Mesoamerica from southern México to Panamá. Juvenile individuals consume mainly invertebrates, but they present an ontogenic change to herbivory as adults. Moreover, the species is highly omnivorous and consumes several types of organisms including young Ctenosaurs. However, the consumption of carrion is rare in this species with only one case of consuming a giant toad (*Rhinella horribilis*) reported. The current study reports the consumption of a dead Yellow Toad (*Incilius luetkenii*) by a young adult Ctenosaur at the dry forest of northwestern Costa Rica. This toad species is common in the dry forest of Santa Rosa National Park where it breeds explosively at the beginning of the rainy season. At this time, several individuals are killed by cars while crossing the roads, and the young adult Ctenosaur, it seems, took advantage of this situation for an easy meal.

Key Words: Black Iguana; Carrion eater; Omnivore; Tropical dry forest.

Introduction

Iguanidae is a Squamata family that contains forty-four species of mostly large herbivorous lizards, eight of which are critically endangered (Buckley *et al*., 2016). The most diverse iguana genus is *Ctenosaura* with fifteen species (Uetz *et al*., 2020). Among these, the Black Iguana or Ctenosaur (*Ctenosaura similis*) has the widest distribution ranging from the Isthmus of Tehuantepec, Mexico, south to central Panama on the Pacific slope, and in several isolated populations along the Atlantic slope, from 0 to 1320 m elevation (Köhler, 2008). However, phylogeographic studies have found considerable variation within this wide-ranging taxon (Buckley *et al*., 2016). As recognized at the moment, *Ctenosaura similis* is a large locally abundant iguana with no crest on the head, and a cylindrical tail that bears whorls of distinctly enlarged and heavily keeled spiny scales that are separated by rows of small scales (Mora, 2010). The standard length of adult males is 489 mm reaching up to 400 mm in females, and the total length is 1300 mm and 800 mm respectively (Leenders, 2019).

The *Ctenosaura* species generally occupy dry terrains with cacti or rocks, or dry forests with hollow trees and many rock crevices, which they use as refuge (Mora, 2010). The *Ctenosaura* is found in various types of habitats; for example, on the Pacific versant of Mesoamerica, it occurs primarily in wooded or semi-forested habitats in xeric environments (Mora, 2010), mainly in dry forests where it prefers open areas (Mora, 1989).

Ctenosaurs consume a wide variety of vegetal and animal food. Juveniles feed mainly on insects, but at the end of the first year of life, the proportion had decreased to only 6% (Mora, 2010). Adults have been considered herbivorous or omnivorous, carnivorous, or opportunists (Mora, 2010). However, frogs and toads are not common items that are consumed mainly because the Ctenosaurs have a diurnal activity with some exceptions (Mora, 1986).

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The Neotropical Yellow Toad (*Incilius luetkenii*) is an explosively breeding species, in particular, when males rapidly shift from a cryptic brown to conspicuous lemon yellow (Rehberg-Besler *et al*., 2015). The very brief mating event coincides with the first rain of the year in their dry forest habitat (Doucet and Mennill, 2010). Right after the amplexus, males return to their cryptic coloration until the females complete the egg-laying and disperse (Rehberg-Besler *et al*., 2015). The Yellow Toad is found across areas from Chiapas, Mexico, to northwestern Costa Rica on the Pacific slope, and in Guatemala, Honduras, and Nicaragua on the Caribbean slope, from sea level to 450 m (Leenders, 2016). This common toad is nocturnal and can be seen in a variety of open areas, including streambeds, disturbed pasturelands, and man-made bodies of water (Leenders, 2016).

Materials and Methods

Ctenosaurs are common at Santa Rosa National Park, Guanacaste Conservation Area, Costa Rica (Mora *et al*., 2015), a UNESCO World-Heritage Site in northwestern Costa Rica (10°40´ N, 85°30´ W; WGS84; 297 m elevation). Tropical dry forests dominate the landscape of Santa Rosa where the rainy season lasts from May to November and the dry season from December to April in average years (Campos and Fedigan, 2013). However, the dry season extends sometimes for some more months, mainly due to El Niño phenomenon (Mora *et al*., 2015).

The researchers conducted observations of the activity of amphibians and reptiles in Santa Rosa from 11 to 21 September 2015. They looked for amphibians and reptiles on the main entrance road to Santa Rosa and saw them feeding on termites on 12 September. The researchers checked for dead herps on this road in the morning of 13 September. On 18 September at about 10.00 p.m., the researchers drove to the main entrance gate and back to the headquarters area of the park (14 km) to look for anuran activity on the road after a heavy rain.

Results

The transition from the wet to the dry season in 2015 in Santa Rosa was delayed until mid-September was well passed with some few showers on the previous days. On 12 September 2015, there was a big storm with heavy rains in Santa Rosa. Termites reproductive caste emerged to mate, and there was a frenetic feeding activity of nocturnal creatures near the headquarters area including toads such as *Rhinella horribilis*, *Incilius luetkenii* and *Rhinophrynus dorsalis*. In the morning of 13 September, there were several dead amphibians in the main entrance road to Santa Rosa. The researchers counted fourteen toads, mainly giant toads (*Rhinella horribilis*) and yellow toads (*Incilius luetkenii*) and three small snakes in a section of 1.5 km of this road. The night before, the researchers observed many toads and frogs (mainly *Rhinella horribilis* and *Lithobates forreri*) on the road feeding on termites (up to 15 individuals/100 m). At 07:44 a.m., they found a young adult Ctenosaur feeding on a yellow toad. The iguana took it from the paved road. The toad, which was a big adult, was dead but basically with no damage. The iguana took the toad from the road and went to a rock where it swallowed it (Figure 1). The whole event took nearly two minutes.

In the afternoon of 18 September, it rained (approximately a twenty-minute shower) in Santa Rosa. The researchers only observed one frog *Lithobates forreri* (at 2220h) after driving 7 km to the main entrance gate and 7 km back to the headquarters area of the park. However, the researchers counted five *Incilius luetkenii* dead on the road on the first 200 m from the Santa Rosa headquarters area on the next morning.

Discussion

Extended dry seasons have a big impact on Santa Rosa organisms mainly due to food shortage. Even though Ctenosaurs are highly omnivorous and very opportunistic, some uncommon behaviors can be observed such as cannibalism during these periods (Mora *et al*., 2015).

Figure 1. Young male Black Iguana (*Ctenosaura similis*) swallowing an adult yellow toad (*Incilius luetkenii*) at Santa Rosa National Park, Costa Rica.

Although the Black Iguana was documented consuming a post-mortem *Rhinella horribilis* (Pasachnik and Corneil, 2011), to the researchers' knowledge, this is the first report of this species consuming yellow toads. *Incilius luetkenii* and *Rhinella horriblis* have two parotid glands that secrete poison, although these glands are small in the first species (Savage, 2002). The researchers could not observe the condition of the glands when the male Ctenosaur took the Yellow Toad from the pavement.

Some organisms take advantage of amphibians that are dead on roads to feed on them, including snakes especially the cat-eye snake (Mora, 1999). *Incilius luetkenii* was the most registered species in 53% of the observations (695 individuals) in a five-month study conducted in the same conservation area (Monge, 2018). On the day following the termite caste emergence, several animals were observed feeding on termites (including Ctenosaurs) or on herp carcasses (including some birds such as caracara falcons –*Caracara cheriway*, and roadside hawks –*Rupornis magnirostris*).

Ctenosaura similis is a true omnivore and a highly opportunistic predator. Juvenile individuals feed mainly on insects (Mora, 2010), and other arthropods including adult tarantulas *Aphonopelma crinirufum* (Dion and Porras, 2014) and *Brachypelma vagans* (Avilés-Novelo *et al*., 2019). However, they are mainly plant-eaters as adults (Mora, 2010). Large individual adults feed on leaves, buds, and fruits, but occasionally they consume lizards such as *Aspidoscelis*, *Sceloporus*, *Marisora unimarginata*, and *Basiliscus vittatus*; frogs, rodents, birds, eggs of other lizards and snakes, and bats (Fitch *et al*., 1971; Henderson, 1973; Fitch and Hackforth-Jones, 1983; Mora, 1987; Cedeño-Vázquez and Beutelspacher-García, 2016; Avilés-Novelo *et al*., 2019).

They even consume juvenile individuals of their own species (Mora, 1991; Mora *et al*., 2015; Garcia-Rosales *et al*., 2020), and they have been observed taking recently hatched hawksbill marine turtles (*Eretmochelys imbricata*), while the hatchlings consume feces of adult individuals (García-Rosales, 2020). Scavenging of vertebrate carcasses is a less common dietary behavior in iguanas (Pasachnik and Corneil, 2011). There are observations concerning this behavior in *Ctenosaura pectinata* (Grant, 1967) and *Iguana iguana* (Loftin and Tyson, 1965). The consumption of *Rhinella horribilis* (Pasachnik and Corneil, 2011), and *Incilius luetkenii* reported here by Ctenosaurs supports an ontogenetic shift to an omnivorous diet in this species. It may be suggested also that carnivory in Ctenosaurs might be more prevalent than what was previously thought (Pasachnik and Corneil, 2011). Also, these observations show that the Black Iguana is one of few opportunistic scavengers of vertebrate carcasses in Iguanidae (Pasachnik and Corneil, 2011).

The Black Iguana is the *Ctenosaura* species with the widest distribution range and it is under the least concern category by the IUCN (Mora, 2010). However, this species is a model organism from the ecological point of view. Its interactions in the dry forest of Costa Rica such as the communal nesting behavior (Mora, 1989), cannibalism (Mora *et al*. 2015) and carrion eater (Pasachnik and Corneil, 2011) are examples of this condition. Besides, this species consumes fruits of several dry-forest plant species, mainly during the dry season, including *Vachellia fernesiana* whose seeds were found in the feces of this iguana which makes it an important seed disperser in this tropical forest (Traveset, 1990), which is one of the mostly threatened tropical ecosystems (Janzen, 1988).

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Morphological and Anatomical Studies on *Buchholzia coriacea* Engl. (Capparaceae) Endemic to West Africa

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Abstract:

Morpho-anatomical and distributional studies of *Buchholzia coriacea* Engl., an endemic species to West Africa, were conducted based on herbaria and fresh samples using physical observation and microtomy. This species is hypostomatic with anomocytic and tetracytic stomata in random distribution on the abaxial surface, and is covered by non-glandular hairs. The subsidiary cells are distinct, epidermal cells polygonal in shape, and the anticlinal walls straight or curved. Abaxial epidermal cells measured 4.139 ± 1.28 µm long and 2.21 ± 0.39 µm wide and the adaxial ones 4.52 ± 0.59 µm long, and 2.74 ± 0.34 µm wide. Guard cells are often equal in size, oval, and with abaxial stomatal index (SI) 36.36. The mesophyll comprised spongy and palisade mesophylls. The palisade parenchyma cells are arranged in rows of 2-3 layers, while the palisade parenchyma cells have 7-8 layers with many intercellular air spaces and a bundle sheath embedded in them. Sclereids and fibre cells occurred in a discontinuous ring outside the secondary phloem. *Buchholzia coriacea* exhibited a latitudinal distribution across the transitional equatorial region of Nigeria which suggests that it is confined to the tropical areas and may not thrive in drier parts. Currently, its conservation status remains unknown and has not been assessed by the IUCN. Therefore, its sustainable collection and use are of paramount importance not only to the Nigerian society, but also to the world at large mainly to face the global climate change resulting from human anthropogenic activities and also because of the medicinal properties of this species.

Keywords: Anatomy, *Buchholzia coriacea,* Capparaceae, Hypostomatic.

Introduction

Buchholzia (Capparaceae) comprises only two species worldwide namely *Buchholzia tholloniana* Hua (synonym: *Buchholzia macrothyrsa* Gilg) and *Buchholzia coriacea* Engl. (synonym: *Buchholzia macrophylla* Pax). *Buchholzia coriacea* is the only species occurring in West Africa (Hutchinson and Dalziel, 1954). These species have close morphological attributes and similar medicinal uses (Lemmens, 2013). *Buchholzia coriacea*is endemic to West Africa and is distributed in the rain forest zone across Nigeria, Ghana, the Central African Republic, Gabon, Congo, Angola, Liberia (Hutchinson and Dalziel, 1954; Ezekiel and Onyeoziri, 2009; Ijarotimi *et al.,* 2015).

Published reports show that much work has been carried out on many genera under this family. Aleykutty and Inamdar (1978) reported the structure, ontogeny, and taxonomic significance of trichomes and stomata in some Capparaceae. El-Ghani *et al.,* (2007) illustrated the taxonomic significance of leaf architecture in the Egyptian species of Capparaceae. Kamel *et al.,* (2009) classified the Egyptian Capparaceae based

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on morphological attributes. Sharma (1969) studied and described the brachysclerieds in *Capparis* and *Crataeva,* while Pranom (2002) described the leaf anatomy of Capparaceae (*Capparis, Cleome, Crateva,* and *Maerua*) in Thailand.

There is adequate literature on the phytochemical, medicinal, antimicrobial, and ethnobotanical uses of *Buchholzia coriacea* (Abubakar *et al.,* 2017; Izah, *et al.,* 2018). *Buchholzia coriacea* has anti-diabetes properties (Adisa, *et al.,* 2011; Okoye, *et al.,* 2012; Egwu, *et al.,* 2017; Obiudu, *et al.,* 2015; Lapshak, *et al.,* 2016), anti-plasmodial activity (Bassey and Izah, 2017), anti-trypanosomal properties (Abubakar, *et al.,* 2017; Izah, *et al.,* 2018), anti-modulatory activities (Eze, *et al.,* 2015), anti-spasmodic and anti-diarrhoea properties (Anowi, *et al.,* 2012), anti-ulcer properties and can be used as worm-expellers (Anowi, *et al.,* 2012; Erhenhi and Obadoni, 2015; Salami, *et al.,* 2017). Traditionally, the seeds of *B. coriacea* are used to treat pregnant women, and has stimulant, tonic, aphrodisiac effects (Anowi, *et al.,* 2012; Erhenhi and Obadoni, 2015). They can also be used as memory boosters (Ibrahim and Fagbohun, 2012; Nwachukwu, *et al.,* 2014), and in the treatment of malaria and fever (Titanji, *et al.,* 2008), cough, hypertension, headaches, sinusitis, and nasal congestion, and in smallpox for skin-itching (Adisa, *et al.,* 2011; Nwaichi, *et al.,* 2017). Moreover, they have effective properties in the treatment of scabies, chest pains and boils (Anowi, *et al.,* 2012; Erhenhi and Obadoni, 2015), syphilis, sinusitis, earache, smallpox, gonorrhea and convulsion in children (Ajaiyeoba, *et al.,* 2003; Nwaichi, *et al.,* 2017).

Previous reports have been done on Nigerian species dealt only with the phytochemical, medicinal, and ethnobotanical uses of this species, while reports from other countries described the morphological, anatomical, palynological, and leaf epidermal features of other taxa in Capparaceae excluding *B. coriacea*. There is no information on the leaf epidermal characters, and the anatomy of *B. coriacea*. The present study presents information on the morphology, leaf micro-morphology, and the ecological distribution of *B. coriacea* from Nigeria and compares the results with other members of Capparaceae to assess its taxonomic position.

Materials and Methods

Voucher specimens studied

The specimens used for this study were collected from the Forestry Research Institute Station Ibadan, Calabar, and Umuelechi-Asa, Abia State (Table 1). **Table 1.** Voucher specimens studied (locations, coordinate, and voucher number)

Distributional study

The information on the specimens deposited in the Forestry Herbarium Ibadan (FHI) and the University of Port Harcourt Herbarium (UPH) is used for the distributional analysis. The localities including the states of collection of the herbarium specimens are used to generate the distributional map of the species (Table 1).

Morphological Studies

The overall morphology of the leaf, flowers, fruits, and seeds of the herbarium and fresh specimens were calculated using a meter ruler and a hand lens. The photographs of the vegetative and other parts of the plant were taken and documented using Nikon D3200 digital camera.

Anatomical Studies

Fresh plant materials were collected from trees growing in the Forestry Research Institute Station Calabar, and Umuelechi Asa, Abia State. Petiole, and midrib; other leaf samples were cut and fixed immediately in Formalin-Acetic-Alcohol for twenty-four hours. After fixation, they were washed thoroughly in distilled water, dehydrated, embedded in paraffin wax after infiltration and sectioned using rotary microtome to the

Table 1. Voucher specimens studied (locations, coordinate, and voucher number)

Locality	Latitude	Longitude	Voucher No.
Ondo State	4.7712	6.7684	FHI 93581
Benin City, Edo State	6.346	5.628	
Eket District, Akwa Ibom State	4.65	7.93	
Sapoba Forest Reserve, Orhionmwon,	6.075677	5.819154	FHI 32885
Onigambari,	7.133333	3.8	
Urhonigbe Forest Reserve, Odigi, Orhionmwon,	5.938197	5.888867	
Omo Forest Reserve, Ijebu East, Nigeria	6.846962	4.371434	
Okomu Forest Reserve, Ovia South-West, Nigeria	6.312748	5.233653	FHI 101633
Aponmu, Ondo State, Nigeria	7.2405	5.0664	FHI25536
Ijebu-Igbo, Ijebu North, Nigeria	6.970306	4.000526	FHI 110096
Idanre Forest Reserve, Idanre, Nigeria	6.857701	5.10551	
Uromi, Edo State	6.708269	6.328938	
Uyo, Akwa Ibom State	5.05127	7.9335	FHI 110746
Umuelechi-Asa, Abia State			UPH/V/1458
Forestry Research Institute Station Calabar,	$5^0$13'24.40"	$8^0$21'44.74"	UPH/V/1457

thickness of 8-12 µm. Sections were stained with Safranin and counter stained with Alcian blue. The photographs of thirty good sections were taken and described.

Results

The results of the current research on *B. coriacea* are presented in Figures 1 to 7 and Table 1.

Ecological Distribution

The available information in the Forestry Herbarium Ibadan (FHI), University of Port Harcourt Herbarium (UPH), Nigeria and the field collections showed that this species exhibits a latitudinal distribution across the transitional equatorial region of Nigeria, extending from Oyo state in the South-West to Akwa-Ibom in the farther south (Figure 1). Most of the species cited in the herbaria were collected from the high rainforest zone of Nigeria. This pattern suggests that *B. coriacea* is confined to tropical areas and is less in the drier parts of Nigeria (Figure 1).

Morphology

A small to medium-size tree of about 4.5 to 6.2 m tall. Leaves lanceolate or elliptic, base cuneate to acute, apex acute, acuminate, 19.5–23.8–25.6 cm. long, 5.2–6.5–8.4 cm. broad, glabrous; midrib very prominent beneath; lateral nerves about 10 - 14, prominent beneath; veins very lax; petiole 2.0–7.5–13.4 cm. long, swollen for about 0.8 - 1 cm. at the apex; inflorescence axillary racemes, slightly branched, 10.2–12.5–14.6 cm. long; pedicels 0·4 – 1 cm. long; bracts 4-5, small green, hook-like; flowers bisexual, stalk about 1·5 cm. long; sepals 4, 4 – 5 × 3 – 4 mm; stamens numerous, free, 1 – 2.5 cm long, cream to yellowish, anthers brownish to blackish; fruit ellipsoid (seeds 2–3) up to 7.8 – 8 × 5-6 cm., with thick woody endocarp about 6 mm. thick; about 1.5 – 2.5 cm. diameter with flattened sides (Figure 2).

Micromorphology

Epidermal characteristics: Lamina hypostomatic with anomocytic and tetracytic stomata in random orientation (Figure 3). Subsidiary cells distinct,

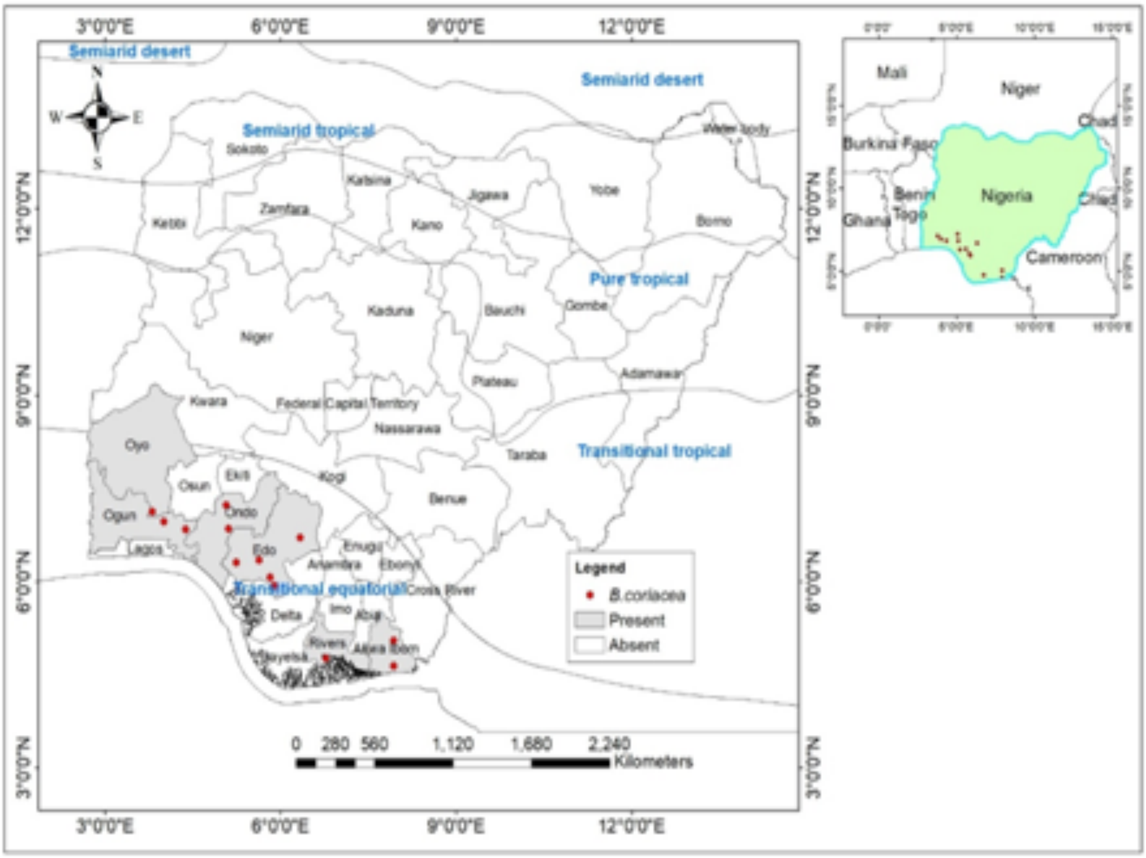


Figure 1. Ecological Distribution of *B. coriacea* in Nigeria

Figure 2. The flowers, fruit and seeds of *B. coriacea*; (A) Flower, (B) fruit, and (C and D) seed.

epidermal cells polygonal in shape, anticlinal walls straight or curved (Figures 3 and 4). Abaxial epidermal cells 4.139 ± 1.28 µm × 2.21 ± 0.39 µm while the adaxial epidermal cells are 4.52 ± 0.59 µm × 2.74 ± 0.34 µm (Table 2). Guard cells are often equal in size, oval, and abaxial stomatal index (SI) 36.36.

Leaf lamina: The transverse section of the lamina exhibits uniseriate upper and lower epidermis with barrel-shaped cells (Figure 5). The adaxial epidermis is covered with a thin cuticle 0.67 µm thick, cells are cylindrical or oval, devoid of stomata, and periclinally elongated. Abaxial epidermal cells are oval, 1.32±0.29 µm thick, and covered with 1.03 µm thick cuticle (Figure 5). The mesophyll comprised spongy and palisade mesophylls. The palisade parenchyma cells are arranged in rows of 2-3 layers, while the spongy parenchyma cells have 7-8 layers with many intercellular air spaces and a bundle sheath embedded in them.

Petiole: A T.S. of petiole has a more or less circular outline with two outwardly directed adaxial ends, and an adaxial surface convex (Figures 6A and 6B). The vascular bundles are collateral in a semi-circle arrangement formed by many distinct strands with patches of fibre on the abaxial side (Figure 6B). The cells of the epidermis are uniseriate, followed by layers of a small, oval, or round collenchymatous hypodermis layer. The ground tissue is composed of round or oval parenchymatous cells.

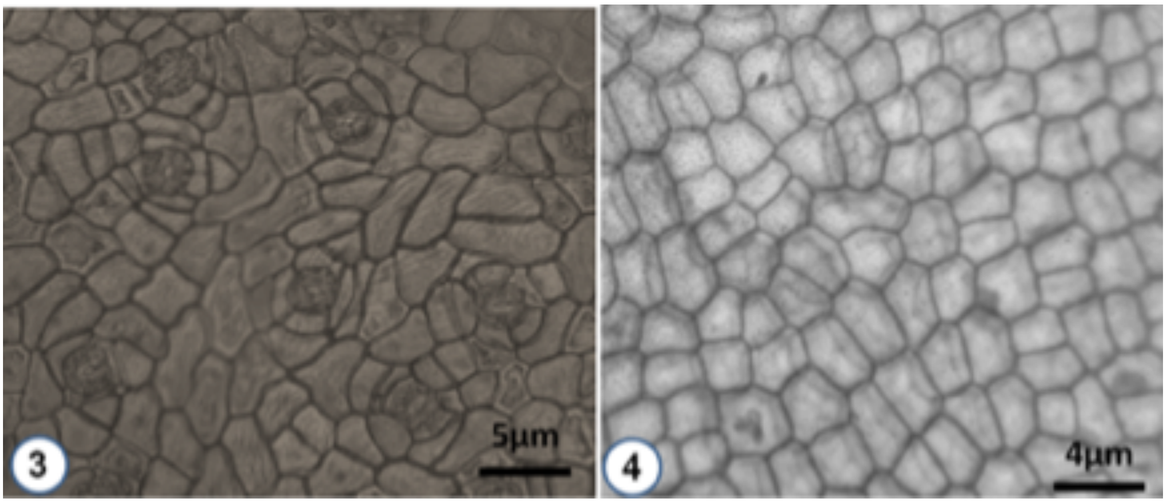


Figure 3-4. Epidermal cells, and leaf lamina of *B. coriacea.* (3) abaxial epidermis, and (4) adaxial epidermis.

Table 2. Measurement of different tissues and cells

Parameter(s)	**Length (µm)**		**Width (µm)**	
	Range	**Mean ± SD**	**Range**	**Mean ± SD**
Stomatal complex	3.83 - 6.56	5.02 ± 0.82	4.15 - 5.26	4.77 ± 0.35
Stomata size	2.37 - 3.38	2.92 ± 0.28	2.20 - 2.96	2.65 ± 0.22
Adaxial epidermal cell	3.31 – 5.58	4.52 ± 0.59	1.86 – 3.38	2.74 ± 0.34
Abaxial epidermal cell	2.22 - 6.17	4.14± 1.28	1.62 - 3.03	2.21 ± 0.39
Leaf Lamina			**Thickness (µm)**	
			Range	**Mean ± SD**
			29.86 - 31.62	30.77 ± 0.55
Adaxial epidermal cell			1.81 - 2.23	2.03 ± 0.13
Abaxial epidermal cell			0.99 – 1.78	1.32 ± 0.29
Palisade mesophyll			4.31 - 6.84	6.06 ± 0.82
Spongy mesophyll			14.11 - 20.8	17.49 ± 2.27

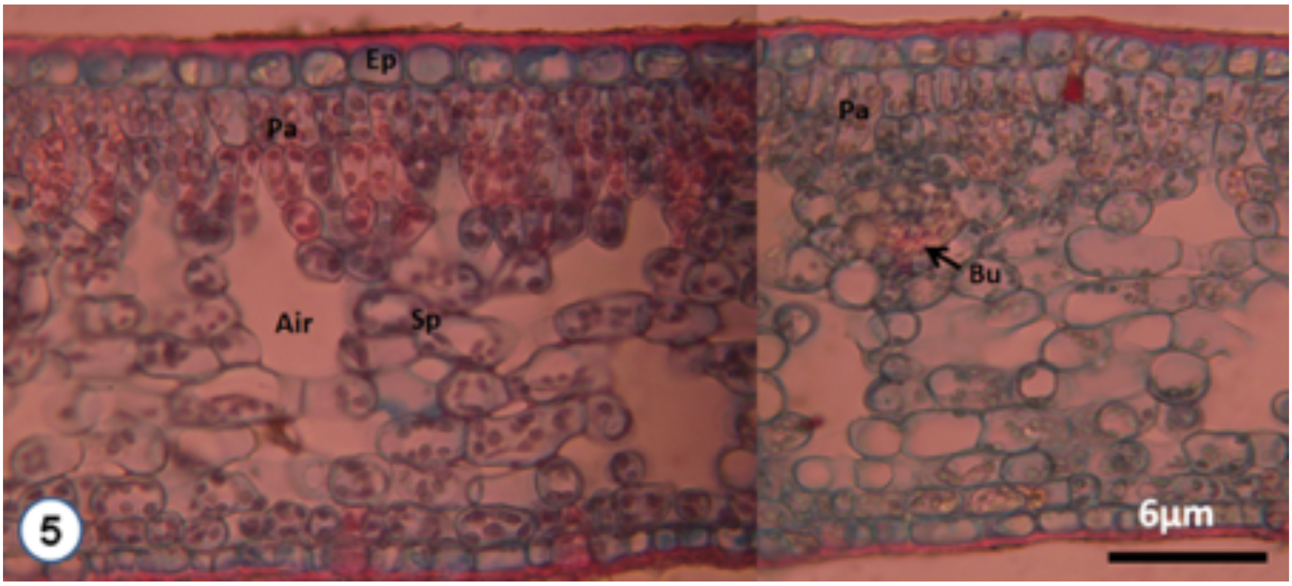
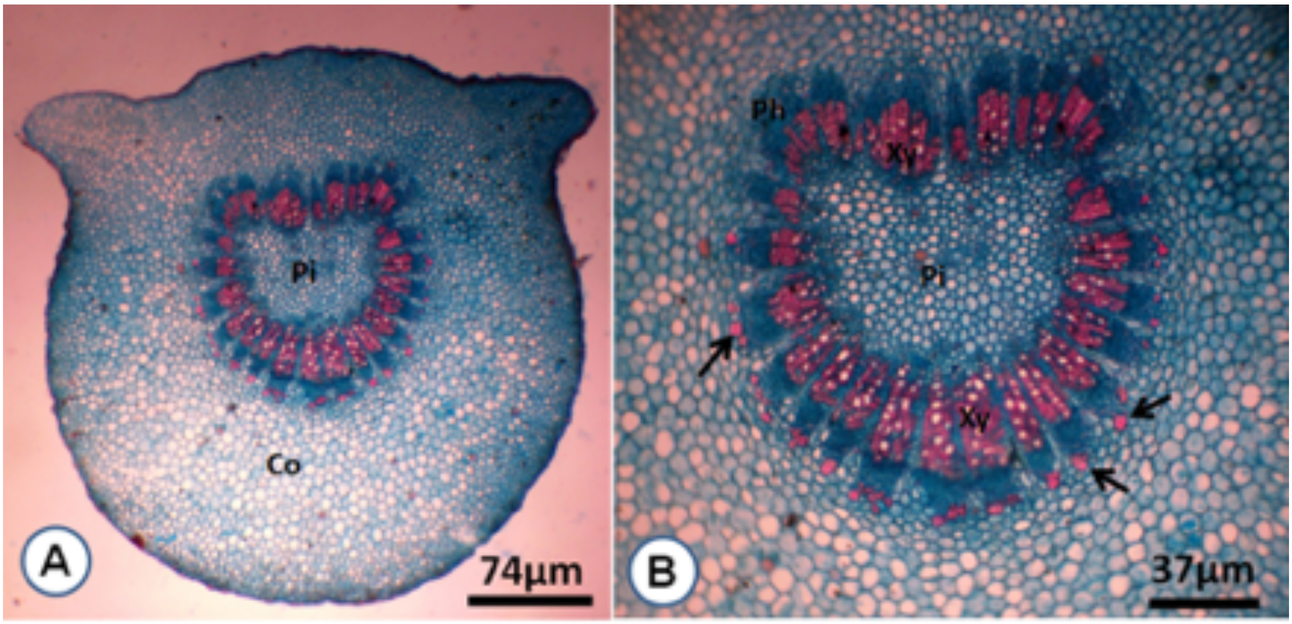


Figure 5. Transverse section (TS) of the lamina of *B. coriacea* (Pa –palisade mesophyll, Pi – pith, Sp –spongy mesophyll, Bu – bundle sheath, Air – air space, Ep – epidermis).

Transverse section of midrib: The outline of the midrib is oval to circular. The adaxial cuticle convex (Figure 7). The epidermis is uniseriate, and the ground tissue is composed of round or oval parenchymatous cells. The vascular system is arranged as a closed ellipse (Fig. 7A), vessels solitary with a continuous layer of xylem tissues and patches of fibre (Figure 7B). The collenchyma or endodermis is separated from the cortex by layers of crushed parenchymatous cells (Figure 7C) and vessels are solitary in radial pairs.

Discussion

The information gathered about the anatomy, and epidermal features makes it possible to compare *B. coriacea* with other members of Capparaceae because there is lack of data on this species endemic to Africa. However, many published works are mainly on *Capparis* L.*, Cadaba* Forsk.*, Boscia, Crataeva , Maerua* Forsk.*, Dipterygium* Decne*, Cleome* L., *and Gynandropsis* DC. (Aleykutty and Inamdar, 1978; Okonwu *et al.,* 2017).



Figures 6. Transverse section of *B. coriacea* petiole (A) complete outline of the petiole, (B) Vascular bundle arrangement (Co- cortex parenchyma, Pi – pith, Ph – phloem, Xy- xyleme, and the arrows show patches of fibre).

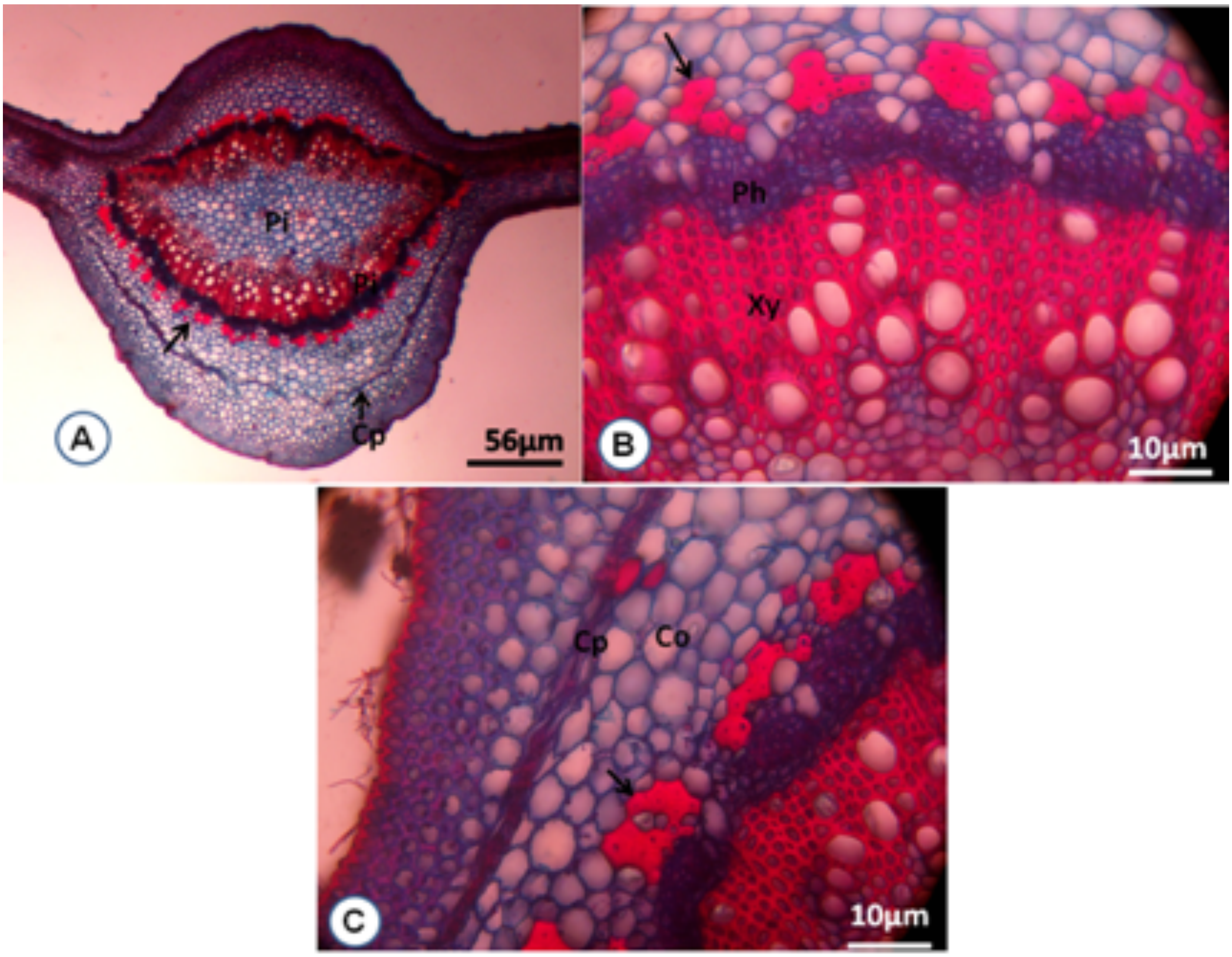


Figure 7. Transverse Section of *B. coriacea* midrib (A) complete outline of the midrib, (B) orientation of the fibre tissues, (C) cortex and collenchyma separated by crushed parenchyma (Cp- crushed parenchyma, Co – cortex, the arrows show patches of fibre cells, Ph –phloem, Xy – xylem).

The importance of the morphological and anatomical features in the systematics of angiosperm cannot be over emphasized. Also, several accounts have explained the value of epidermal characteristics in differentiating many plant families, genera, and species (Metchalfe and Chalk, 1950, 1976). In their work on the epidermal features of Capparaceae, Metcalfe and Chalk (1950, 1976) reported several types of hair namely non-glandular shaggy hairs in the *Morisonia* and *Cadaba* species, stellate hairs in *Steriphoma*, glandular hairs, branched or dendritic non-glandular hairs, capitate glandular hairs with the long or fairly long stalk in *Cleome* species, and peltate glandular or non-glandular hairs in *Atamisqea, Cadaba,* and *Capparis*. They also recorded anomocytic stomata, and papillose on the lower epidermis of the family. In the current study, the researchers observed anomocytic and tetracytic stomata in *B. coriacea*. Aleykutty and Inamdar (1978) reported cyclocytic, tricytic, staurocytic, tetracytic, anomocytic, anisocytic, paracytic stomata, and stomata with a single subsidiary cell in *Cleome*, *Capparis*, *Cadaba*, *Crataeva*, and *Maerua* from Thailand. This characteristic supports the placement of this species in this family as a distinct species.

The distribution of sclereids in the genera *Capparis* and *Crataeva* is documented (Rao, 1951; Sharma, 1969). In *Capparis*, sclereids from a more or less continuous ring outside the secondary phloem or interspersed between the sclerenchyma patches in the stem (Rao, 1951). In *C. moonii* Wight and *C. orbiculata* Wall. ex Hook. f. and Thomson sclereids are present in the leaf and have a direct relationship with the veins and veinlets. In *Crataeva religiosa* Forst. f. the sclereid distribution is similar to *Capparis horrida* L.f. and differs from *C. grandis* L.f. and *C. sepiaria* L. The form of the sclereid is also slightly different (Sharma, 1969). In *B. coriacea,* sclereids and fibre cells occurring in a discontinuous ring outside the secondary phloem.

Ecologically, and based on the habits, members of the Capparaceae family can occur in different habitats (Zahran and Willis 1992; Abd-El-Ghani and Marei 2006; Boulos and El-Hadidi 1984; Abd-El-Ghani *et al.,* 2007). Abd-El-Ghani *et al.,* (2007) investigated the Egyptian taxa and reported that they vary considerably in their growth forms from small trees (*Boscia*) or shrubs (*Capparis*) to annual (*Gynandropsis gynandra*) or perennial herbs (*Cleome*), while the present study shows that *B. coriacea* is a small tree or shrub that grows in dryland and rainforest areas. The Egyptian taxa of Capparaceae belong to the xerophytic communities (Zahran and Willis 1992; Abd El-Ghani and Marei 2006), except for *Gynandropsis gynandra* which is common among the weed flora of the arable fields (Boulos and El-Hadidi 1984). *Buchholzia coriacea* exhibits a latitudinal distribution across the transitional equatorial region of Nigeria, extending from Oyo state in the South-West to Akwa-Ibom in the farther south. This pattern suggests that *B. coriacea* is confined to the tropical areas and may not thrive in drier parts. Currently, its conservation status remains unknown and has not been assessed by the IUCN. Therefore, its sustainable collection and use are of paramount importance not only to the Nigerian society but to the world at large especially in the face of climate change resulting from human anthropogenic activities.

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The Reproductive Ecology of *Asystatia gangetica* (L.) T. Anderson (Acanthaceae)

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Abstract: *Asystasia gangetica* is represented by two subspecies in the study area *alba* and *micrantha* of which the former is the most common, and the latter is very rare. It is hermaphroditic, prominently protandrous, self-compatible, self-pollinating, facultatively xenogamous, melittophilous but also psychophilous. Floral rewards for pollinators include nectar and pollen, both with several essential and non-essential amino acids and proteins. The fruit and seed characteristics enable the plant to produce several batches of plants in the same growing season. The dual modes of reproduction and the flexible facultative xenogamous mating system ensure the plant'sformation of huge populations within a short period of time even in the absence of its pollinators and sustains it as a successful invasive weed.

Keywords - *Asystasia gangetica*, Facultative xenogamy, Melittophily, Psychophily.

Introduction

The *Asystasia* genus belongs to the Justicieae tribe, the Acanthoideae subfamily, and the Acanthaceae family. Jackson (1990) described the name *Asystasia* by inconsistency which relates to the fact that the corolla is more or less regular, which is unusual in Acanthaceae. Acevedo-Rodriquez (2005) confirmed that the genus *Asystasia* includes about forty species of a paleotropical origin. Tsai-Wen *et al.* (2005) reported that *Asystasia* consists of of seventy species, distributed across Africa, India, mainland China, and Australia, but there is almost no information on any aspect of the reproductive ecology of the different species of this genus throughout their distribution. Mardan and Kiew (1985) reported that *A. intrusa* is used as a nectar plant by *Apis cerana* in Malayasia. Edwards and Norris (1987) reported that *A. pinguijolia* in Natal, South Africa, is visited by domestic bees. Aliakbarpour and Rawi (2012) reported that *A. coromandeliana* is the breeding site for *Thrips hawaiiensis* and *Megalurothrips usitatus* in the Mango Orchards of Pulau Pinang, Malaysia. Jongjitvimol and Poolprasert (2014) noted that *A. salicifolia* is an important pollen source for different species of stingless bees in the Nam Nao National Park, Thailand.

Asystasia gangetica is indigenous to the tropics of the Old World from Malaya to Africa (Kamemoto and Storey, 1955). However, later, *A. gangetica* was believed to be originated in India and South Africa, even though it is widely distributed in tropical regions such as the Pacific Islands, Central America, and Australia (Josekutty *et al.,* 2002; Burg *et al.,* 2012). The species epithet "*gangetica*" was named after the Ganges River in India where it was presumed to be occurring (Jackson, 1990). It is introduced into some countries as an ornamental plant or as a cover crop (Burg *et al.,* 2012). It grows rapidly, reproduces excessively, and damages native flora in the new areas, where it prevails as an invasive weed (Josekutty *et al.,* 2002). In the Hawaiian Islands, the flowers are purple, white, and yellow with the purple flowers being the most dominant (Kamemoto and Storey, 1955, Elliot *et al.,* 2004) attracting bees, black ants, and butterflies regularly (Murali *et al.,* 2013). The pollen of this plant species was found to be dominant in the colonies of the meliponine bee, *Heterotrigona itama* throughout the year in Malaysia (Lob *et al.,* 2017).

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Oecophylla smaragdina acts as a predator by capturing *Apis cerana* when the latter is engaged in probing the flowers of *Asystasia gangetica* for pollen and/or nectar (Rodriquez-Girones *et al.,* 2013). The plant is used as a folklore medicine in India, Kenya, and Nigeria (Akah *et al.,* 2003; Reddy *et al.,* 2010).

Ensermu (1994) recognized two subspecies in *A. gangetica*: *gangetica* and *micrantha*; the former is the large-flowered type distributed in areas from India, throughout Asia to Indonesia and the Pacific Islands, while the latter is the smaller-flowered type and is confined to Africa. Westaway *et al.* (2016) stated that the subsp. *gangetica* is cultivated more widely in tropical zones. Kiew & Vollesen (1997) and Daniel and Figueiredo (2009) documented the subsp. *micrantha* as native to the African continent but it is also cultivated and is now widely naturalized in Asia, the Pacific, and central and southern America. The National Herbarium of New South Wales (PlantNet) and the Australian Plant Census (APC) have relegated the two subspecies as synonyms (Westaway *et al.,* 2016). The *A. gangetica,* subsp. *Gangetica* was named *A. gangetica.* subsp. *alba* (Grubben, 2004) which differs from the second subspecies; *A. gangetica* subsp. *micrantha*; on the basis of the petal colour. The *A. gangetica* subsp. *micrantha* is intricately designed for bee-pollination and butterflies use it as a nectar source. Furthermore, it is the larval host for the nymphalid butterflies *Doleschallia bisaltide pratipa, Hypolimnas bolina bolina, H. bolina jacintha* and *Junonia orithya wallacei* in Singapore (Tan and Khew, 2012), *Hypolimnas misippus* in Sri Lanka (Jayasinghe *et al.,* 2014), *Precis almana* and *P. hierta* (Harinath and Venkata Ramana, 2014) and the hesperiid butterfly *Celaenorrhinus leucocera* in the Western Ghats of India (Churi *et al.,* 2020). *A. gangetica* is a nectar host plant for papilionid *Papilio polytes, Princeps demoleus*, the pierid *Pareronia valeria* and the hersperiid *Borbo cinnara* in Visakhapatnam, India (Deepika *et al.,* 2014). This work is aimed at investigating the reproductive ecology involving phenology, flowering, floral biology, sexual system, breeding system, pollinators, fruiting ecology, seed dispersal and the regeneration of *Asystasia gangetica* (L.) T. Anderson.

Materials and Methods

The Study Area and the Identification of Subspecies:

A large population of *Asystasia gangetica* growing in an area of about 500 sq. m at the outskirts of Visakhapatnam City (17°42’N Longitude and 82°18’E Latitude, altitude 45 m amsl), Andhra Pradesh, India was selected for the study over the period from March 2018 to December 2019. Regular field visits were made to this population site for the sake of studying the vegetative growth, flowering and fruiting aspects. Petal color variations were noted and two subsp. *alba* and *micrantha* were identified; the former is the most common, while the latter is very rare, and both occur in the same population. All aspects investigated and described in the results section relate to the subsp. *alba* only unless otherwise specified.

Anthesis and anther dehiscence:

Twenty-five mature buds nearly open were tagged and observed to record the timing of anthesis. The same buds were also used to record the timing and mode of anther dehiscence.

Flower morphology:

The flower aspects such as flower sex, shape, size, colour, odour, sepals, petals, stamens, and ovary were recorded. The stamens were described regarding their position, that is whetherthey were exposed or hidden during the open state of the flower. The stamen attachment and detachment in the proximal and distal portion of the corolla were examined and the details were described in relation to their role in nectar concealment in order to give access to appropriate foragers which are involved in effecting pollination.

Pollen production:

Ten mature but un-dehisced anthers were collected from different plants and kept in a Petri dish. A single anther was taken out each time and placed on a clean microscope slide (75 x 25 mm). It was crushed with a glass rod and a small drop of lactophenol-aniline-blue was added to disperse the pollen grains equally to the fixed area on the slide and the pollen grains were counted under a compound microscope (40x objective, 10x eye piece). This procedure was followed for the sake of counting the number of pollen grains in all ten anthers. Based on the pollen counts of each anther, the mean number of pollen grains produced per anther was determined.

The mean pollen output per anther was multiplied by the number of anthers in the flower to obtain the mean number of pollen grains per flower. At the same time, the pollen grain characteristics were recorded. Also, the pollen-ovule ratio was calculated using the formula noted by Cruden (1977).

Mondal *et al.* (2009) described the protocols for the analysis of amino acids in the pollen. These protocols were followed for identifying amino acid types present in the pollen. The pollen was collected from mature anthers and was sieved using meshes of different sizes (100, 200 and 300 µm) to remove the debris. After that, the pollen was rapidly dried over silica gel at 30°C and stored. Free amino acids were extracted from the pollen using the method of Bieleski and Turner described in Mondal *et al.* (2009).

Later, the extract thus obtained was used for the qualitative analysis of the free amino acids of the pollen using thin-layer chromatography. The protocol described in Sadasivam & Manickam (1997) was followed for the extraction of protein from the pollen samples using phosphate buffer of pH 7.4 and then the protocol described by Lowry *et al.* (1951) was followed for estimating the protein content in the sample.

Nectar production and analysis:

The presence of nectar was determined by observing the mature buds and open flowers. The micropipette was inserted into the flower to extract the nectar for measurement. The average of the nectar of ten flowers was taken as the total volume of nectar/flower and was expressed in µl. The same sample size was used for measuring the nectar's sugar concentration; the Hand Sugar Refractometer (Erma, Japan) was used in recording the sugar concentration. Nectar analysis for sugar types was done according to the paper chromatography method described in Dafni *et al.* (2005). The sugar content/flower is expressed as the product of nectar volume and sugar concentration per unit volume, mg/µl. This was done by first noting the conversion value for the recorded sugar concentration on the Refractometer scale and then by multiplying it with the volume of nectar/flower. The procedure in Table 5.6 given in Dafni *et al.* (2005) was followed to record the value converted to mg of sugars present in one µl of nectar. The protocols provided by Sadasivam *and* Manickam (1997) were followed for the quantitative estimation of sucrose, glucose, and fructose in mg/flower. The caloric reward of nectar/flower/day was measured according to the formula given by Heinrich (1975). He assumed that 1 mg of sugar yields 16.74 joules or four calories of energy, and accordingly he used the formula for calculating the caloric reward of the nectar.

$$\frac{\text{Nectar volume (µl) X Concentration of nectar (\%)}}{100} \text{ X } 16.74$$

The paper chromatography method described in Dafni *et al.* (2005) was followed to identify the amino acid types in the nectar. Lowry *et al.* (1951) described the method for measuring the protein content.

Stigma receptivity:

The stigma receptivity was tested with hydrogen peroxide from the mature bud stage to the late evening of the secondday of anthesis. When applied to bifid stigma, Hydrogen peroxide did not stain but produced bubbles as a result of catalase (peroxidase) presence. This test is widely followed although it does not indicate the exact location of the receptive area (Dafni *et al.* 2005). The period of the release of bubbles from the stigma surface following the application of hydrogen peroxide was taken as the total duration of stigma receptivity during the flower life.

Breeding systems:

Breeding systems were tested for apomixis, self-pollination and cross-pollination. The number of mature buds selected was thirty for each mode of pollination; they were observed for four weeks for fruit set. Based on the flowers that produced fruits, the percentage of fruit set was calculated. Mature buds were emasculated and bagged to test apomoxis. Mature buds were bagged without emasculation and pollination to test the spontaneous self-pollination (autogamy). Mature buds were bagged on the evening of the previous day, and were opened in the afternoon of the next day by which time anthesis, anther dehiscence, and stigma receptivity occurred; the stigma was then pollinated with the pollen of the same flower using a brush and was bagged to test hand self-pollination (autogamy).

The mature buds were bagged after emasculation, and were opened in the afternoon of the next day by which time anthesis and stigma receptivity occurred; the stigma was then pollinated with the fresh pollen of a different flower of the same plant using a brush and was bagged to test hand self-pollination (geitonogamy).

The mature buds were bagged after emasculation, and were opened in the afternoon of the next day by which time anthesis and stigma receptivity occurred. The stigma was then pollinated with the fresh pollen from the flower of a different plant using a brush and was bagged to test hand cross-pollination (xenogamy).

Fruit set in open pollinations:

Eighty flowers taken at random from thirty plants were tagged prior to anthesis and were observed for fruit set. Based on the flowers that produced fruits, the percentage of fruit set was calculated.

Flower-visitors and pollination:

Flowers were observed from morning to evening for four days to record flower-visitors. The flower visitors included bees and butterflies only; the beeswere identified by the Zoological Survey of India, Calcutta, India, while the butterflies were identified with the help of the Field Guide of Butterflies book by Gunathilagaraj *et al.* (1998).

The approach of the flower visitors to the flowers, flower-probing, the forage collected by them, and the contact between the body parts of the flower visitors with the stigma and stamens were carefully observed by standing close to the flowering patch and also by using a field binocular to record their pollination role. The number of foraging visits made by the flower visitors was recorded at each hour for ten minutes from morning to evening for four days at thirty profusely flowering plants. The data collected on the foraging visits of these insects were tabulated, and the mean number of foraging visits at each hour was calculated to know the foraging pattern of insects through time. The same data were also used to calculate the percentage of foraging visits made by bees and butterflies separately.

Fruit and seed aspects:

Forty mature buds were tagged and observed over a period of three months to record fruit growth, development, and the maturation period. The fruit dehiscence mode and seed dispersal aspects were observed carefully. Fruit and seed morphological characteristics were described to understand fruit/seed dispersal modes. Seventy-five mature and dry fruits were collected from twenty-five plants, and were classified according to their seed number per fruit, and the seed set rates were calculated. Field observations were made of the seed germination and the production of new plants during the rainy season and the winter season.

Results

Plant and flowering phenology:

It is a fast-growing low-ground perennial prostrate glabrous weedy herb with a mat-forming habit in open, dry, and sandy soils especially during the rainy season (Figure 1a). It spreads by seeds as well as by stems which turn into roots aftercontacting moist soils. The stem is quadrangular and slightly covered with hairs. The leaves are opposite, petiolate with simple, ovate blade—and entire margin. Even with its mat-forming habit, this herb is intermingled with several weedy species such as *Sida cordifolia, S. acuta* (Malvaceae), *Triumfetta rhomboidea* (Tiliaceae), *Pedalium murex* (Pedaliaceae), *Merremia tridentata* (Convolvulaceae), and *Antigonon leptopus* (Polygonaceae). All these weedy species flower simultaneously along with *A. gangetica*. The flowering occurs during the rainy season from July to November. The inflorescence is an axillary and terminal secund raceme with 13.2 ± 1.40 buds/flowers arranged on one side only (Figure 1b, c). The flowers are pedicellate and horizontally-oriented, but are projected above the leaves making them quite distinct against the foliage. Based on the flower color, two subspecies have been identified, the *A. gangetica* subsp. *alba* with a complete creamy white corolla with a yellow throat and the *A. gangetica* subsp. *micrantha* with a white corolla consisting of bluish-purple blotches in two parallel lines on the inside of the bottom petal lobe, of which the former is the most common, while the latter is very rare occuring in combination with the subsp. *alba*. The description of observations and results relate to the *A. gangetica* subsp. *alba* only unless otherwise stated.

Flower morphology:

The flowers are large (3.45 ± 0.07 cm long), funnel-shaped, creamy white, slightly pungent, and bisexual. The calyx is green, 5-7 mm long, lanceolate, hairy, fused basally and five-lobed terminally. The corolla is tubate and hairy with five 1.1 ± 0.04 cm wide rounded lobes apically forming a yellow-colored throat. The stamens and pistil (3 cm long) are inserted on the corolla tube. The stamens are four, epipetalous and free terminally; the filaments are green while the anthers are creamy white, dithecous, and dorsifixed (Figure 1d). The stamen and petal portions display two types of regions, synstapetal and apostapetal. In the synstapetal region, the proximal portion of the corolla and the stamens are fused while in the apostapetal region, the stamens are free from the distal portion of the corolla wall. In the synstapetal region, the filament ridges form channels that lead to the nectar. The corolla lobe traces are geniculate and positioned at the border of synstapetal and apostapetal corolla regions. Along this border, the corolla tube expands into a wider corolla throat. The filaments are decurrent and are situated along the synstapetal corolla region and fused in two-by-two mode proximally in the apostapetal region. The ovary is ellipsoid, densely pubescent, bicarpellary syncarpous with two locules, and each locule consists of two ovules on the axile placentation (Figure 1g- j). The style is subulate and velutinous, while the stigma is slightly capitate and bi-lobed (Figure 1h).

Floral biology:

The flowers are open during 0600-0800 h. Anthers dehisce by longitudinal slits an hour after anthesis. The subulate style runs from the center of the corolla tube and extends beyond the height of the stamens but remains inside the corolla throat (Figure 1e). The anthers are positioned laterally inside the corolla throat but below the level of the stigma. The pollen output is 787.8± 29.19 per anther and 3, 151.2 per flower. The pollen ovule ratio is 787.8. The upright style bends at the stigmatic end, and the stigmatic surface exudes a sticky substance which enables the capture and germination of the pollen deposited by foraging insects. The stigma is receptive from the afternoon of the day of anthesis and remains so until

Figure 1. *Asystasia gangetica*: a. Habit, b. Mature bud, c. Flower, d. Stamens, e. Relative positions of stamens and stigma, f. Pollen grain, g. Ovary, h. Style with bifid stigma, i. Placement of ovules in ovary, j. Ovules, k. Growing fruit, l. Mature and dry seeds.

the evening of the next day. Nectar secretion begins by nectary situated at the base of the corolla tube during the mature-bud stage and ceases soon after anthesis, it is 3.35 ± 1.35 µl with a sugar concentration of 31.7 ± 4.07% per flower. The total sugar content is 106.20 mg with 17.8 joules of energy per flower. The sugar types in the nectar include sucrose, glucose, and fructose; their quantity per flower varies with sugar type. The sucrose is 0.2 mg, glucose 0.078 mg, and fructose 0.069 mg. The nectar contains five essential amino acids and ten non-essential amino acids. The essential amino acids include threonine, valine, isoleucine, histidine, and arginine. The non-essential amino acids include alanine, amino butyric acid, aspartic acid, cysteine, cystine, glutamic acid, glycine, hydroxyproline, proline, and serine (Table 1). The protein content in the nectar is 0.012 mg/flower. The pollen contains six essential amino acids and seven non-essential amino acids. The essential amino acids are threonine, valine, isoleucine, lysine, histidine, and arginine. The non-essential amino acids include alanine, amino-butyric acid, cysteine, cystine, glutamic acid, glycine and hydroxyproline (Table 1). The total protein content per 1 mg of pollen is 204.05 µg. The corolla together with the stamens fall off on the third day any time, while the calyx remains intact and turns into a fruiting calyx. The style

Table 1. Essential and non-essential amino acids present in the nectar and pollen of *Asystasia gangetica*.

Essential amino acids			Non-essential amino acids		
Amino acid type	Nectar	Pollen	Amino acid type	Nectar	Pollen
Threonine	+	+	Alanine	+	+
Valine	+	+	Amino butyric acid	+	+
Methionine	-	-	Aspartic acid	+	-
Leucine	-	-	Cysteine	+	+
Iso leucine	+	+	Cystine	+	+
Lysine	-	+	Glutamic acid	+	+
Phenyl alanine	-	-	Glycine	+	+
Histidine	+	+	Hydroxy proline	+	+
Arginine	+	+	Proline	+	-
Tryptophan	-	-	Serine	+	-
			Tyrosine	-	-

(+) = Present; (-) = Absent

and stigma remain as a vestige at the tip of the fruit.

Breeding systems:

The hand-pollination tests showed that the flowers do not set fruit through apomixis. Fruit set occurs through self- and cross-pollination. Spontaneous self-pollination is not functional. Fruit set is 27% in hand self-pollination, 47% in geitonogamy, 87% in xenogamy and 82% in the open-pollination mode (Table 2).

The results of hand-pollinations indicated that the plant is facultatively xenogamous.

Foraging activity and pollination:

The flowers were foraged by bees and butterflies during day-light hours. The bees were *Apis dorsata* (Figure 2a-d), *A.cerana*, *A. florea* (Figure 2e,f), *Xylocopa pubescens* (Apidae) (Figure 2h), *Anthophora cingulata* (Anthophoridae) (Figure 2g), and *Megachile* sp. (Megachilidae) (Figure 2h) from 0700 to1800 h.

The butterflies included *Papilio polytes* (Papilionidae) (Figure 2i), *Pareronia valeria* (Pieridae) (Figure 2j), *Iambrix salsala* (Figure 2k), *Pelopidas mathias* (Figure 2l),

Table 2. Results of breeding systems in *Asystasia gangetica*.

Treatment	Number of flowers sampled	Number of flowers' fruit set	Fruit set (%)
Apomixis	30	0	0
Spontaneous self-pollination (Mature buds just bagged)	30	0	0
Hand self-pollination (Flowers hand-pollinated and bagged)	30	8	27
Geitonogamy (Flowers hand-pollinated and bagged)	30	14	47
Xenogamy (Flowers hand-pollinated and bagged)	30	26	87
Open pollination (Flowers tagged)	80	66	82

Figure 2. *Asystasia gangetica*: a-d. subsp. *alba*: Different stages in flowering probing for nectar collection by *Apis dorsata,* e. *Apis florea* collecting pollen, f. *Apis florea* probing for nectar collection, g. subsp. *micrantha*: *Anthophora cingulata* collecting pollen from subsp. *micrantha*, h-m. subsp. *alba*: left side – h. *Megachile* sp. approaching the flower and right side *Xylocopa pubescens* puncturing the base of corolla tube for nectar collection, i. Papilionid butterfly, *Papilio polytes*, j. Pierid butterfly, *Pareronia valeria*, k-m. Hesperiid butterflies – k. *Iambrix salsala,* l. *Pelopidas mathias*, m. *Borbo cinnara*.

and *Borbo cinnara* (Hesperiidae) (Figure 2m) (Table 3). Among bees, *X. pubescens* probed the flowers regularly for nectar illegitimately by making puncture at the base of the corolla tube, and it never probed legitimately from the front side of the flowers. This foraging behavior characterized this bee as an exclusive nectar robber. All other bees probed the flowers legitimately from the front side of the flower. For nectar collection, they first landed on one of the petal lobes, usually on the lower lobe and then inserted their tongues into the corolla tube through the central space of the stamens to access the nectar. In the subsp. *micrantha,* the lower petal lobe with the bluish-purple was always used as a landing platform for probing the flowers for nectar and/or pollen by the bees and butterflies. The horizontal orientation of the flowers enabled the nectar to leak and flow slightly towards half-way of the proximal portion of the corolla tube. Such a placement of nectar enabled the bees to collect the nectar with great ease. During the bees' probing for nectar collection from the side of the lower petal lobe , the backside of their head and thorax brushed against the stigma first and then their dorsal and ventral lateral side against the anthers receives pollen onto those areas and subsequently,

Table 3. List of insect foragers on Asystasia gangetica.

Order	Family	Genus	Species	Common name	Forage sought
Hymenoptera	Apidae	*Apis*	*dorsata* F.	Rock Honey Bee	Pollen and Nectar
		Apis	*cerana* F.	Indian Honey Bee	Pollen and Nectar
		Apis	*florea* F.	Dwarf Honey Bee	Pollen and Nectar
		Xylocopa	*pubescens* Spinola	Carpenter Bee	Pollen and Nectar
	Anthophoridae	*Anthophora*	*cingulata* F.	Blue Banded Bee	Pollen and Nectar
	Megachilidae	*Megachile*	sp.	Leafcutter bee	Pollen and Nectar
Lepidoptera	Papilionidae	*Papilio*	*polytes* L.	Common Mormon	Nectar
	Pieridae	*Pareronia*	*valeria* Cr.	Common Wanderer	Nectar
	Hesperiidae	*Iambrix*	*salsala* Moore	Chestnut Bob	Nectar
		Pelopidas	*mathias* F.	Dark Small Branded Swift	Nectar
		Borbo	*cinnara* Wallace	Rice Swift	Nectar

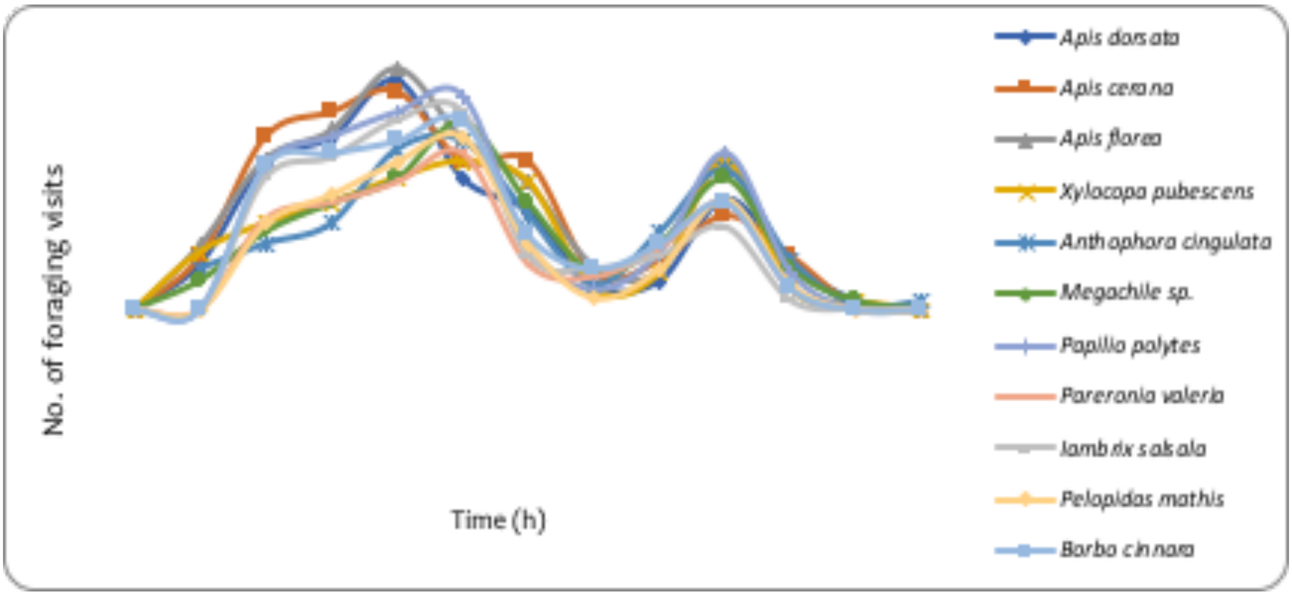

Figure 3. Hourly foraging activity of bees and butterflies on *Asystasia gangetica*.

the pollen is spread on the dorsal surface of the rear part of the head, thorax, and even the abdomen. Such a temporal difference in the contact between the nectar probing bee and the stigma and the anthers was viewed as an adaptation for the promotion of cross-pollination. In this foraging mode, if the bee is already pollen-laden, it affects cross-pollination, and if not, it is loaded with the pollen, carries it along, and pollinates another flower while collecting the nectar. In the same visit, the bees also collected pollen by rotating themselves around the throat to access the anthers. All bee species recorded were regular and consistent foragers to the flowers. Since *A. gangetica* has a mat-type population with numerous flowers on any given day, the bees mainly concentrated on this floral source. The bees foraged daily from 0700 to 1800 h with a peak activity occurring from 0800 to1300 h and again between 1500 and 1600 h (Figure 3); they made 56% of the total foraging visits. The butterflies recorded were not as regular and consistent as bees. They foraged exclusively for nectar legitimately from the front side of the flowers from 0800 to 1700 h with a peak activity between 0800 and 1300 h and again between 1500 and 1600 h (Figure 3); they made 44% of the total foraging visits.

As for the butterflies, *P. polytes* and *P. valeria*, theyinserted their long proboscis into the corolla tube and accessed the nectar with great ease when compared to hesperiid butterflies which have relatively short proboscis.

However, the hesperiids also accessed the nectar easily due to the wide nature of the corolla tube. During nectar collection, all these butterflies contacted the stigma first and the stamens later with their proboscis, antennae, and the forehead affecting cross- or self-pollination.

The depletion of nectar due to the nectar robbery practiced by *X. pubescens* appeared to be a driving force for the bees to make multiple visits to the standing crop of flowers, and such repeated visits to the same flowers did increase the pollination rate, especially the out-crossing. Therefore, the plant is principally melittophilous and supplemented by psychophily.

Fruiting and seed ecology:

Fruits mature rapidly within two to three

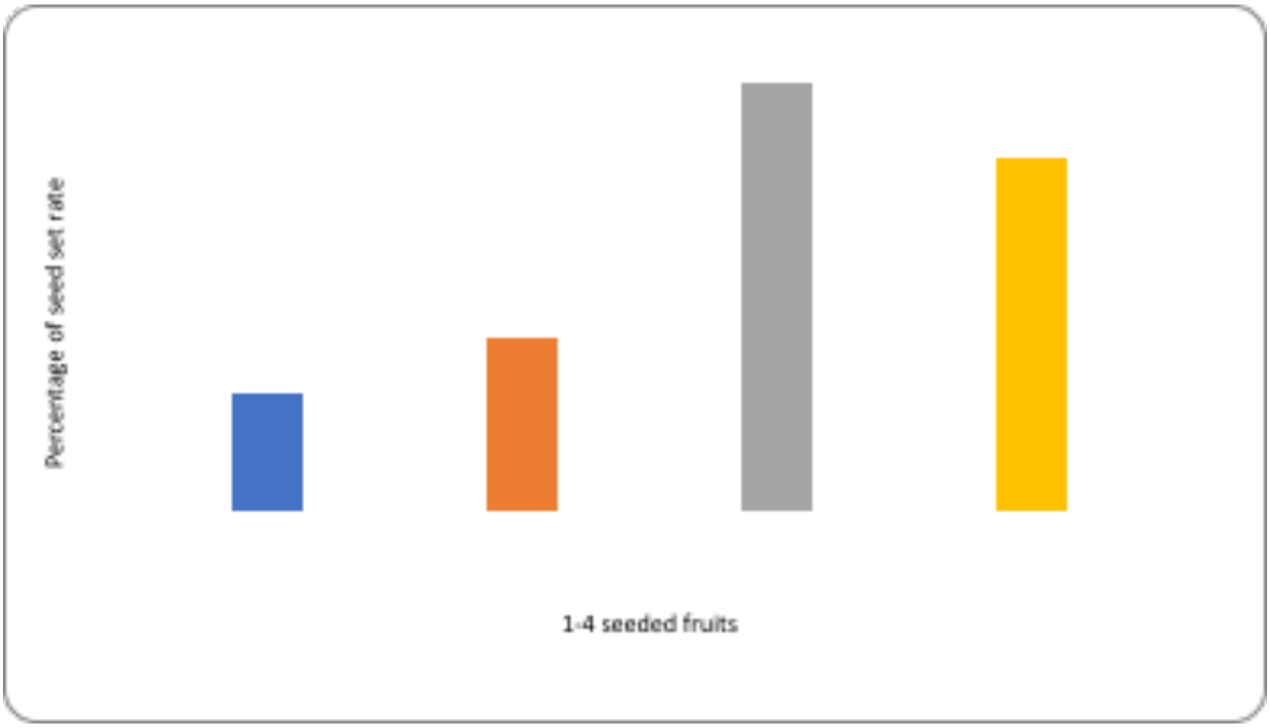

Figure 4. Percentage of seed set rate in *Asystasia gangetica.*

weeks. They are initially green (Figure 1k), brown and turn to black dry fruits at maturity. The fruit is an elongated 26-33 mm long capsule with two compartments, each compartment with zero to two seeds. The seeds are whitish to brownish black, circular, flattened, beaked, 5 mm long and 1 mm wide (Figure 1l). The seed set rate is 11% in one-seeded fruits, 16% in two-seeded fruits, 40% in three-seeded fruits and 33% in four-seeded fruits (Figure 4).

The dry capsules dehisce loculicidally with an explosive force around midday when sunlight is very intense, and the seeds released disperse to short distances only. Fruit dehiscence did not occur on rainy days due to the low ambient temperature and the high relative humidity. The seeds falling to the ground were subsequently dispersed by the rainwater. They are non-dormant, germinate immediately and form new plants if the soil is moderately wet. In addition to the seed propagation, the plant propagates by a vegetative mode through trailing stems that produce roots when nodes establish a contact with moist soils.

Therefore, the plant, with its ability to propagate through seeds and rhizomes, spreads easily and forms a huge mat-type population in open areas either in natural areas or in agricultural ecosystems.

Discussion

The color of the petal in *Asystasia gangetica* has been used by many authors to distinguish between the subspecies under this taxon (Kiew and Vollesen, 1997; Daniel and Figueiredo, 2009; Grubben, 2004; Danthanawanit *et al*, 2015). In this work, the A. gangetica populations showed the subspecies, alba and micrantha of which the former is the most common, while the latter is very rare. The color of the petal of the subspecies *alba* matches the description of the petal color provided by Grubben (2004), while that of the subspecies *micrantha* matches the description of the petal color provided by Danthanawanit *et al.*, (2015). In Acanthaceae, most of the species distributed in Mexico are self-compatible and are capable of self-pollination when pollinators are scarce (Daniel, 2004; 2008). In the present study, *Asystasia gangetica* subsp. *alba* is prominently protandrous, self-compatible, and self-pollinating as substantiated by the hand-pollination tests. The placement of stigma ahead of the anthers at the corolla throat is designed for promoting cross-pollination and the legitimately probing bees and butterflies also contact the stigma first and then the anthers which suggests that the plant is principally adapted for out-crossing, but the function of self-compatibility does not preclude the occurrence of autogamy and geitonogamy. However, the self-pollination modes are strictly vector-dependent indicating that the plant has evolved its breeding system destined for maximizing the cross-pollination rate and minimizing the self-pollination rate. Therefore, the *A. gangetica* subsp. *alba* is strictly facultatively xenogamous.

Olmstead *et al.*, (1993) stated that the characteristic of the fusion of petals into the sympetalous corolla is most prevalent and is key to the Acanthaceae family. Ritterbusch (1991) used the terminology of the “synstapetal” and “apostapetal” regions in the corolla; the former refers to the fusion of the proximal portion of the corolla and the stamens, while the latter refers to the condition of the free state of the stamens from the wall of the distal portion of the corolla. Manktelow (2000) identified four types of filament curtains, namely the phaulopsoid type, the corolla fold, the reduced type and the strobilanthoid type in Acanthaceae. In the present study, the *A. gangetica* subsp. *alba* as well as the subsp. *micrantha* represent the phaulopsoid filament curtain type in which the decurrent filaments form a barrier to the nectar. Manktelow (2000) also noted that most species representing the phaulopsoid type of filament curtain produce flowers characterizing the melittophilous syndrome. The present study found that both subspecies of *A. gangetica* have floral traits adapted to melittophily. The flowers open during early morning indicating that they are destined for pollination during daytime. The floral traits of the subsp. *alba* such as the tubate corolla with the anthers at the corolla throat and the stigma situated beyond the height of anthers, the moderate volume of the nectar with a high sugar concentration, and the presence of an energetically rewarding sucrose-rich nectar with several essential and non-essential amino acids are adaptations for bee-pollination (Baker and Baker, 1983; Opler, 1983). The production of sucrose-rich nectar by *A. gangetica* has also been reported by Freeman *et al.*, (1991). Furthermore, the pollen of the subsp. *alba* is an important source of several essential and non-essential amino acids and proteins. The field study showed that bees exhibit fidelity to this floral source to collect both nectar and pollen and in this process, they affect both self- and cross-pollination. The carpenter bee, *Xylocopa pubescens*, collects only nectar illegitimately by making a puncture at the base of the corolla tube, and hence it is a mere nectar robber. However, its nectar-robbing behavior compels other bees, which collect the forage legitimately by probing the flowers from the front side of the corolla throat, to make multiple visits and contribute to the promotion of pollination rate, mostly cross-pollination. Additionally, while collecting nectar legitimately from the flowers of *A. gangetica* subsp. *alba* as well as the subsp. *Micrantha,* butterfliesaffect self- and/or cross-pollination, but they are not as regular and consistent as bees, and hence they are supplementary pollinators. Therefore, the *A. gangetica* subspecies are primarily melittophilous but psychophily is supplementary.

Murali *et al.* (2013) reported that the *A. gangetica* flowers attract bees, black ants, and butterflies regularly in South India. Lob *et al.* (2017) reported that the *A. gangetica* pollen is the most dominant pollen stored in the colonies of the meliponine bee, *Heterotrigona itama*, in Malaysia. Tan and Khew (2012) reported that the *A. gangetica* subsp. *micrantha* is intricately designed for bee pollination and butterflies use it as a source of nectar . Deepika *et al.* (2014) reported that *A. gangetica* is a nectar host plant for papilionid *Papilio polytes, Princeps demoleus*, the pierid *Pareronia valeria*, and the hersperiid *Borbo cinnara* in Visakhapatnam, India. The present study also found that the *A. gangetica* subspecies attract bees and butterflies which while collecting nectar and/or pollen affect pollination, and hence this characterizes a mutualistic relationship between the plant and the bees/butterflies; the former for pollination and the latter for food.

Josekutty *et al.* (2002) reported that *Asystasia gangetica* grows rapidly, reproduces excessively, and prevails as an invasive weed in the areas they were introduced to. Kamemoto and Storey (1955) stated *A. gangetica* produces seeds profusely under a wide range of environmental conditions, ranging from wet to dry and from sunny to shady conditions. It propagates vegetatively very easily by means of cutting. The present study found that the *A. gangetica* subsp. *alba* is an invasive species when occurring in both agricultural and non-agricultural open areas. The invasiveness functions through both the sexual and asexual system, the former through facultative xenogamy andthe latter through rhizomes. The characteristics of explosive fruit dehiscence and non-dormant seeds enable the plant to produce several batches of plants in the same growing season. Furthermore, the seeds dispersed through fruit explosion migrate to distant areas via rainwater. Therefore, the dual mode of reproduction and the flexible facultative xenogamous mating system ensure the plant'sformation of huge populations within a short period of time even in the absence of its pollinators and susutains it as a successful invasive weed.

Elliot *et al.* (2004) recommended *Asystasia gangetica* for cultivation as a cover crop in mature oil palm plantations because it fulfills several conditions such as its quick covering of the land, and the ability to increase the N, P, K available in the soil. Different authors reported that *A. gangetica* is an important forage source for bees and butterflies (Tan and Khew, 2012; Murali *et al.,* 2013; Rodriquez-Girones *et al.,* 2013; Deepika *et* *al.,* 2014; Lob *et al.,* 2017). This plant is also the larval host for the nymphalid butterflies *Doleschallia bisaltide pratipa, Hypolimnas bolina bolina, H. bolina jacintha* and *Junonia orithya wallacei* (Tan and Khew, 2012), *Hypolimnas misippus* (Jayasinghe *et al.,* 2014), *Precis almana* and *P. hierta* (Harinath and Venkata Ramana, 2014), and the hesperiid butterfly *Celaenorrhinus leucocera* (Churi *et al.,* 2020). These reports indicate that *A. gangetica* is important in increasing soil fertility, providing pollen and/or nectar for local insects and is useful as a larval host plant for several butterflies. The present study proves that this plant, being a prolific weed, covers the soil and prevents soil erosion, and hence is useful for consideration in the restoration of ecologically destroyed, degraded, and damaged ecosystems and natural areas. Therefore, *A. gangetica* as a C3 plant with a less efficient carbon fixation system, as mentioned by Hnatiuk (1980), is ecologically valuable and useful in carbon sequestration in the context of global warming and climate change problems regradles of being a menace, especially in agricultural areas.

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Phytodiversity and Morpho-Ecological Features of the Plants of the Tirah Valley, Khyber District, Pakistan

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Abstract: The first phytodiversity ever analyzed during 2015-2016 revealed 330 species (sp) and 230 genera (G) of seventy-eight families in the Tirah Valley, Khyber District, Pakistan. The dicots had 277 species, 188 genera, and sixty-one families. Monocots shared thirty-five species with twenty-five genera of nine families. Bryophytes, pteridophytes and gymnosperms, respectively contributed two, ten and six species. The leading families were Asteraceae (30 sp; 24 G), Lamiaceae (28 sp; 19 G), Rosaceae (27 sp; 13 G), Poaceae (19 sp; 15 G), Brassicaceae (15 sp; 10 G), Solanaceae (13 sp; 7 G), Cucurbitaceae (12 sp; 7 G), and Papilionaceae (11 sp; 8 G). The remaining families had fewer than ten species. *Orobanche aegyptiaca* was the only root parasitic plant. The average number of species per genus was 1.43. The average number of species per family was 4.23, and the average number of genera was 2.95. The life form spectra were dominated by therophytes (128 sp; 38.89 %), followed by hemicryptophytes (56 sp; 16.97%), geophytes (41 sp; 12.42) and megaphanerophytes (40 sp; 12.12 %). Leaf size spectra revealed that nanophylls and microphylls (each with 108 sp; 32.73 %) were leading groups. The dominant species were annual herbs (128 sp; 38.795), perennial herbs (122 sp; 36.79%), deciduous plants (280 sp; 84.85%), heliophytes (253 sp; 76.67%), mesic (198 sp; 60%), non-spiny (305 sp; 92.42%) and wild (267 sp; 80.91%) species. The investigated area is under severe degradation due to deforestation and overgrazing which necessitates a proper ecological management for its maintenance. Further investigation to explore the conservation status of important plants is required.

Key words: Phytodiversity; Tirah Valley; Morpho-ecological features; Leaf and life form spectra; Pakistan.

Introduction

Phytodiversity varies across different geographical regions that impart characteristic physiognomic contrasts between vegetation types. Th identification of plants is an essential pre-requisite for initiating any plant-related scientific work. Detailed national, regional, and local floras are required to achieve this purpose. A short version of the flora is listing or the floristic composition of the desired plants of an area in a specific season. For this reason, various floristic studies have been conducted in different parts of Pakistan. Badshah *et al.* (2013, 2016), respectively, recorded 205 species from the District of Tank and 283 species from Parachinar, Kurram District. Shah *et al.* (2013) documented 319 species among eighty-nine families, 215 genera from Chakesar, Shangla District. Poaceae and Asteraceae were the leading families. Therophytes were the dominant life form. Hussain *et al.* (2015) listed 571 plant species along with their ecological features from the Mastuj Valley, Chitral District.

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Ali *et al.* (2016) collected 463 species of 104 families from the Chail Valley, Swat District. Sultan-ud-Din *et al.* (2016) reported 515 plant species from the District of Shangla, which were distributed in 101 families with the dominance of herbaceous elements. Asteraceae, Lamiaceae and Rosaceae had a high number of species. Therophytes and phanerophytes were the dominant life forms. Ilyas *et al.* (2018) enumerated 229 species, 181 genera and seventy families from Kabal Swat. The diverse flora of the Shigar Valley, Baltistan consisted of 345 species distributed among 206 genera and sixty-three families. It included 338 angiosperms (Abbas *et al.* 2019). Hayat *et al.* (2019) listed 167 species among sixty-five families and 139 genera from Tehsil Razar, the Swabi District. Bibi *et al.* (2019) recorded 286 species among eight-six families from the Tanawal Valley Mansehra District. Herbaceous species (187 species), Asteraceae and therophytes dominated the flora. Raza and Shah (2020) identified 336 plant species belonging to 229 genera and seventy-nine families from Mir Ali, N. Waziristan. There were 269 dicots, sixty monocots, four gymnosperms and three pteridophyte species. Anjum *et al.* (2020) listed 154 plant species of thirty-nine families from Karkhasa dry rangelands of Quetta. Das and Desai (2020) identified 226 species of flowering plants of 173 genera and sixty-six families from the Dharampur Hill ranges, Western Ghats, Gujarat**.** Yeshitila and Awas (2020) recorded 129 plant species representing 106 genera and fifty-five families from the Sidama Zone, Southern Ethiopia. Reena and Samuel (2020) identified 161 **s**pecies of 125 genera and forty-six families from Coconut Plantations in the Kanyakumari District. These included thirty-one dicots, fourteen monocots and three Pteridophyte families. Recently, Hussain *et al.* (2020) reported 654 species distributed within 401 genera, and 116 families with Poaceae, Asteraceae, Rosaceae, Lamiaceae, Papilionaceae, Brassicaceae, Ranunculaceae and Apiaceae as the topmost families from the Koh-e-Sufaid Range Pakistan. Salama *et al.* (2021) reported eighty-five macrophytic species along with their life forms' classification from the river channel in Egypt. Al-Sghair and Mahklouf (2021) recorded 110 plant species from the Tripoli University Camp with ninety-five genera and thirty-five families. They also classified the flora into life form classes including therophytes (52.73%), Hemicryptophytes (14.54) and a low number of phanerophytes. Rafiqullah *et al.* (2021) recorded 270 species of plants including sixty-five families, sixty-two Genera, and 219 dicot species from Pishin, Baluchistan. The families Asteraceae, Papilionaceae, and Brassicaceae were well represented.

The above endeavors suggest that no scientific information on the floristic composition of Tirah, Khyber District is available. Although, the *Flora of Pakistan* is a comprehensive document (Nasir and Ali, 1970-1989; Ali and Nasir, 1989-1991; Ali and Qaiser, 1993-2020 continued) of the plants of Pakistan, the local and regional flora, or the floristic composition of a specific area are always advantageous for an easy handling of locations and for a quick identification of the plant species. With this approach in mind, the present investigation was initiated to list the most common plants of the Tirah Valley as a first record. The present study, therefore, provides the first-hand information on the rapidly declining flora due to socioeconomic pressures on the forest plant resources. This base line data will be a commencing point for future workers involved in the management of forest biodiversity in this remote, neglected, and unexplored area.

Materials and Methods

Study area

The Tirah Vally is located in the Khyber, Kurram, and Orakzai districts between 33.73N 71.01E having an altitudinal range between 2500 and 3000 m (Figure 1). The present study was confined to the Tirah Valley within the District of Khyber. Four sites viz. Dwa seray, Angori Sar, Kovono Sar, and Landawar were selected on the basis of

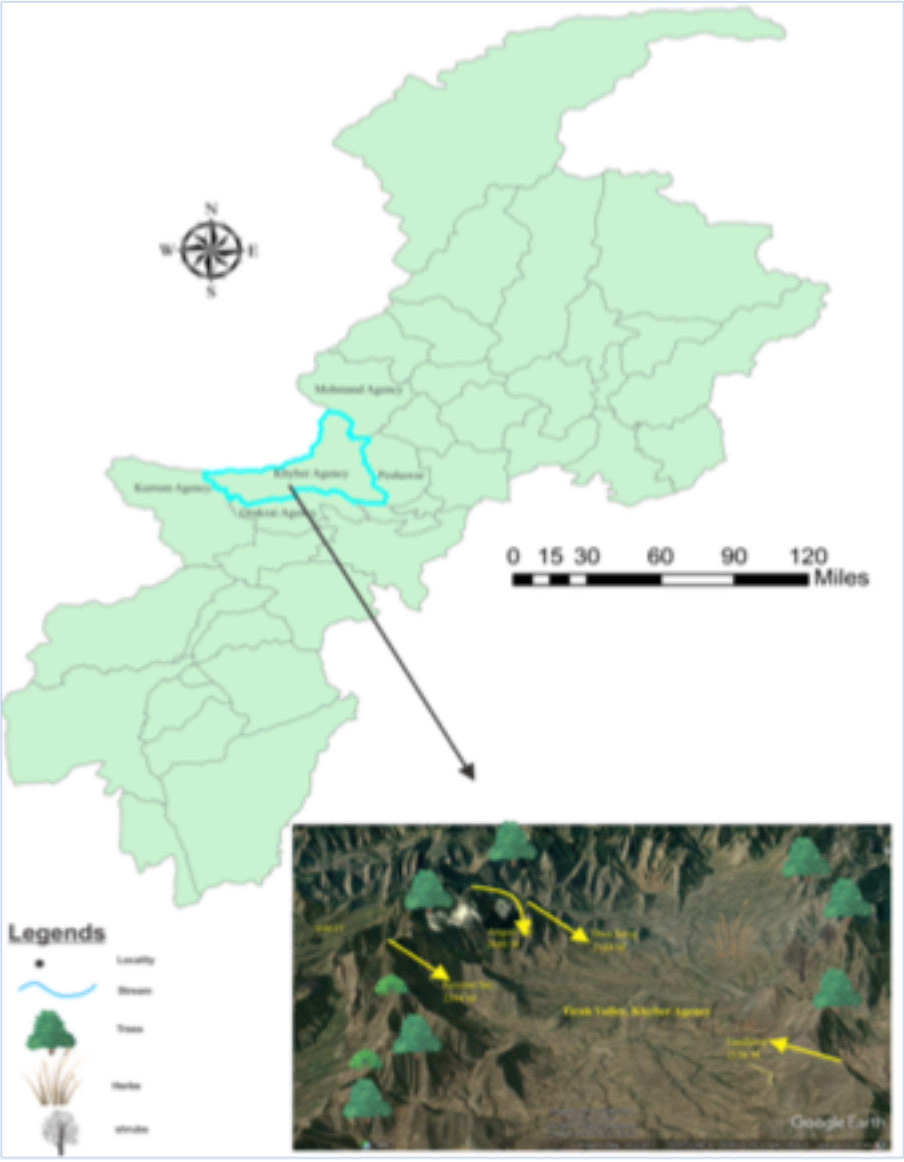

Figure 1. Map of Khyber Pakhtunkhwa showing the location of Tirah Valley. The research sites are shown in the inset with yellow arrows.

floristic, physiographic, and physiognomic variation. The climate of the Tirah Valley is pleasant in summer and severely cold in winter with temperature dropping to –7°C.

Floristic composition

Plants were collected during 2015-2016 with frequent visits to the selected area. Dried preserved specimens were mounted on standard herbarium sheets. Identification was done following the *Flora of Pakistan* (Nasir and Ali, 1970-1989; Ali and Nasir, 1989-1991; Ali and Qaiser, 1993-2020 continued). Plants were alphabetically arranged into major groups, families, genera, and species. Life form and leaf size spectra were prepared after Hussain (1989) and Raunkiaer (1934). The voucher specimens were submitted to the Herbarium, Department of Botany, University of Peshawar, Pakistan.

Results

Floristic composition

The investigation revealed 330 species scattered among 230 genera and seventy-eight families (Tables 1, 3). Of these, angiosperms had seventy families, 213 genera, and 312 species. Further synthesis showed that 277 (84.24%) and thirty-five species (10.61%) were, respectively dicots and monocots. Bryophytes had two families

(2.56%) with two genera (0.87%),and two species (0.61%). Pteridophytes contributed four families (5.13%) with ten genera (4.35%),and ten species (3.0%) . Gymnosperms had two families (2.56%), five genera (2.17%) and six species (1.82%). The average number of species/genus was 1.43, and the average number of species/family was 4.23. The average number of genera/family was 2.95. The richest families with respect to the number of species (Tables 2, 3) were respectively; Asteraceae (30 sp; 9.09%), Lamiaceae (28 sp; 8.48) and Rosaceae (27 sp; 8.18%), Poaceae (19 sp; 5.76%), Brassicaceae (15 sp; 4.55%), Solanaceae (13 sp; 3.94%), Cucurbitaceae (12 sp; 3.64%), Papilionaceae (11 sp; 3.33%), and Caryophyllaceae & Ranunculaceae (each with 10 sp; 3.0%). Pteridaceae had seven species. All the other remaining families had less than ten species. One species representation was made by forty-three families (Tables 2, 3).

Morpho-ecological characteristics

The habit form (Tables 1, 3) revealed 128 (38.79%) annual herbs, 122 (36.97%) perennial herbs, 41 (12.42%) shrubs and 39 (11.82%) tree species. The habitat form included sixty-three (19.09%) dry habitat species, 198 (60%) mesic species, and sixty-nine (20.91%) species of moist/aquatic habitats. The kind and population of species are generally more diverse under the most favorable optimum part of any ecological factor. Mesic habitats favor mesophytes. The majority of the species, *i.e.*, 76.67% in the present investigation were heliophytes. The spiny nature of the plants is an adaptation to the dry arid conditions to conserve the plant moisture. The climatic conditions of Tirah vary from humid subtropical conditions to the temperate type. Therefore, in the present study, 305 (92.42%) species were non-spiny. Deciduous species dominated (280 sp; 84.85%) the flora compared to only fifty (15.15%) evergreen species. The morphology, shape, and arrangement of leaves also reflect the local climatic conditions. The classification of leaf types showed that the leaves were simple-entire in 224 (67.88%) species (Tables 1, 3); and simple-incised leaves with various degrees of incisions or segmentations in thirty (9.1%) species. Six (1.82%) species of gymnosperms had simple needle-like leaves. Pinnate, palmate, and trifoliate compound leaves were present respectively in thirty-three (10%), fifteen (4.55%), and fourteen (4.24%) species (Tables 1, 3). *Marsilia quadrifolia* (1sp; 0.3%) was the only palmate four-foliate species. Scale leaves and cladodes were, respectively present in five (1.52%) and two (0.6%) species.

Biological spectra

Physiognomic attributes including life form and leaf size spectra indicate habitat deterioration, biotic interaction, and the climate of an area. Physiognomic contrast primarily depends on a dominating life form. It was evident that therophytes (128 sp; 38.79%), followed by hemicryptophytes (56 sp; 16.97%) and geophytes (41 sp; 12.42 %) were the major life forms in the envisaged flora. Megaphanerophytes (40 sp; 12.12%), nanophanerophytes (33 sp; 10%) and chamaephytes (31 sp; 9.39%) (Table 2) were the next important groups. Tree canopy is generally open due to the low number of tree species in the area. Tree species were mostly bushy due to continuous cutting and overgrazing. *Orobanche aegyptiaca* was the only root parasite in the area.

Leaf size spectra

Leaf sizes reflect environmental and climatic conditions. Small leaves dominate in hot or cold deserts with extreme temperature conditions. The current study revealed the dominance of nanophylls and microphylls, both categories collectively had 108 species, each sharing 32.73% cover (Tables 1, 3). Next were leptophylls with fifty-eight species (17.58%) and mesophylls (47 sp; 14.24 %). Macrophyllous (6 sp; 1.82 %) and aphyllous (3 sp; 0.91%) were rare in the area.

Discussion

Floristic composition

The richness of the flora of any area depends upon ecological, climatic, edaphic, and biotic factors. Generally, high floristic diversity is a sign of favorable habitat features. The present study revealed 330 species among 230 genera and seventy-eight families. In a similar study, Hussain *et al.* (2020) recorded four families of gymnosperms and pteridophytes and ninety-two dicot families with 318 genera from Koh-e-Sufaid. The later study covers a larger area with a temperate climate compared to Anjum *et al.* (2020), who listed 154 plant species of thirty-nine families from Karkhasa, the dry temperate rangelands of Quetta. The present findings also agree with Hayat *et al.* (2019), who also reported 134 dicots and thirty-one monocot species. *Cypresses sempervirens* was the only gymnosperm and *Adiantum caudatum* was the only pteridophyte from Razar Tehsil, Swabi District. The richest families in the envisaged area with a high number of species included: Asteraceae, Lamiaceae, Rosaceae, Poaceae, Brassicaceae, Solanaceae, Cucurbitaceae, Papilionaceae, Caryophyllaceae, and Ranunculaceae. These families are also leading families in the *Flora of Pakistan* (Nasir and Ali, 1970-1989; Ali and Nasir, 1989-1991; Ali and Qaiser, 1993-2020 continued). The findings regarding the major families in terms of species and genera agree with many workers (Shah *et al*., 2013; Sultan-u-Din *et al*., 2016; Bibi *et al*., 2019; Rafiqullah *et al*., 2021; Al-Saghair and Mahklouf, 2021; Salama *et al*., 2021) who also identified the same families as the major families in their investigated areas. Yeshitila and Awas (2020) regarded Fabaceae (17 sp; 13.2 %), Asteraceae (9 sp; 7.00%), and Lamiaceae (5 sp; 3.9%) as the diverse families in their study site. Anjum *et al.* (2020) also stated that Asteraceae (26 sp.) and Poaceae (21 sp.) were the richest families in Karkhasa, which supports the findings in the present study. Hussain *et al.* (2015) also stated that the same families had the highest number of species in the Flora of Mastuj. Similarly, Poaceae (20 sp.), Asteraceae (16 sp.) and Papilionaceae (9 sp.) were the leading families in the flora of Razar (Hayat *et al*., 2019). Poaceae (44 sp., 13.09 %) and Asteraceae (28 sp., 8.33 %) were the major families in the flora of Mir Ali S. Waziristan (Raza and Shah, 2020). Similarly, some other floristic studies (Ali *et al*., 2016; Das and Desai, 2020; Reena and Samuel, 2020; Hussain *et al.,* 2020) also valued the same families as the topmost families in their explored localities. Species richness depends on the suitability of optimum habitat conditions for the members of a particular family (Figure 2 A). The same family may have a different status in various environmental conditions. Deforestation and overgrazing also reduce the richness and diversity of species.

Morpho-ecological characteristics

The morphological and ecological adaptations of the flora closely follow the habitat conditions. In addition to physiological adaptation, plants depend on morphological features such as their habit, growth, and habitat forms. The structure, texture, the arrangement of leaves, the shape and size of the lamina and deciduousness play an important role in the plant survival. In the present work, the majority of the species were annual and perennial herbs with few tree species. The leaves were generally small, simple, and variously dissected. Most of the species belonged to mesic habitats. Similar results were achieved by Anjum *et al.* (2020) for the flora of Karkhasa, who documented 130 herbs and twenty-four shrubs. The results are supported by Hussain *et al.* (2020) and Das and Desai (2020), who also observed the dominance of herbaceous flora in their investigated area. Bibi *et al.* (2021) also recorded a high percentage of the annual flora in Tanawal Valley. The present findings in this respect are in line with Sultan-u-Din *et al.* (2016). Hayat *et al.* (2019) found 62.9% species in terrestrial habitats. Raza and Shah (2020) listed the majority of the species

(82.14%) in terrestrial habitats. Hussain *et al*. (2020) also recorded more than 66% species in dry habitats. All these references support the results of the present study.

Light availability and tolerance also cause variation in the occurrence and distribution of plant species. The majority of the species, i.e., 76.67% in the present investigation were heliophytes. This also agrees with Hayat *et al*. (2019), who reported that the bulk of species (130 spies) were heliophytes in the Flora of Razar Tehsil. Shade-loving species are generally understory plants of moist habitats. It was observed that few scattered tree species enabled (Figure 2 B) the light to reach the soil surface in the investigated areas of the Tirah Valley. Such habitats are more suitable for sun-loving plants and that is why 76.77% of the species were heliophytes. Spiny or prickly nature is an adaptation against grazing and the loss of water in dry regions. Since the Tirah Valley has a humid and tropical to a temperate climate which the non-spiny species favors, it was found that 92% of the species were non-spiny. The findings agree with some other similar studies reporting the dominance of non-spiny plants (Badshah *et al.,* 2016; Raza and Shah, 2020; Husain *et al*., 2020). The deciduous habit of plants is an adaptive feature to climatic conditions. In the present research, 84.85% of the species were deciduous because plants are exposed to the direct heat in summers and the snow-cold weather in winters. On the contrary, Badshah *et al.* (2016) reported that the majority of the perennial species were evergreen. The current study's findings are close to the findings of Raza and Shah (2020), who confirmed that 93.15% of the investigated species in their study area were deciduous. Like other studies (Hayat *et al*., 2019; Hussain *et al.,* 2015), the wild flora (80.91%) was dominant compared to the cultivated species (8.79%). Some thirty-four species (10.30%) grew in both wild and cultivated areas . The morphology, shape, and arrangement of leaves are dependent upon climatic conditions. Investigations of the leaf types revealed that the simple-entire leaves were seen in 67.88% of the species. These findings are in line with Badshah *et al.* (2016) who reported the dominance of the simple leaf lamina (81.27%) and the compound leaves (17.66%) in the flora of Parachinar. Likewise, Hussain *et al.* (2015) stated that more than 70% of the species had a simple leaf lamina. The present study is also consistent with Raza and Shah (2020) who listed simple leaves in 69.35% of the species and compound leaves in 15.48% of the species in the Flora of Mir Ali, N. Waziristan.

Biological spectra

Physiognomic attributes including life forms and leaf size spectra are indicators of habitat deterioration, biotic interaction, and the climatic conditions of an area. Dominating life forms produce a physiognomic contrast between vegetation types. In many contemporary studies (Shah *et al*., 2013; Sultan-u-Din *et al.,* 2016; Bibi *et al*., 2019; Salama *et al.,* 2021; Al-Sghair and Mahklouf, 2021; Rafiqullah *et al*., 2021), therophytes (38.79%), hemicryptophytes (16.97%) and geophytes (12.42 %) were the major life forms in the investigated flora. Megaphanerophytes (12.12%), nanophanerophytes (10%) and chamaephytes (9.39%) were uncommon in the investigated part of the Tirah Valley. The vegetation was open owing to the poor woody cover (Figure 2 C). The dominance of therophytes and hemicryptophytes indicates unfavorable habitat conditions. The soils of the Tirah Vally are generally shallow and stony (Figure 2 B) which suits shallow-rooted plants such ase annuals and hemicryptophytes. Overgrazing along with heavy deforestation have stressed the shrubby and tree species to assume a cushion-like habit. Therophytes dominate by virtue of their short life span, and strong capability to resist unfavorable conditions. Therophytes (50.9%), nanophanerophytes (12.79%) and megaphaneropyhtes (11.01%) were the dominant life forms in the arid area Mir Ali, N. Waziristan (Raza and Shah, 2020); and this agrees with the present findings. Furthermore, Badshah *et al.*

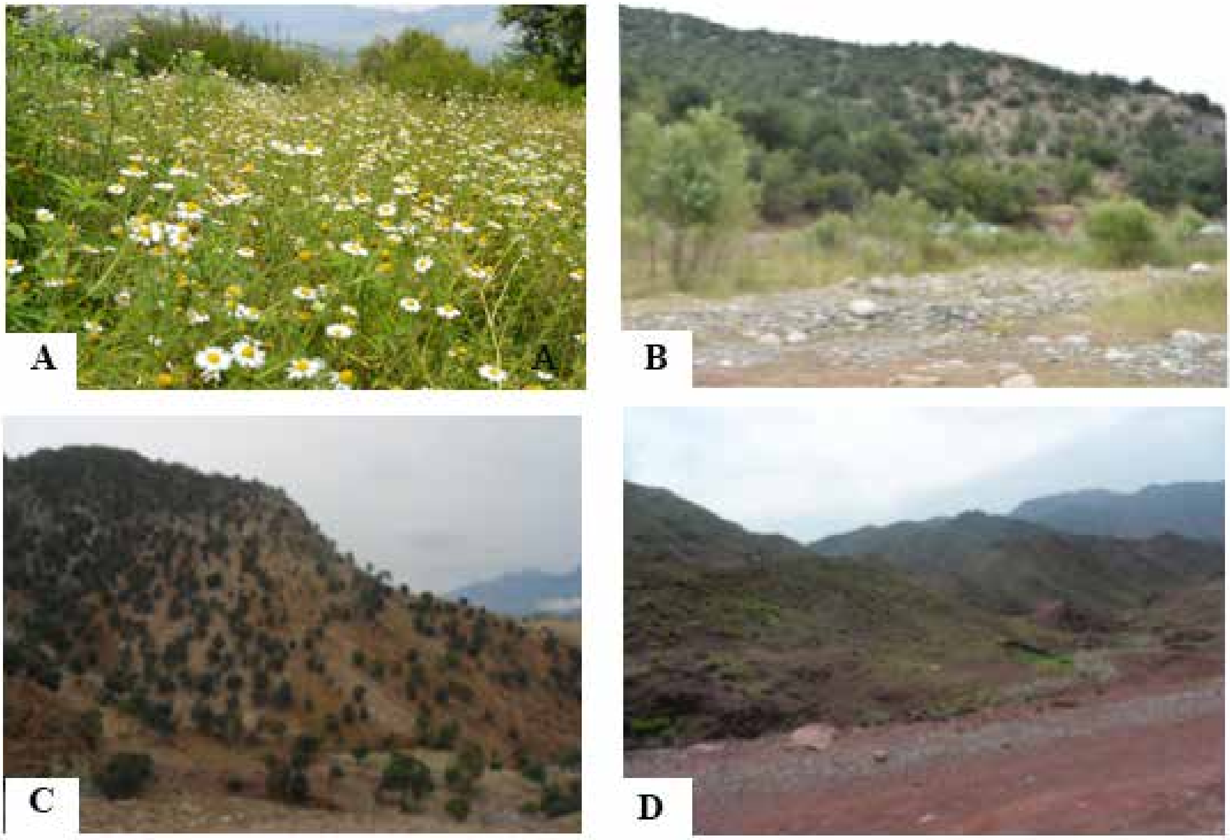

Figure 2. Different habitats of Flora of Tirah Valley.
A. A spring community of *Matricaria* along field borders and roadsides with moist habitat. **B**. A low hill with open forest canopy and dry ravine at the foot-hill showing erosion and degradation. **C**. Deformed bushy *Olea* forest with open canopy resulting from deforestation and overgrazing. See the exposed bare soil with no or poor plant growth. **D**.A degraded eroded and barren hill with dry water course at the foot-hill. See the poor overgrazed vegetation.

(2016) recorded therophytes (37.80%) and nanophanerophytes (16.7%) as the leading life forms in the flora of Parachinar.

Leaf size spectra

Leaf sizes are related to the severity of climate. Small leaves are generally common in hot dry or cold deserts with extreme temperature conditions. The current study divulged the supremacy of nanophylls and microphylls; both collectively had 108 species. Leptophylls (17.58%) and mesophylls (14.24 %), macrophyllous (1.82 %) and aphyllous (0.91%) were next in the order of occurrence in the area. The presence of aphyllous and scale-leaved species in the flora indicates a dry climate. Hussain *et al.* (2020) reported eleven aphyllous species from the Koh-e-Sufaid range, Pakistan. The findings are parallel with those of Anjum *et al*. (2020) who also recorded nanophylls followed by microphylls and leptophylls as the important leaf sizes in the flora of Karkhasa. Badshah *et al.* (2016) similarly revealed that nanophylls (42.75%) and leptophylls (31.44%) were the topmost leaf form classes in the flora of Parachinar. Raza and Shah (2020) listed the nanophylls (41.4%), microphylls (19.34%) and leptophylls (15.5%) as the major leaf sizes in the flora of Mir Ali. N. Waziristan.

Environmental Change in the area

No metrological station nor internet services are available in the Tirah Valley; therefore, reliance is made on the interviews and discussion with local elders above fifty years of age. These elderly people stated that some fifty to sixty years back, there were thick forests of blue pine in the upper parts above 2000 meters; and thick *Olea* *ferrugnea* forests in the lower reaches. The forest canopies were generally complete. The rainfall and snowfall were quite high and regular, but have now decreased due to deforestation, over-exploitation, and overgrazing problems. The mountain slopes have been converted into agricultural fields that further aggravated the situation. Wildlife has declined owing to overhunting and habitat degradation. The data retrieved from the internet (*WWW*, 2021) for the years 2010-2020 shows a slight increase in the temperature of the hot months of May through July. Similarly, the monthly rainfall during July and August is less than 240 mm with an average of twenty rainy days. The rainfall is 25-35 mm with an average of ten to fifteen rainy days from February to April. Although we did not collect quantified data on plant population, but open bare spaces and the decline in woody species speak of degradation, erosion, and habitat loss (Figure 2 D).

Conclusion

Rich floral diversity is a sign of a healthy and friendly environmental condition. Flora as producers is an important component of any ecosystem developed under a particular set of environmental and habitat condition. Floristic diversity simply refers to the plant richness of a community or a geographical area. The study concludes that the area is rich in humid subtropical and temperate species. It requires further extensive surveys round the year to enlist the complete floristic variability. The local inhabitants depend upon forest resources for fodder, medicinal plants, fuelwood, and many other varied needs. This puts a tremendous pressure on the regeneration, growth, conservation, and the survival of plant resources. The overharvesting of fuelwood and medicinal species and overgrazing are some of the major ecological threats hindering the regeneration of forest resources. An ecological approach with the participation of local community can maintain the original plant resources. More investigations are recommended to assess the present conservation status of the important plant resources of this remote and unexplored valley.

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Declaration of competing interests

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Contribution by authors

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Table 1. Summary of the Flora of the Tirah Khyber District and its and morpho-ecological features.

A	**Floristic Composition**	**Families**		**Genera**		**Species**	
	Major Group	**No**	**%**	**No**	**%**	**No**	**%**
	i. Bryophyta	2	2.56	2	0.87	2	0.61
	ii. Pteridophyta	4	5.13	10	4.35	10	3.03
	iii. Gymnosperms	2	2.56	5	2.17	6	1.82
	iv. Angiosperms	70	89.75	213	92.61	312	94.55
	a. Monocots	9	11.54	25	10.87	35	10.61
	b. Dicots	61	78.21	188	81.74	277	83.94
	Total	**78**	**100**	**230**	**100**	**330**	**100**
B	**Habitat Form**	**No**	**%**		**C. Habit Form**	**No.**	**%**
	i. Dry	63	19.09		i. Annual herbs	128	38.79
	ii. Mesic	198	60.0		ii. Perennial herbs	122	36.97
	iii. Moist/aquatic	69	20.91		iii. Shrubs	41	12.42
	Total	**330**	**100**		iv. Trees	39	11.82
					Total	**330**	**100**
D	**Shade & Light Requirement**				**E. Spinescence**		
		No	**%**			**No**	**%**
	i. Heliophytes	253	76.67		i. Non spiny	305	92.42
	ii. Sciophytes	77	23.33		ii. Spiny	25	7.58
	Total	**33o**	**100**		**Total**	**330**	**100**
F	**Leaf Types**	**No**	**%**		**F. Deciduousness**	**No**	**%**
	i. Simple entire	224	67.88		i. Deciduous	280	84.85
	ii. Simple incised	30	9.1		ii. Evergreen	50	15.15
	iii. Simple needles	06	1.82		**Total**	**330**	**100**
	iv. Compound pinnate	33	10.0				
	v. Compound palmate	15	4.55		**H. Cultivation status**	**No**	**%**
	vi. Compound trifoliate	14	4.24		i. Wild	267	80.91
	vii. Compound 4-foliate	01	0.3		ii. Cultivated	29	8.79
	viii. Scale leaves	05	1.52		iii. Wild/Cultivated	34	10.30
	ix. Cladodes	02	0.6		**Total**	**330**	**100**
	Total	**330**	**100**				
I	**Biological Spectrum**	**No**	**%**		**J. Leaf size Spectrum**	**No**	**%**
	i. Therophytes	128	38.79		i. Aphyllous	03	0.91
	ii. Hemicryptophytes	56	16.97		ii. Leptophyll	58	17.58
	iii. Geophytes	41	12.42		iii. Nanophyll	108	32.73
	iv. Megaphanerophytes	40	12.12		iv. Microphyll	108	32.73
	v. Nanophanerophytes	33	10.0		v. Mesophyll	47	14.24
	vi. Chamaephytes	31	9.39		vi. Macrophyll	06	1.82
	vii. Parasite	01	0.30		**Total**	**330**	**100**
	Total	**330**	**100**				

Table 2. Summary of Importance status of various families based on number of genera and species.

A.	**Based on the Number of Species (Total species=330)**		
S. No.	Name of Family	No. of Species	%
	Asteraceae	30	9.09
	Lamiaceae	28	8.48
	Rosaceae	27	8.18
	Poaceae	19	5.76
	Brassicaceae	15	4.55
	Solanaceae	13	3.94
	Cucurbitaceae	12	3.64
	Papilionaceae	11	3.33
	Caryophyllaceae	10	3.03
	Ranunculaceae	10	3.03
	Euphorbiaceae, Boraginaceae	8 each	2.42%
	Pteridaceae	7	2.12
	Geraniaceae, Polygoniaceae, Scrophulariaceae	6 each	1.82% each
	Chenopodiaceae, Salicaceae, Pinaceae	5 each	1.52% each
	10 families	3 each	0.91% each
	11 families	2 each	0.61% each
	35 families	1 each	0.3% each
Total	**78 families**		

B.	**Based on the Number of Genera (Total Genera= 230)**		
S. No.	Name of Family	No. of Genera	%
	Asteraceae	24	30.76
	Lamiaceae	19	24.36
	Poaceae	15	19.23
	Rosaceae	13	16.67
	Brassicaceae	10	12.82
	Papilionaceae	8	10.26
	Solanaceae, Cucurbitaceae, Caryophyllaceae, Boraginaceae, Pteridaceae	7 each	8.97% each
	Ranunculaceae	6	7.69
	Polygonaceae, Scrophulariaceae	5 each	6.41% each
	Euphorbiaceae, Pinaceae	4 each	5.13% each
	Geraniaceae, Thymelaeaceae,Urticaceae	3 each	3.85% each
	16 families	2 each	2.56% each
	43 families	1 each	1.28%each
Total	**78 families**		

Table 3. Floristic inventory and morpho-ecological features of the flora of the TirahValley Khyber District, Pakistan.

	Species	**Habit**	**Life Form**	**Leaf Size**	**Habitat**	**Light/ shade**	**Spine- scence**	**Leaf type**	**Leaf fall**	**Cultivation status**
	A. Bryophyta (2F; 2G; 2Sp)									
	1. Family Funariaceae (1G; 1Sp)									
1	*Funaria hgrometrica* Hedw	AH	Th	L	Moi	S	NS	SL	E	W
	2. Family Polytrichaceae (1G; 1Sp)									
2	*Polytrichum commune* Hedw	AH	Th	L	Moi	S	NS	SL	E	W
	B. **Pteridophytes (4F; 10 G; 10 sp)**									
	1. Family Equisetaceae (1G; 1sp)									
3	*Equisetum ramosissimum* Desh	PH	G	L	Moi	S	NS	SL	E	W
	2. Family Marsiliaceae (1G; 1sp)									
4	*Marsilea quadrifolia* L	PH	G	Mes	Aq	S	NS	C4f	E	W
	3. Family Pteridaceae (7G; 7 sp)									
5	*Adiantum capillus-veneris* L.	PH	G	Mic	Moi	S	NS	CPin	E	W
6	*Asplenium dalhousiae* Hook	PH	G	Mc	Moi	S	NS	CPin	E	W
7	*Cetrach dalhousii*	PH	G	Mic	Moi	S	NS	CPin	E	W
8	*Dryopteris sp*	PH	G	Mic	Moi	S	NS	CPin	E	W
9	*Pteris cretica* L	PH	G	Mic	Moi	S	NS	Cpin	E	W
10	*Pteridium aquilinum* (L) Kuhn	PH	G	L	Moi	S	NS	CPin	D	W
11	*Onychium contiguum* Wall ex Hope	PH	G	L	Moi	S	NS	CPin	D	W
	4. Family Selaginellaceae (1G; 1ap)									

12	*Selaginella sp*	PH	G	L	Moi	S	NS	SL	D	W
	C. **Gymnosperms (2F, 5G; 6Ss)**									
	1. Family Pinaceae (4G; 5 sp)									
13	*Abies pindrow* Royle	Tree	MP	N	Dry	H	NS	SN	E	W
14	*Cedrus deodara* (Roxb. ex D. Don) G.Don	Tree	MP	N	Dry	H	NS	SN	E	W
15	*Picea smithiana* (Wall.) Boiss.	Tree	MP	N	Dry	H	NS	SN	E	W
16	*Pinus roxburghii* Sargent	Tree	MP	L	Dry	H	NS	SN		
17	*Pinus wallichiana* A.B. Jackson	Tree	MP	N	Dry	H	NS	SN	E	W
	2. Family Taxaceae (1G; 1sp)									
18	*Taxus wallichiana* Zucc	Tree	MP	N	Dry	S	NS	SN	E	W
	D. **Angiosperms**									
	I. Monocotyledons (9F, 25G, 35 sp)									
	1. Family Alliaceae (1G; 3 sp)									
19	*Allium cepa* Linn	PH	G	Mic	Mes	H	NS	SE	D	C
20	*Allium griffithianum* Boiss.	PH	G	N	Mes	H	NS	SE	D	W
21	*Allium sativum* Linn	PH	G	N	Mes	H	NS	SE	D	C
	2. Family Araceae (2G; 3 sp)									
22	*Arisaema jacquemontii* Blume	PH	G	Mes	Moi	S	NS	CP	D	W
23	*Arisaema flavum* (Forssk.) Schott	PH	G	Mes	Moi	S	NS	CP	D	W
24	*Sauromatum venosum* (Ait.) Schott,	PH	G	Mes	Moi	S	NS	CP		
	3. Family Asparagaceae (1G; 2 sp)									
25	*Asparagus adscendens* Roxb	PH	G	Aph	Moi	S	NS	Cld	E	W

26	*Asparagus officinalis* L	PH	G	Aph	Moi	S	NS	Cld	E	W
	4. Family Cyperaceae (1G; 2 sp)									
27	*Cyperus rotundus* Linn	PH	G	L	Moi	S	NS	SE	D	W
28	*Cyperus difformis* Linn	AH	Th	L	Moi	S	NS	SE	D	W
	5. Family Haemodoraceae (1G; 1 sp)							SE		
29	*Liriope graminifolia* (L.) Baker.	PH	G	N	Mes	H	NS	SE		W
	6. Family Iridaceae (1G; 1 sp)									
30	*Moraea sisyrinchium* (L.) Ker Gawl.	PH	G	L	Mes	H	NS	SE	D	W
	7. Family Liliaceae (2G; 2 sp)							SE		
31	*Fritillaria roylei* Hook.	PH	G	Mic	Mes	S	NS	SE		W
32	*Tulipa clusiana* DC.	PH	G	Mic	Mes	H	NS	SE	D	W
	8. Family Orchidaceaes (2G; 2 sp)							SE		
33	*Dactylorhiza hatagirea* (D. Don) Soo	PH	G	Mic	Moi	S	NS	SE	D	W
34	*Spiranthes sinensis* (Pers.) Ames	PH	G	Mic	Moi	H	NS	SE	D	W
	9. Family Poaceae (15G; 19 sp)							SE		
35	*Arundo donax* Linn	PH	Ch	N	Moi	H	NS	SE	E	W
36	*Avena sativa* L.	AH	Th	N	Mes	H	NS	SE	D	W/C
37	*Arthraxon prionodes* (Steud.) Dandy	PH	He	Mic	Mes	H	NS	SE	D	W
38	*Cymbopogon jwarancusa* (Jones) Schult.	PH	He	Mic	Mes	H	NS	SE	E	W
39	*Cynodon dactylon* L.	PH	He	L	Mes	H	NS	SE	E	W
40	*Echinochloa crus-galli* (Linn.) P. Beauv	AH	Th	L	Mes	H	NS	SE	D	W

41	*Echinochloa colona* (Linn.) Link	AH	Th	L	Mes	H	NS	SE	D	W
42	*Eragrostis sp*	AH	Th	L	Mes	H	NS	SE	D	W
43	*Hyparrhenia hirta* (L.) Stapf	PH	He	L	Mes	H	NS	SE	E	W
44	*Lolium perenne* Linn	PH	H	L	Mes	H	NS	SE	D	W
45	*Poa annua* L.	AH	Th	L	Mes	H	NS	SE	D	W
46	*Sorghum bicolor* (Linn.) Moench	AH	Th	N	Mes	H	NS	SE	D	C
47	*Sorghum halepense* (Linn.) Pers	PH	He	N	Mes	H	NS	SE	D	W/C
48	*Saccharum spontaneum* Linn	PH	Ch	Mic	Moi	H	NS	SE	E	W
49	*Saccharum griffithii* Munro ex Boiss	PH	Ch	Mic	Moi	H	NS	SE	E	W
50	*Saccharum officinarum* Linn	PH	Ch	Mic	Moi	H	NS	SE	E	C
51	*Triticum arstivum*	AH	Th	N	Mes	H	NS	SE	D	C
52	*Hordeum vulgare*	AH	Th	N	Mes	H	NS	SE	D	C
53	*Zea mays* L.	AH	Th	Mes	Mes	H	NS	SE	D	C
	II. **Dicotyledons**									
	1. Family Acanthaceae (2G; 2 sp)									
54	*Strobilanthes glutinosus* Nees	Shrub	Ch	Mic	Moi	S	NS	SE	D	W
55	*Dodonaea viscosa* (Linn.) Jacq.	Shrub	NP	N	Dry	S	NS	SE	E	W/C
	2. Family Amaranthaceae (2G; 3 sp)							SE		
56	*Amaranthus viridis* L.	AH	Th	N	Mes	H	NS	SE		W
57	*Amaranthus spinosus* L.	AH	Th	Mic	Mes	H	SP	SE		W
58	*Digera muricata* (L.) Mart	AH	Th	L	Mes	H	NS	SE	D	W
	3. Family Apiaceae (2G; 3 sp)									
59	*Bupleurum falcatum L*	PH	He	L	Mes	H	NS	SE	D	W
60	*Bupleurum longicaule* Wall. ex DC.	AH	Th	Mic	Mes	H	NS	SE	E	W
61	*Coriandrum sativum* Linn.	AH	Th	L	Mes	H	NS	SI	D	C
	4. Family Araliaceae (1G; 1 sp)									

62	*Hedera nepalensis* K. Koch.	PH	MP Cl)	Mic	Mes	S	NS	SE	E	W
	5. Family Asteraceae (24G; 30 sp)									
63	*Anthemis arvensis* Linn.	AH	Th	L	Mes	H	NS	SI	D	W/c
64	*Artemisia vulgaris* L.	Shrub	Ch	N	Dry	H	NS	SI	D	W
65	*Artemisia scoparia* Waldst & Kit.	Shrub	Ch	N	Dry	H	NS	SI	D	W
66	*Calendula arvensis* (Vaill.) L.	AH	Th	N	Mes	H	NS	SE	D	W
67	*Calendula officinalis* Linn.	AH	Th	N	Mes	H	NS	SE	D	C
68	*Carpesium cernuum* Linn.	PH	Ch	Mic	Mes	H	NS	SE	D	W
69	*Centaurea iberica* Treviranus ex Sprengel	AH	Th	N	Mes	H	SP	SI	D	W
70	*Chrysanthemum leucanthemum* Linn	PH	He	L	Mes	H	NS	SI	D	W
71	*Cichorium intybus* L.	AH	Th	N	Mes	H	NS	SE	D	W
72	*Cirsium arvense* (L.) Scop.	AH	Th	N	Mes	H	SP	SE	D	W
73	*Cirsium verutum* (D.Don) Spreng.	AH	Th	Mes	Mes	H	SP	SE	D	W
74	*Cnicus benedictus* L	AH	Th	Mes	Mes	H	SP	SI	D	W
75	Echinops echinatus Roxb.	AH	Th	Mes	Dry	H	SP	SI	D	W
76	*Conyza bonariensis* (L) Cronquist.	AH	Th	Mes	Mes	H	NS	SE	D	W
77	*Conyza canadensis* (L.) Cronquist.	AH	Th	N	Mes	H	NS	SE	D	W
78	*Cotula hemisphaerica* (Roxb.) Wall. ex Benth. & Hook. f	AH	Th	L	Mes	H	NS	SE	D	W
79	*Filago arvensis* L.	AH	Th	Mic	Mes	H	NS	SE	D	W
80	*Galinsoga parviflora* Cavanilles	AH	Th	N	Mes	H	NS	SE	D	W
81	*Helianthus annuus* L.	AH	Th	Mic	Mes	H	NS	SE	D	W/C
82	*Launaea nudicaulis* (L.) Hook.f.	AH	Th	Mic	Mes	H	NS	SE	D	W
83	*Leucanthemum vulgare* Lam.	PH	He	Mic	Mes	H	NS	SE	D	W

84	*Matricaria chamomile* L.	AH	Th	L	Mes	H	NS	CPin	D	W
85	*Senecio analogus* DC.	PH	G	Mic	Mes	H	NS	SI	D	W
86	*Senecio chrysanthemoides* DC.	AH	Th	Mes	Mes	H	NS	SI	D	W
87	*Seriphidium kurramenesis* (Qazilb.) Y. R. Lling	Shrub	Ch	L	Mes	H	NS	SI	D	W
88	*Sonchus asper* L.	AH	Th	Mic	Moi	S	NS	SI	D	W
89	*Sonchus oleraceus* L.	AH	Th	Mic	Moi	S	NS	SI	D	W
90	*Tagetus patula.*	AH	TH	Mic	Mes	S	NS	SI	D	W
91	*Taraxacum officinale* Weber.	AH	Th	Mic	Mes	H	NS	SI	D	W
92	*Xanthium strumarium* L.	AH	Th	N	Dry	H	SP (Fruit spiny)	SE	D	W
	6. Family Balsaminaceae (1G; 4 sp)							SE		
93	*Impatiens bicolor* Royle	AH	Th	Mes	Mes	S	NS	SE	D	W
94	*Impatiens brachycentra* Kar.	AH	Th	N	Mes	S	NS	SE	D	W
95	*Impatiens edgeworthii* Hook.	AH	Th	Mes	Mes	S	NS	SE	D	W
96	*Impatiens glandulifera* Royle	AH	Th	N	Mes	S	NS	SE	D	W
	7. Family Berberidaceae (1G; 1 sp)							SE		
97	*Berberis lycium* Royle	Shrub	NP	Mic	Dry	H	SP	SE	E	W
	8. Family Bignoniaceae (1G; 1 sp)									
98	*Incarvillea emodi* (Royle ex Lindl.) Chatterjee	PH	He	N	Mes	H	NS	CPin	D	W
	9. Family Boraginaceae (7G; 8 sp)									
99	*Cordia gharaf* (Forssk.) Ehren.ex Asch.	Tree	MP	Mes	Mes	H	NS	SE	D	W/C
100	*Cynoglossum lanceolatum* Forssk.	PH	He	N	Mes	H	NS	SE	D	W
101	*Ehretia obtusifolia*Hochst.ex DC	Shrub	NP	Mic	Dry	H	NS	SE	D	W

102	*Heliotropium europaeum*var. *lasiocarpum*(F. & M.) Kazmi	AH	Th	N	Dry	H	NS	SE	D	W
103	*Lithospermum officinale* L.	PH	He	N	Mes	H	NS	SE	D	W
104	*Nonea edgeworthii* A. DC.	AH	Th	N	Mes	H	NS	SE	D	W
105	*Nonea pulla* (L.) DC	AH	Th	N	Mes	H	NS	SE	D	W
106	*Onosma khyberianum* I. M. Johnston	AH	Th	Mic	Mes	H	NS	SE	D	W
	10. Family Brassicaceae (10 G; 10 sp)									
107	*Brassica juncea* (Linn.) Czern. et Coss	AH	Th	N	Dry	H	NS	SI	D	C
108	*Brassica napus* subsp. *napus*	AH	Th	N	Dry	H	NS	SI	D	C
109	*Brassica nigra* (Linn.) Koch	AH	Th	N	Dry	H	NS	SI	D	W/c
110	*Brassica oleracea* var. *botrytis* Linn. Gobi	AH	Th	N	Dry	H	NS	SI	D	C
111	*Brassica rapa* subsp. *campestris* (Linn.) Clapham	AH	Th	Mic	Mesi	H	NS	SI	D	W/C
112	*Eruca sativa* Mill	AH	Th	L	Dry	H	NS	SI	D	W/C
113	*Capsella bursa-pastoris* (Linn) Medikus	AH	Th	L	Moi	H	NS	SI	D	W
114	*Cardaria draba* (L.) Desv.	AH	Th	N	Mes	H	NS	SI	D	W
115	*Coronopus didymus* L.	AH	Th	L	Moi	H/S	NS	SI	D	W
116	*Nasturtium officinale* R. Br	PH	G	N	Aq	H	NS	SI	E	W
117	*Neslia apiculata* Fisch., C.A. Mey. & Ave'-Lall	AH	Th	L	Mes	H	NS	SE	D	W
118	*Lepidium apetalum* Willd	AH	Th	L	Dry	H	NS	SE	D	W
119	*Lepidium sativum* Linn	AH	Th	L	Dry	H	NS	SI	D	W
120	*Rorippa indica* (Linn.) Hiern,	AH	Th	L	Aq	H	NS	SI	D	W
121	*Sisymbrium irio* Linn	AH	Th	L	Mes	H	N	SI	D	W
	11. Family Cannabaceae (1G; 1 sp)									
122	*Cannabis sativa* L.	AH	Th	Mic	Mes	H	NS	CP	D	W
	12. Family Convallariaceae (1G; 1 sp)									
123	*Polygonatum multiflorum* L.	PH	G	Mic	Mes	S	NS	SE	D	W

	13. Family Caprifoliaceae (2G; 3 sp)									
124	*Lonicera griffithii* Hook.f. & Thoms.	Shrub	NP	Mic	Mes	H	NS	SE	D	W
125	*Lonicera quinquelocularis*	Shrub	NP	Mic	Mes	H	NS	SE	D	W
126	*Viburnum cotinifolium* D. Don	Shrub	NP	Mic	Mes	H	NS	SE	D	W
	14. Family Caryophyllaceae (7G; 10 sp)									
127	*Arenaria serpyllifolia* L	AH	Th	L	Mes	H	NS	SE	D	W
128	*Cerastium dichotomum* L	PH	He	L	Mes	H	NS	SE	D	W
129	*Cerastium cerastioides* (L.) Britton	PH	He	L	Mes	H	NS	SE	D	W
130	*Cerastium glomeratum* Thuill	AH	Th	L	Mes	H	NS	SE	D	W
131	*Dianthus anatolicus* Boiss	PH	Ch	N	Dry	H	NS	SE	D	W
132	*Silene vulgaris* (Moench) Garcke	AH	Th	L	Mes	H	NS	SE	D	W
133	*Silene conoidea* L.	AH	Th	L	Mes	H	NS	SE	D	W
134	*Spergula arvensis* L.	AH	Th	L	Mesic	H	NS	SE	D	W
135	*Spergularia media* (L.) Presl	PH	He	L	Mesic	H	NS	SE	D	W
136	*Stellaria media* (L.) Vill	AH	Th	N	Mesic	S	NS	SE	D	W
	15. Family Chenopodiaceae (2G; 5 sp)									
137	*Chenopodium album* L.	AH	Th	Mic	Mesic	H	NS	SE	D	W
138	*Chenopodium ambrosioides* L.	AH	Th	Mic	Moist	H	NS	SE	D	W
139	*Chenopodium botrys* L.	AH	Th	N	Mesic	H	NS	SE	D	W
140	*Chenopodium murale* Linn	AH	Th	N	Mesic	H	NS	SE	D	W
141	*Spinacia oleracea* Linn	AH	Th	N	Mesic	H	NS	SE	D	C

	16. Family Cucurbitaceae (7G; 12 sp)									
142	*Cucurbita maxima* Duch. ex Lam Metha kadu	AH, trailer	Th	Meg	Mesic	H	NS	SE	D	W
143	*Cucurbita moschata* (Duch. ex Lam.) Duch. ex Poir	AH trailer	Th	Meg	Mesic	H	NS	CP	W	C
144	*Lagenaria siceraria* (Molina) Standley	AH trailer	Th	Mes	Mesic	H	NS	CP	D	C
145	*Cucumis melo* subsp. *melo* var. *melo* Sweet melon	AH trailer	Th	Mic	Mesic	H	NS	SE	D	C
146	*Cucumis prophetarum* Linn	AH trailer	Th	Mic	Mesic	H	NS	SE		W
147	*Cucumis sativus* Linn	AH	Th	Mic	Mesic	H	NS	SE	D	C
148	*Momordica charantia* Linn	AH trailer	Th	Mic	Mesic	H	NS	CP	D	C
149	*Citrullus lanatus* (Thunb.) Mats. & Nakai Tarboa	AH trailer	Th	Mes	Mesic	H	NS	SE	D	C
150	*Citrullus colocynthis* (Linn.) Schrad.	PH trailer	He	Mes	Dry	H	NS	SE	D	W
151	*Luffa cylindrica* (Linn.) Roem	AH	Th	Mes	Mesic	H	NS	SE	D	C
152	*Luffa acutangula* var. *acutangula*	AH	Th	Mes	Mesic	H	NS	SE	D	C
153	*Praecitrullus fistulosus* (Stocks) Pangalo Tinda	AH	Th	Mes	Mesic	H	NS	SE	D	C
	17. Family Convolvulaceae (2G; 2 sp)									
154	*Convolvulus arvensis* Linn.	PH	He	N	Mesic	H	NS	SE	D	W
155	*Ipomoea purpurea* L.	AH	Th	N	Mesic	H	NS	CP	D	W
	18. Family Cornaceae (1G; 1 sp)									
156	*Cornus macrophylla* Wall.	Tree	MP	Mic	Mesic	H	NS	SE	D	W
	19. Family Dipsacaceae (1G; 1 sp)									
157	*Dipsacus* sp.	AH	Th	Mic	Mesic	H	NS	SE	D	W
	20. Family Ebenaceae (1G; 1 sp)									

158	*Diospyros lotus* L.	Tree	MP	Mic	Mesic	H	NS	SE	D	W
	21. Family Euphorbiaceae (4G; 8 sp)									
159	*Andrachne cordifolia* (Wall. ex Decne.) Muell. Arg.	Shrub	NP	Mic	Dry	H	NS	SE	D	W
160	*Chrozophora tinctoria* (L) Raf.	AH	Th	Mic	Dry	H	NS	SE	D	W
161	*Euphorbia indica* Lam.	AH	Th	L	Dry	H	NS	SE	D	W
162	*Euphorbia helioscopia* L.	AH	Th	N	Mesic	H	NS	SE	D	W
163	*Euphorbia hirta* L	AH	Th	L	Mesic	H	NS	SE	D	W
164	*Euphorbia granulata* Forssk	PH	Th	L	Mesic	H	NS	SE	D	W
165	*Euphorbia prostrata* Ait	AH	Th	L	Mesic	H	NS	SE	D	W
166	*Ricinus communis* L.	Shrub	Ch	Mac	Mesic	H	NS	CP	D	W
	22. FamilyFagaceae (1G; 2 sp)									
167	*Quercus baloot* Griffth	Tree	MP	Mic	Dry	H	Leaf spiny	SE	E	W
168	*Quercus dilatata* Royle	Tree	MP	Mic	Dry	H	NS	SE	E	W
	23. FamilyFumariaceae (1G; 1 sp)									
169	*Fumaria indica* (Hausskn.) Pugsley	AH	Th	N	Mesic	S	NS	SI	D	W
	24. Family Geraniaceae (3G; 6 sp)									
170	*Erodium malacoides* (L.) L'Herit ex Aiton,	AH	Th	N	Mesic	D	NS	SI	D	W
171	*Erodium cicutarium* (L.) L'Herit, ex Aiton	AH	Th	N	Mesic	D	NS	SI	D	W
172	*Geranium lucidum* L.	AH	Th	N	Mesic	S	NS	SI	D	W
173	*Geranium nepalense* Sweet,	AH	Th	Mic	Mesic	S	NS	SI	D	W
174	*Geranium wallichianum* D. Don ex Sweet.	PH	He	Mic	Mesic	S	NS	SI	D	W
175	*Pelargonium zonale* L'Herit ex Soland	PH	He	N	Mesic	S	NS	SE		C
	25. Family Hypericaceae (1G; 1 sp)									

176	*Hypericum perforatum* L.	PH	He	N	Mesic	H	NS	SE	D	W
	26. FamilyJuglandaceae1G; 1 sp)							SE		
177	*Juglans regia* L.	Tree	MP	Mg	Mesic	H	NS	SE	D	W
	27. Family Lamiaceae (19 G; 28 sp)									
178	*Ajuga bracteosa* Wall.	PH	He	Mic	Moist	S	NS	SE	D	W
179	*Ajuga parviflora* Benth.	PH	He	Mic	Moist	S	NS	SE	D	W
180	*Clinopodium umbrosum* (M. Bieb.) Fisch. & Meyer	PH	He	Mic	Moist	H	NS	SE	D	W
181	*Isodon rugosus* (Wall. ex Benth.) Codd	Shrub	NP	N	Dry	H	NS	SE	D	W
182	*Lamium album* L.	PH	He	N	Mesic	S	NS	SE	D	W
183	*Lamium amplexicaule* L	AH	Th	N	Moist	S	NS	SE	D	W
184	*Leonurus cardiaca* L.	AH	Th	Mic	Mesic	H	NS	SE	D	W
185	*Marrubium vulgare* L.	PH	H	Mic	Mesic	H	NS	SE	D	W
186	*Mentha arvensis* L.	PH	G	Mic	Moist	H	NS	SE	E	W
187	*Mentha longifolia* L.	PH	G	N	Moist	H	NS	SE	E	W
188	*Mentha viridis* L.	PH	G	Mic	Moist	H	NS	SE	E	W
189	*Micromeria biflora* (Buch.-Ham.ex D. Don) Benth.	PH	He	L	Mesic	S	NS	SE	D	W
190	*Nepeta erecta* (Boyle ex Benth.) Berth.	PH	He	Mic	Mesic	H	NS	SE	D	W
191	*Nepeta laevigata* (D. Don) Hand.	PH	He	L	Mesic	H	NS	SE	D	W
192	*Ocimum basilicum* L.	pH	Ch	Nan	Mesic	H	NS	SE	E	C
193	*Origanum vulgare* L.	Shrub	Ch	Mic	Dry	H	NS	SE	D	W
194	*Phlomis cashmeriana* Royle ex Benth.	PH	Ch	Mic	Mesic	H	NS	SE	D	W
195	*Phlomis spectabilis* Falc. Ex Bth	PH	Ch	Mic	Mesic	H	NS	SE	D	W
196	*Prunella vulgaris* L.	PH	He	N	Mesic	H	NS	SE	D	W
197	*Salvia hians* Royle ex Benth	PH	Ch	N	Mesic	H	NS	SE		

198	*Salvia moocroftiana*Wall. Ex Benth.	PH	He	Mic	Mesic	H	NS	SE	D	W
199	*Salvia nubicola* Wall. ex Sweet,	PH	He	Mic	Mesic	H	NS	SE	D	W
200	*Salvia plebeia* R. Br.	AH	Th	Mes	Mesic	H	NS	SE	D	W
201	*Scutellaria chamaedrifolia* Hedge & Paton	PH	Ch	N	Mesic	H	NS	SE	D	W
202	*Stachys emodi* Hedge.	PH	He	N	Mesic	H	NS	SE	D	W
203	*Teucrium royleanum* Wall. ex Benth.	PH	Ch	Mic	Dry	H	NS	SE	D	W
204	*Teucrium stocksianum* Boiss	PH	Ch	L	Dry	H	NS	SE	D	W
205	*Thymus linearis* subsp. *linearis* Jalas	PH	He	N	Mesic	H	NS	SE	E	W
	28. Family Malvaceae (2G; 3 sp)									
206	*Hibiscus rosa-sinensis* Linn	Shrub	Ch	N	Mesc	H	NS	SE	E	
207	*Malva neglecta* Wallr.	PH	He	Mic	Mesic	H	NS	SE	DC	W
208	*Malva parviflora* L.	AH	Th	Mic	Mesic	H	NS	SE	D	W
	29. Family Moraceae (2G; 4 sp)									
209	*Ficus carica* L.	Tree	MP	Mes	Mesic	H	NS	SE	D	W
210	*Ficus palmata* Forssk.	Tree	MP	Mes	Mesic	H	NS	SE	D	W
211	*Morus alba* L.	Tree	MP	Mes	Mesic	H	NS	SE	D	W
212	*Morus nigra* L.	Tree	MP	Mes	Mesic	H	NS	SE	D	W
	30. FamilyMorinaceae(1G; 1 sp)									
213	*Morina coulteriana* Royle	PH	He	Mes	Mesic	H	SP	SE	D	W
	31. Family Oleaceae (2G; 3 sp)									
214	*Jasminum humile* L.	Shrub	NP	Mic	Mesic	H	NS	CPin	E	W/C
215	*Jasminum officinale* L.	Shrub	NP	Mic	Mesic	H	NS	CPin	E	W/C
216	*Olea ferruginea* Royle	Tree	MP	Mic	Dry	H	NS	SE	E	W/C
	32. Family Onagraceae (2G; 2 sp)									
217	*Epilobium hirsutum* L.	PH	He	N	Mesic	H	NS	SE	D	W
218	*Oenothera rosea* L	PH	He	Mic	Mesic	H	NS	SE	D	W
	33.Family Orobonchaceae (1G; 1 sp)									

219	*Orobanche agyptiaca* Steph.	AH	Root (Para)	Aph	Mesic	H	NS	SL	D	W
	34. Family Oxalidaceae (1G; 1 sp)									
220	*Oxalis corniculata* L.	PH	He	N	Moist	S	NS	CT	D	W
	35. Family Papaveraceae (1G; 1 sp)									
221	*Papaver somniferum* L.	AH	Th	Mes	Mesic	H	NS	SE	D	W
	36. Family Papilionaceae(8G; 11sp)									
222	*Astragalus graveolens* Buch.	Shrub	Ch	L	Dry	H	NS	CPin	D	W
223	*Desmodium elegans* DC.	Shrub	NP	Mes	Dry	H	NS	CT	D	W
224	*Astragalus neubauerianus* Sirjaev & Rechinger fil	PH	Ch	N	Dry	H	NS	CPin	D	W
225	*Indigofera heterantha* Wall.ex Brandis	Shrub	NP	L	Dry	H	NS	CPin	D	W
226	*Lespedeza juncea* (L. f.) Pers.	PH	He	N	Mesic	H	NS	CT	D	W
227	*Medicago lupulina* L.	AH	Th	N	Mesic	H	NS	CT	D	W
228	*Medicago minima* (Linn.) Grufb	AH	Th	N	Mesic	H	NS	CT	D	W
229	*Medicago polymorpha* L.	AH	Th	N	Mesic	H	NS	CT	D	W
230	*Sophora mollis* (Royle) bakerin hook.	Shrub	NP	L	Dry	H	NS	CPin	D	W
231	*Trifolium repens* L.	PH	He	N	Moist	H	NS	CT	D	W
232	*Robinia pseudo-acacia* L.	Tree	MP	N	Dry	H	NS	Cpin	D	W/C
	37. Family Plantaginaceae (1G; 4 sp)									
233	*Plantago himalaica* Pilger	PH	He	Mic	Moist	H	NS	SE	D	W
234	*Plantago lanceolata* L.	PH	He	Mes	Mesic	H	NS	SE	D	W
235	*Plantago major*L.	PH	G (Aq)	Mic	Moist	H	NS	SE	D	W
236	*Plantago ovata* Forssk.	AH	Th	N	Mesic	H	NS	SE	D	W
	38. Family Platanaceae (1G; 1 sp)									
237	*Platanus orientalis* Linn	Tree	MP	Mac	Mesic	H	NS	CP	D	W/C

	39. F amilyPlumbaginaceae(1G; 1 sp)									
238	*Limonium macrorhabdon* (Boiss.) O. Kuntze.	PH	Ch	Mic	Mesic	H	NS	SE	D	W
	40. Family Podophyllaceae (1G; 1sp)									
239	*Podophyllum emodi* Wall. ex Royle	PH	G	N	Mesic	S	NS	CT	D	W
	41. Family Polygonaceae (5G; 6 sp)									
240	*Bistorta amplexicaulis* (D. Don) Green	PH	He	Mes	Moist	S	NS	SE	D	W
241	*Emex spinosus* (L.) Campd	AH	Th	Mes	Moist	S	SP	SE	D	W
242	*Persicaria glabra* (Willd.) M. Gomes	PH	He	N	Moist	S	NS	SE	D	W
243	*Polygonum plebejum* R. Br.	AH	Th	N	Moist	H	NS	SE	D	W
244	*Rumex dentatus* subsp. klotzschianus (Meisn.) Rech. f	AH	Th	Mes	Dry	H	NS	SE	E	W
245	*Rumex hastatus* D. Don	PH	Ch	N	Dry	H	NS	SE		
	42. Family Primulaceae (2G; sp)									
246	*Anagallis arvensis*	AH	Th	L	Moist	H	NS	SE	D	W
247	*Androsace himalaica* (Knuth) Handel-Mazzi	PH	He	L	Mesic	S	NS	SE	D	W
248	*Androsace rotundifolia* Hardwicke	PH	He	L	Moist	S	NS	SE	D	W
	43. Family Punicaceae (1G; 1 sp)									
249	*Punica granatum* L.	Tree	MP	N	Dry	H	NS	SE	D	W/C
	44. Family Ranunculaceae (6G; 10 sp									
250	*Actaea spicata* L.	PH	He	N	Mesic	H	NS	CPin	D	W
251	*Aquilegia fragrans* Benth.	PH	G	L	Mesic	S	NS	SE	D	W
252	*Clematis grata* Wall.	Tree	MP (Cl)	Mic	Mesic	H	NS	CPin	D	W
253	*Clematis montana* Buch. -Ham. ex DC	Tree	MP (Cl)	Mic	Mesic	H	NS	CPin	D	W
254	*Delphinium uncinatum* Hk.f. & T.	PH	He	N	Mesic	S	NS	SI	D	W
255	*Ranunculus laetus* Wall. ex Hook.	PH	G	Mes	Moist	H	NS	CP	D	W
256	*Ranunculus muricatus* L.	AH	Th	Mic	Moist	H	NS	CP	D	W

257	*Ranunculus sceleratus* L.	AH	Th	N	Moist	H	NS	SI	D	W
258	*Thalictrum foliolosum* DC.	PH	He	Mic	Mesic	S	NS	CPin	D	W
259	*Thalictrum pedunculatum* Edgew	PH	He	Mic	Mesic	S	NS	CPin	D	W
260	**45. FamilyRhamnaceae (1G; 1 sp)**									
	Sageretia thea (Osbeck) M.C Johnston	Shrub	NP	Mic	Mesic	H	NS	SE	E	W
	46. Family Rosaceae (13G; 27 sp)									
261	*Cotoneaster microphyllus* Wall. Ex Lindl.	Tree	MP	L	Dry	H	NS	SE	E	W
262	*Cotoneaster nummularius* Fisch. & C.A. Mey.	Shrub	NP	N	Dry	H	NS	SE	D	W
263	*Crataegus songarica* K. Koch	Tree	MP	Mic	DRy	H	NS	SE	D	W/C
264	*Duchesnea indica* (Andrews) Focke	PH	G	N	Moist	S	NS	CT	D	W/C
265	*Fragaria nubicola* (Hook.f.) Lindl.ex Lacaita	PH	G	L	Moist	S	NS	CT	D	W/C
266	*Malus pumila* Mill.	Tree	MP	Mes	Dry	H	NS	SE	D	W/C
267	*Potentilla supina* L.	AH	Th	N	Dry	H	NS	CT	D	W/C
268	*Prunus armeniaca* L.	Tree	MP	Mes	Dry	H	NS	SE	D	W/C
269	*Prunus domestica* L.	Tree	MP	Mes	Dry	H	NS	SE	D	W/C
270	*Prunus persica* (L.) Butsch	Tree	MP	Mes	Dry	H	NS	SE	D	W/C
271	*Pyrus communis* L.	Tree	MP	Mic	Dry	H	NS	SE	D	W/C
272	*Pyrus pashia* Buch-Ham.ex D.Don	Tree	MP	Mes	Dry	H	NS	SE	D	W/C
273	*Pyrus pyrifolia* (Burn.) Nak.	Tree	MP	Mes	Dry	H	NS	SE	D	W/C
274	*Rosa alba* L.	Shrub	NP (Cl)	N	Dry	H	SP	CPin	D	W
275	*Rosa brunonii* Lindl.	Shrub	NP (Cl)	Mic	Mesic	H	SP	CPin	D	W
276	*Rosa indica* Lindl	Shrub	NP, (Cl)	N	Mesic	H	SP	CPin	D	W/C
277	*Rosa macrophylla* Lindl.	Shrub	NP (Cl)	N	Mesic	H	SP	CPin	D	W/C
278	*Rosa moschata* J. Herrm	Shrub	NP (Cl)	Mic	Mesic	H	SP	CPin	D	W/C
279	*Rosa webbiana* Wall. ex Royle	Shrub	NP (Cl)	Mic	Mesic	H	SP	CPin	D	W

280	*Rubus macilentus* Jacquem ex Cambess	Shrub	NP	Mic	Mesic	H	SP	CT	D	W
281	*Rubus fruticosus* L	Shrub	NP (Cl)	Mic	Moist	S	SP	CPin	D	W
282	*Rubus niveus* Thunb	Shrub	NP (Cl)	Mic	Mesic	H	SP	CPin	D	W
283	*Rubus sanctus* Schreber	Shrub	NP (Cl)	Mic	Mesic	H	SP	CT	D	W
284	*Sorbaria tomentosa* (Lindl.) Rehdr	Shrub	NP	Mic	Mesic	H	NS	Cpin	D	W
285	*Spiraea canescens* D. Don	Shrub	NP	Mic	Mesic	H	NS	SE	D	W
286	*Spiraea hypericifolia* L	Shrub	NP	Mic	Dry	H	NS	SE	D	W
287	*Spiraea vacciniifolia* D.Don	Shrub	NP	Mic	Dry	H	NS	SE	D	W
	47. Family Rubiaceae (2G; 2 sp)							SE		
288	*Galium aparine* L	AH cl	Th	L	Mesic	S	SP	SE	D	W
289	*Rubia cordifolia* L.	PH	He (Cl)	Mic	Moist	S	SP	SE	D	W
	48. Family Rutaceae (1 G; 1 sp)									
290	*Skimmia laureola* (DC.) Sieb.	Shrub	NP	Mes	Mesic	S	NS	SE	E	W
	49. Family Salicaceae (2G; 5 sp)									
291	*Populus alba* L.	Tree	MP	Mes	Mesic	H	NS	SE	D	W/C
292	*Populus nigra* L.	Tree	MP	Mic	Mesic	H	NS	SE	D	W/C
293	*Salix alba* L.	Tree	MP	N	Mesic	H	NS	SE	D	W/C
294	*Salix tetrasperma* Roxb	Tree	MP	Mic	Moist	H	NS	SE	D	W
295	*Salix babylonica* Linn	Tree	MP	Mic	Moist	H	NS	SE	D	W
	50. Family Sambucaceae (1G; 1 sp)									
296	*Sambucus wightiana* Wall. ex Wight & Arn	PH	Ch	N	Mesic	H	NS	CP	D	W
	51. Family Saxifragaceae (1G; 1sp)									
297	*Bergenia ciliata* (Haw.) Sternb.	PH	G	Mes	Moist	S	NS	SI	D	W
	52. Family Scrophulariaceae (5G; 6 sp)									

298	*Euphrasia himalaica* Wettst.	AH	Th	L	Moist	S	NS	SE	D	W
299	*Scrophularia polyanthis*	Ph	He	L	Mesic	S	NS	SE	D	W
300	*Verbascum thapsus* L.	AH	Th	Mes	Dry	H	NS	SE	D	W
301	*Veronica anagallis-aquatica* L.	PH	G	N	Moist	H	NS	SE	D	W
302	*Veronica biloba*	AH	Th	L	Moist	S	NS	SE	D	W
303	*Wulfeniopsis amherstiana* (Wall. ex Bth.) Hong	PH	He	Mes	Moist	S	NS	SI	E	W
	53. Family Simaroubaceae (1G; 1 sp)									
304	*Ailanthus altissima* (Mill.) Swingle	Tree	MP	Mes	Dry	H	NS	CPin	D	W
	54. Family Solanaceae (7G; 13 sp)									
305	*Capsicum annuum* L	AH	Th	Mes	Mesic	H	NS	SE	D	C
306	*Datura innoxia* Miller	AH	Th	Mes	Dry	H	NS (fruit spiny)	SE	D	W
307	*Datura stramonium* L.	AH	The	Mic	Dry	H	NS	SE	D	W
308	*Hyoscyamus niger* L	AH	Th	L	Dry	H	NS	SE	D	W
309	*Solanum nigrum* L.	AH	Th	Mic	Mesic	H	NS	SE	D	W
310	*Solanum surattense* Burm.f.	AH	Th	N	Mesic	H	SP	SI	D	W
311	*Solanum tuberosum* L	PH	G	Mic	Mesic	H	NS	CPin	D	C
312	*Solanum melengena*	AH	Th	Mic	Mesic	H	NS	SE	D	C
313	*Solanum pseudocapsicum* L	PH	Ch	Mic	Mesic	H	NS	SE	D	W
314	*Physalis divaricata* D. Don	AH	Th	Mic	Mesic	S	NS	SE	D	W
315	*Lycopersicon esculentum* Miller	AH	Th	L	Mesic	H	NS	CPin	D	C
316	*Withania somnifera* (L.) Dunal	PH	Ch	N	Mesic	H	NS	SE	D	W
317	*Withania coagulans* (Stocks) Dunal	PH	Ch	N	Dry	H	NS	SE	D	W

	55. Family Thymelaeaceae (3G; 3 sp)									
318	*Daphne mucronata* Royle.	Shrub	NP	N	Mesic	S	NS	SE	E	W
319	*Thymelaea passerina* (L.) Cosson and Germain	AH	Th	L	Mesic	H	NS	SE	D	W
320	*Wikstroemia canescens* Meisn.	Shrub	NP	N	Mesic	H	NS	SE	D	W
	56. Family Ulmaceae (1G; 1 sp)									
321	*Celtis caucasica* Willd.	Tree	MP	N	Dry	H	NS	SE	D	W
	57. Family Urticaceae (3G; 3 sp)									
322	*Girardinia palmata* (Forssk.) Gaudich. (Stining nettle)	PH	Ch	Mac	Moist	S	NS	CP	D	W
323	*Pilea umbrosa* Blume	PH	Ch	N	Moist	S	NS	SE	D	W
324	*Urtica dioica* L. (Stining nettle)	PH	Ch	N	Mesic	S	NP	SE	D	W
	58. Family Valerianaceae (1G; 2 sp)									
325	*Valeriana jatamansi*Jones	PH	G	Mic	Moist	S	NS	SE	D	W
326	*Valerianella muricata* (Stev.) Baxt.	AH	Th	N	Moist	S	NS	SE	D	W
	59. Family Verbenaceae (2G; 2 sp)									
327	*Verbena officinalis* L.	PH	He	Mic	Mesic	H	NS	SI	D	W
328	*Vitex negundo* Linn	Shrub	NP	Mic	Misic	H	NS	CT	E	W
	60. Family Violaceae (1G; 1 sp)									
329	*Viola canescens* Wall. ex Roxb.	PH	He	N	Moist	S	NS	SE	D	W/C
	61. Family Vitaceae (1G; 1 sp)									
330	*Vitis vinifera* L.	Tree (Cl)	MP	Mes	Mesic	H	NS	CP	D	W/C

Key to the legend:

Habit: AH=Annual herb, PH=Perennial herb. **Life form**: Th=Therophyte, He=Hemicryptophyte, CH=Chamaephyte, G=Geophyte, NP=Nanophanerophyte, MP= Megaphanerophyte, Cl= Climber/scandent/trailing. **Leaf sizes**: L=Leptophyll, N= Nanophyll, Mic=Microphyll, Mes=Mesophyll, Mac=Macrophyll, Meg=Megaphyll, Aph=Aphyllous. **Habitat**: Dry= Dry/ no moisture, Mes= normal/ terrestrial soil, Moi= with some soil moisture, Aq= Aquatic/hydrophytic. **Light requirement**: H= Heliophyte, S=Sciophyte. **Spinescence**: SP= Spiny (any part), NS= Non-spiny. **Deciduousness**: D= Deciduous, E=Evergreen. **Cultivation status:** W=Wild, C= Cultivated, W/C= both wild and cultivated. Leaf Type: SE= Simple entire, SI= Simple incised, SN=Simple Needles, CP= Compound palmate, CPin= Compound pinnate, CT= Compound Trifoliate, SL= Scale leaves, Cld: Cladodes.

Differences between Bird Communities in the Forest Parks of two Megalopolises (Ukraine)

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Abstract: This work presents a comparative analysis of the avifauna of forest parks in two megalopolises in Ukraine by providing an Annex containing a list of all the species classified in categories as illustrated in Figure 2 including categories of protected species; this is believed to be very helpful in understanding the composition of the avifauna. The aim of the work is to study the composition and structure of bird communities in the forest park zones of Ukrainian cities, considering their avifauna as a reserve for the native bird species of the forest-steppe zone. The number of breeding species decreases eastwards for there are currently sixty-seven species in Kyiv and fifty-two species in Kharkiv. Most representatives of the species composition of birds in the forest parks of the cities are common for the faunas of the compared regions. The absence of some species in any of the researched forest parks can be attributed to the fact that the individuals of the population in this region select forest sites located outside the city for nesting. However, they use the forests in some regions for elements of ecological niche not pertaining to nesting. The similarity of the revealed communities is 0.70 according to the Jacquard index, and 0.82 using the Sorensen index. Birds nesting openly in the ~~trees~~ trees canopies prevail over birds nesting in hollows of various types (respectively: 46.3–26.9% in Kyiv and 46.2–25.0% in Kharkiv). The proportion of species that are eurytopic in the selection of nesting sites and that use several types either natural or anthropogenic, differs slightly (8.9–7.7%); their number eastwards is higher. The synanthropization of the avifauna studied in the forest park of the region located eastwards is higher: the proportion of synanthropes is between 0.868 and 0.836, and the values of the index of community synanthropization are between 0.69–0.55.

Keywords: Bird communities, Ecological groups, Sinanthropization, Forest parks, Forest-steppe zone.

Introduction

Large-scale changes in regional faunas are now observed practically throughout the Palearctic region (Guneralp and Seto, 2013; Lawlor and Meng, 2019). Excessive anthropogenic press results in the elimination of indigenous species that cannot adapt to the effects of disturbance factors (Ditchkoff *et al*., 2006; Heyman, 2010). Birds are mobile animals that are flexible in acquiring new adaptations (Chapygina, 2015), which allow them to settle in territories that have a strong pressure of anthropogenic factors (Blair and Johnson, 2008; Blinkova, *et al.*, 2020). This leads to the formation of a new community of birds nesting in urban areas (Kooiker, 2007; Batary *et al.,* 2014; Shupova, 2017). It consists mainly of species that undergo changes in a number of ecological and ethological characteristics (Palomino and Carrascal, 2005; Kurosawa, 2009; Blinkova, *et al*., 2020). Therefore, it becomes really necessary to solve the problem of preserving the native fauna and biotic diversity in the transformed landscapes (Blinkova and

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Shupova, 2017; 2018).

In the residential areas, parks are the centers of wildlife habitats, with conditions close to natural. They provide the sites that many bird species need for nesting and foraging (Amrhein, 2013; Paker, *et al.*, 2013). However, not all bird species can live safely in city parks (Tomialojc, 2007). Landscape parks, which occupy a large area and include parts of natural biotopes serve as one of the main sources for city fauna recovery (Grimm *et al.*, 2008; Moller *et al.*, 2015). A study of the avifauna of such forest parks makes it possible to develop an algorithm for the coexistence of humans and the indigenous species of birds, including those classified as ‘vulnerable.’ For the present work, the researchers selected plots similar in environmental conditions in the urbanized areas of two large cities with a population of more than two million people within the same geographical zone.

The aim of the work is to study the species composition and the ecological structure of bird communities in the forest park zones of Ukrainian cities, considering their avifauna as a reserve for the native bird species of the forest-steppe zone.

Material and Methods

Study site

Bird species composition and the numbers of nesting pairs were investigated over the nesting periods from 2013 to 2017 within the area of model forest parks inside the two megacities of Kharkiv and Kyiv in Ukraine. For the analysis, the researchers used the average data for each of the cities during the above mentioned period. The geographic coordinates of the Kyiv and Kharkiv centers were as follows– Kyiv 50°27’03” N, 30°31’21” E; Kharkiv – 49°59’31” N and 36°13’52” E. Forest-steppe landscapes occupy 39.4% of the Kyiv area and are common to the south-west and south of the city. They are represented by mixed oak forests, where flood and dry meadows, meadow steppes are present in small fragments. The Kharkiv forest park is represented by an integral upland maple-linden oak grove on the watershed of the Lopan and Kharkiv rivers. The forest has a natural origin, yet forest plantations occupy a significant part. The plant cover is made up of meadows, near-water plants, ruderals, and invasive vegetation. An important distinctive feature of the studied forest park zones is that they are transformed forest areas, which surrounded the cities in the recent past. However, currently, the cities penetrated into the territories of the forests. The residual fragments of the forests, entering the city line, are the recreation area for urban populations. The forest parks contain areas of natural forests with the predominance of *Quercus robur* L., *Acer platanoides* L., *Carpinus betulus* L., *Alnus glutinosa* Gaerth., and *Tilia cordata* L. and with century-old trees on such transformed forests . In some places, the forest plots require reforestation (Figure 1). The forest parks are densely surrounded by residential areas quite adjacent to them. The Kharkiv forest park extends over a huge forest area of 2385 hectares, and is located on the periphery of the city. In Kyiv, the forest park zone is fragmented into plots of various sizes (the largest of which is the Goloseevsky forest, with an area of 1052 ha), located on the outskirts of the city and in the center of a residential area. These forest areas have been conserved after they have been assigned the status of protected natural areas .

Bird surveys

The number and distribution of birds were determined by route counting (Bibby, *et al.*, 2000). The length of the counting lines was 0.8–1.0 km limited by the extent of homogeneous biotope fragment. The width on both sides of the direction of movement was 50 m, and the total length of fixed route was 5.7 km in Kyiv and 3.5 km in Kharkiv. On each route, observations were carried out annually with three repetitions during the nesting period when the birds are most attached to their habitats (end of April–June). The taxonomy and the nomenclature of birds were adopted according to the ‘International

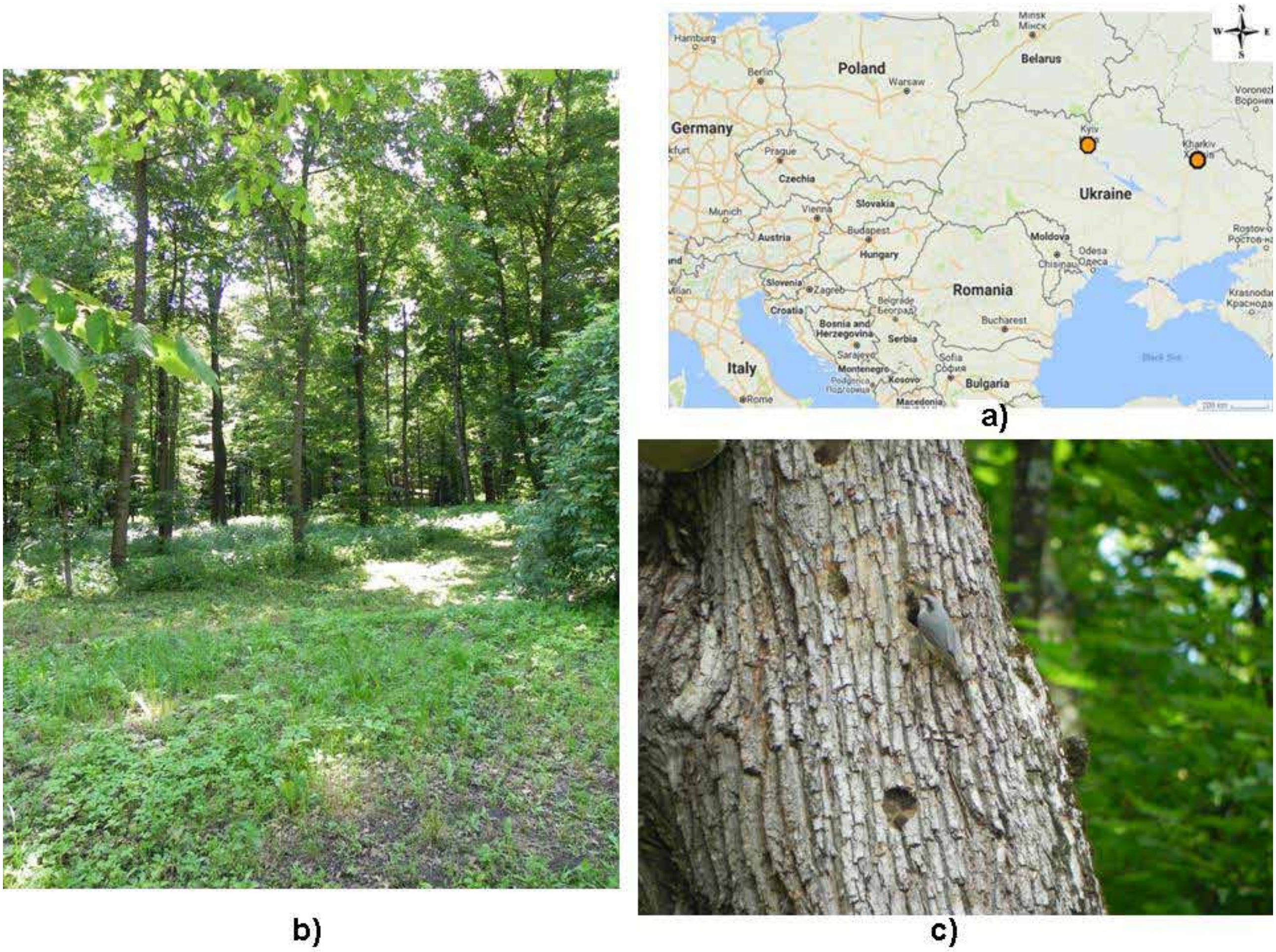

Figure 1. Research area: a) location of two megalopolises (red points); b) fragment of oak and hornbeam forests in a Kyiv forest park in summer; c) *Sitta europaea* on oak in a Kyiv forest park.

Code of the Zoological Nomenclature' (2012). The species of birds were determined and the search for their nests in tree canopies was performed visually using binoculars Nikon Aculon A211/10×50. The singing male bird was counted as a nesting pair for the passerine bird species (Bibby, *et al.,* 2000). The status of the species (breeding, feeding, and nomadism) was determined by the behaviour or the presence of a nest for the non-Passeriformes species.

The average data for the total study period (2013–2017) were calculated for each city. For the average number of pairs, the standard deviation was calculated.

The number of species to be protected according to the lists of various international conventions (Bern Convention, Bonn Convention, Washington Convention) was estimated. The synanthropization index of nesting bird communities for the forest park areas in the studied regions was determined by Jedryczkowski (Klausnitzer, 1990): $W_s = L_s/L_o$, where L_s is the number of synanthropic species, and L_o is the total number of community species. In this index, the researchers took into account the species (populations) which occur in the Kyiv and Kharkiv cities and the populations of species which were nesting in the natural areas of the Kyiv and Kharkiv regions. Bird species forming synanthropic and natural populations were isolated simultaneously into the group of hemysynanthropes.

Bird species were also classified into ecological groups according to the patterns of microhabitat choice (Belik, 2006). The dendrophils are bird's species that live on the trees of plantation. The species of this category are divided into groups: birds nesting openly in the canopies of trees, ground nesters and nesters of tree hollows. The tree-hollow nesters are divided into primary birds that make hollows (Picidae), and secondary ones, which settle in ready-made hollows (Sturnidae, some Muscicapidae, Paridae, and some Sittidae). The category of ground nesters includes birds associated with the forest open habitats (Scolopacidae, Caprimulgidae, Motacillidae). The category of cavity nesters includes birds associated with vertically dissected reliefs (cracks in rocks, trees, stumps): some Columbidae, Alcedinidae, Hirundinidae, some Corvidae, some Muscicapidae, some Passeridae. The category of building nesters includes birds associated with urban constructions (in particular, secondary synanthroposized tree hollow nesters or cavity nesters).

Results

In the forest parks of the megalopolises' forest-steppe zone, seventy-one species of birds were recorded, of which sixty-four species (90.1%) are mentioned in various lists of international environmental conventions (Table 1). Forest parks in Kyiv are the nesting places for sixty-seven bird species; the relative number on average is 1.99 (± 0.49) pairs/km. In Kharkiv, the number is fifty-two species – 3.15 (± 0.54) pairs/km. The relative average of nesting pairs in the forest parks of the eastern region is almost twice higher than that in the western region. The similarity in the species composition between the nesting birds of the forest parks in the two cities is great (0.70 according to the Jacquard index, and 0.82 using the Sorensen index.

The basis of the communities are dendrophils. Birds nesting openly in the tree crowns prevail over birds nesting in hollows of various types (respectively: 46.3–26.9% in Kyiv and 46.2–25.0% in Kharkiv). The proportion of species that are eurytopic in the selection and use of nesting sites, whether natural or anthropogenic, differs slightly (8.9–7.7%). Six species nest in buildings

Table 1. The relative number of birds in the forest park areas in Kyiv and Kharkiv cities.

	Species	Relative number (pair/km)		Conservation status
		Kyiv	Kharkiv	
1	*Anas platyrhynchos*	0.1	–	Bk3; Bo1,2
2	*Accipiter gentilis*	–	0.3	Bk2; Bo1,2; W2
3	*Accipiter nisus*	0.2	0.3	Bk2; Bo1,2; W2
4	*Buteo buteo*	0.1	–	Bk2; Bo1,2; W2
5	*Falco tinnunculus*	0.1	–	Bk2; Bo2; W2
6	*Tringa ochropus*	0.3	–	Bk2; Bo1,2
7	*Tringa totanus*	0.3	–	Bk3; Bo1,2
8	*Columba palumbus*	1.5	0.9	–
9	*Columba livia*	0.5	–	Bk3
10	*Streptopelia decaocto* *	0.1	1.1	Bk3
11	*Cuculus canorus*	0.4	0.9	Bk3
12	*Asio otus*	0.1	0.3	Bk2; W2
13	*Strix aluco*	0.1	–	Bk2; W2
14	*Caprimulgus europaeus*	0.7	–	Bk2
15	*Alcedo atthis*	–	0.3	Bk2
16	*Jynx torquilla*	0.3	1.7	Bk2
17	*Dendropicos spodocephalus*	0.2	0.5	Bk2
18	*Dryocopus martius*	0.9	–	Bk2

19	*Dendrocopos major*	1.9	2.8	Bk2
20	*Dendrocopos syriacus* *	0.1	0.6	Bk2
21	*Leiopicus medius*	1.7	0.6	Bk2
22	*Dryobates minor*	1.3	1.1	Bk2
23	*Hirundo rustica*	0.1	3.4	Bk2
24	*Delichon urbicum*	0.1	1.7	Bk2
25	*Anthus trivialis*	1.6	1.1	Bk2
26	*Motacilla alba*	0.3	1.7	Bk2
27	*Lanius collurio*	0.9	0.3	Bk2
28	*Lanius minor*	0.2	–	Bk2
29	*Lanius excubitor*	0.1	–	Bk2
30	*Oriolus oriolus*	2.7	1.7	Bk2
31	*Sturnus vulgaris*	3.8	2.9	–
32	*Garrulus glandarius*	0.6	1.7	–
33	*Pica pica*	0.3	4.6	–
34	*Corvus monedula*	–	0.5	–
35	*Corvus cornix*	1.7	1.7	–
36	*Corvus corax*	0.2	–	Bk3
37	*Troglodytes troglodytes*	2.1	–	Bk2
38	*Hippolais icterina*	0.5	0.5	Bk2
39	*Sylvia atricapilla*	1.4	2.8	Bk2
40	*Sylvia borin*	0.1	0.5	Bk2
41	*Sylvia curruca*	0.1	0.8	Bk2
42	*Phylloscopus collybita*	4.2	6.3	Bk2
43	*Phylloscopus sibilatrix*	1.6	2.9	Bk2
44	*Ficedula hypoleuca*	1.0	0.5	Bk2; Bo2
45	*Ficedula albicollis*	1.6	16.0	Bk2; Bo2
46	*Ficedula parva*	0.3	–	Bk2; Bo2
47	*Muscicapa striata*	2.0	2.0	Bk2; Bo2
48	*Phoenicurus phoenicurus*	0.1	–	Bk2; Bo2
49	*Phoenicurus ochruros* *	0.2	0.9	Bk2; Bo2
50	*Erithacus rubecula*	7.7	5.4	Bk2; Bo2
51	*Luscinia luscinia*	3.8	3.4	Bk2; Bo2
52	*Turdus pilaris*	2.6	2.9	Bk3; Bo2
53	*Turdus merula*	11.3	7.1	Bk3; Bo2
54	*Turdus philomelos*	2.9	10.3	Bk3; Bo2
55	*Aegithalos caudatus*	0.8	–	Bk2
56	*Poecile palustris*	1.2	0.6	Bk2
57	*Periparus ater*	0.8	–	Bk2
58	*Cyanistes caeruleus*	1.5	1.1	Bk2
59	*Parus major*	24.1	18	Bk2
60	*Sitta europaea*	7.6	4.5	Bk2
61	*Certhia familiaris*	2.1	2.9	Bk2

62	*Passer domesticus*	–	3.4	–
63	*Passer montanus*	3.3	5.7	Bk3
64	*Fringilla coelebs*	19.1	14.9	Bk3
65	*Serinus serinus* *	0.2	–	Bk2
66	*Chloris chloris*	0.8	4.0	Bk2
67	*Carduelis carduelis*	0.9	5.7	Bk2
68	*Acanthis cannabina*	0.3	2.5	Bk2
69	*Coccothraustes coccothraustes*	3.3	3.4	Bk2
70	*Emberiza citrinella*	0.2	2.0	Bk2
71	*Emberiza hortulana*	0.1	–	Bk3

Note * - alien speceis; categories of: Bk2, Bk3- Bern: Bo1, Bo2- Bonn; W2- Washington Conventions.

(8.9–11.5%) (Figure 2). The common kingfisher (*Alcedo atthis*), was recorded within the area of the Kharkiv forest park. The nest of this bird was found on a bank in a gully inside the forest.

The study showed four species which are alien to the fauna of Ukraine: one in the forest park zone in Kyiv, and three in Kharkiv (see Table 1). They are: *Streptopelia decaocto, Dendrocopos syriacus, Phoenicurus ochruros,* and *Serinus serinus.* All of them are obligate synanthropes. In addition to these species, three native obligate synanthropes were recorded in the forest-park zone of each city. In the Kyiv and Kharkiv forest parks, thirty-seven and thirty bird species were identified correspondingly as hemysynanthropic. The abundance of synanthropes in the bird communities in the Kharkiv forest park zone has a tendency to be higher than that in the Kyiv forest park (Figure 3)**.** The index of synanthropization of the nesting bird communities in Kyiv was 0.55, and in Kharkiv – 0.69, which reveals a high degree of synanthropization of the nesting bird communities in the forest-park zone of the region located further to the east.

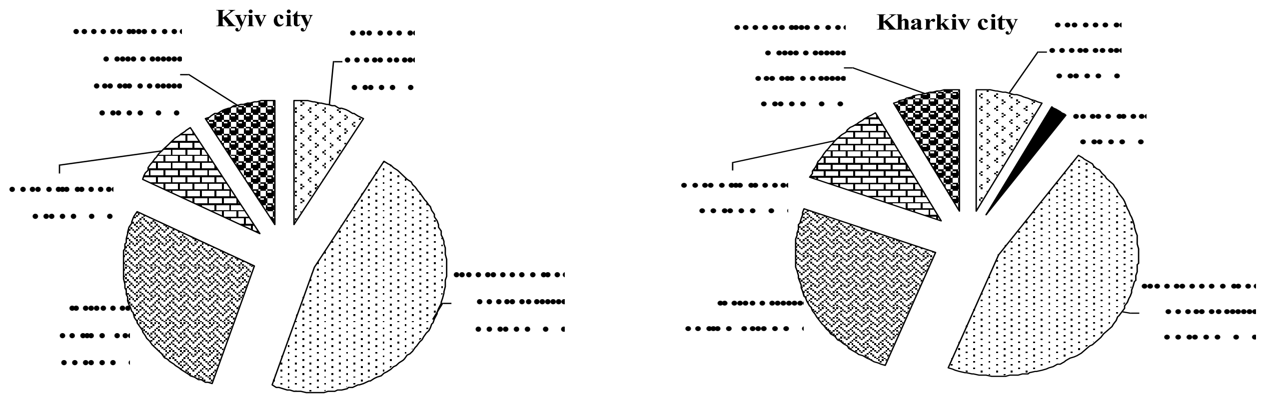

Figure 2. The distribution of the birds depending on the use of nesting habitats in the forest parks of the megalopolises (%).

Discussion

Studies have shown that the relative average of bird population of the forest park zones in the eastern region is almost twice higher than that in the western parts. Perhaps the data confirm the works of colleagues by the return of the local juveniles of birds due to dispersion (Norton *et al.*, 2000; Belisle and Clair, 2001; Brotons *et al.*, 2003; Caplat and Fonderflick, 2009) across a large area of forests in the city of Kharkiv. The similarity of the studied bird communities can be explained by the fact that the avifauna belongs to the forest

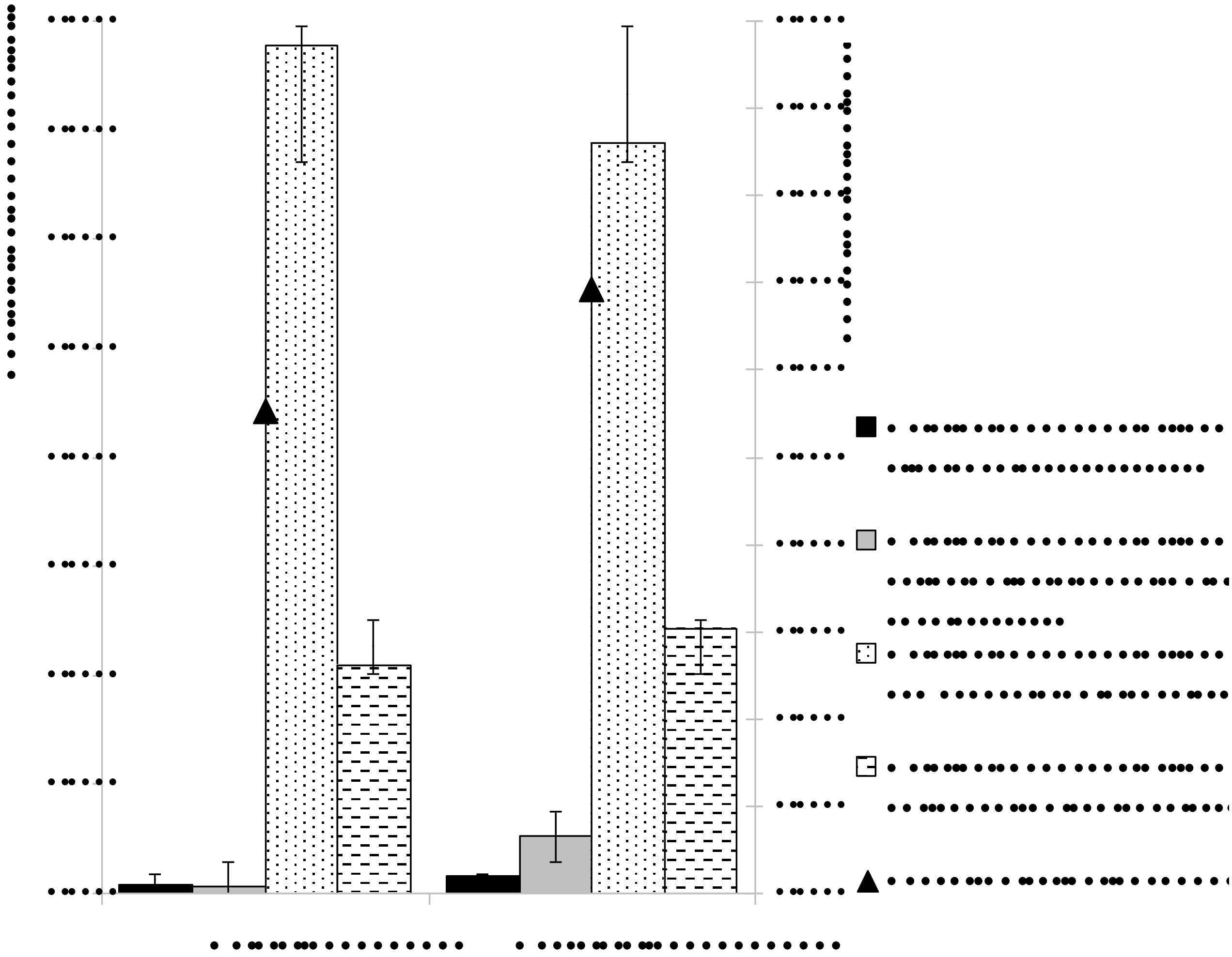

Figure 3. Synanthropization of the nesting bird communities in forest parks areas.

parks of one natural-geographical zone.. The similarity of the avifauna in the western and eastern areas of the study area can also be attributed to the lack of oak regeneration in the oak-hornbeam forests of Kiev and its environs; instead, the Norway maple and field maple grow there (*Acer platanoides* and *Acer campestre*). The transformation of biotopes leads to changes in the populations of the fauna (McD. Sweeney *et al*., 2010). Any changes in the plants are reflected in changes in the richness and subsequently in the avian structure (Martin and Joron 2003; Katsimanis *et al*., 2006; Wenny *et al*., 2011; Pawson *et al*., 2013; Tryjanowski *et al*., 2017).

For a detailed study of the ecological characteristics of bird communities, the researchers analyzed the distribution of birds by guilds, depending on their use of nesting microhabitats. The differences between the avifaunas of the forest-park zones in the two megalopolises are manifested when comparing these parameters, although the tendency to similarity persists. The most striking difference is the kingfisher nesting in the forest ravines in Kharkiv. Since the end of the twentieth century, such nesting has become characteristic for some populations of the species due to the lack of typical nesting habitats in shore cliffs or in the case of the excessive disturbance of birds by people within the recreational areas (Shupova, 1999). In the forest parks of Kyiv, this species does not nest, despite the presence of ponds with fish and forest ravines, although it lives in the region. In some years, the kingfisher was noted using the ponds of the forest parks for feeding during the migration period, but due to the fact that the lakes are in the parks that are actively used by vacationers, the birds do not settle there. In spring and autumn, when there are few vacationers and no swimming occurs, the kingfisher uses the ponds for feeding. The researchers believe that it is the activity of people resting in the forest parks of Kyiv that makes kingfishers not comfortable for nesting.

Although some similarities in the distribution of bird communities nesting on the ground or openly in the tree crowns and in hollows were noted, the species composition and the number of species in each region are different. The number of species nesting in the crowns of trees is greater in Kyiv forest parks (thirty-one species). In Kharkiv forest parks, only twenty-four species are canopy-nesting birds. Analyzing the lists of species, it was found that, some birds were absent in the forest zone of Kharkiv, but they exist in Kyiv. For species such as the serin (*Serinus serinus*) and the great grey shrike (*Lanius excubitor*), the territory of Kharkiv is located outside the nesting area. For the Kharkiv region, only one case of vocalization of a European finch is documented (Nadtochiy, 2002). It should be noted that the great grey shrike is a species typical for the forest zone (Tajkova, 2010; Tajkova and Red'kin, 2014). The southern border of its nesting area passes through the territory of Kyiv, and birds do not nest here regularly. Through the investigation of the avifauna of the Kiev region from 2008 to the present day in this work, it was observed that the nesting of the great grey shrike took place only once and that was in 2013. The northern goshawk (*Accipiter gentilis*) is a common species in the forest park of Kharkiv; it does not nest in the forest parks of Kyiv, but in forests outside the city.

In the studied regions, the species composition of cavity-nesting birds differs insignificantly, which is due mainly to the existence of secondary cavity-nesting birds that use readymade places. Thus, in the Kharkiv forest park zone, unlike that in Kyiv, there are no tawny owls (*Strix aluco*), red-breasted flycatcher (*Ficedula parva*), common redstart (*Phoenicurus phoenicurus*), and coal tits (*Parus ater*). The reason behind the insufficient number of hollows is likely the small number of woodpeckers (Robles *et al*., 2011; Felton *et al*., 2016). With a lack of hollows, secondary cavity-nesting birds are less common (Carlson *et al*., 1998; Robles *et al*., 2012). In biotopes without artificial nests put up, woodpeckers annually support the "housing stock" and contribute to a rich diversity of birds and animals (Mikusiński *et al*., 2001; Robles *et al*., 2011), although during the fight for hollows, woodpeckers often drive out and kill secondary cavity-nesting birds (Michalczuk and Michalczuk, 2016). In the present study, the number of the species of primary cavity-nesting birds differs between the regions in relation to only one species due to the fact that the territory of the Kharkiv region is outside the black woodpecker's nesting area, in contrast to Kyiv. The number of secondary cavity-nesting bird species differs more significantly; there are fourteen of them in the Kyivforest park zone and nine in the Kharkiv region. The number of bird species nesting on the ground in the forest parks of Kyiv is higher due to the redshank's (*Tringa totanus*) and the nightjar's nesting (*Caprimulgus europaeus*).

The conversion of natural habitats to human settlements left major impacts on the fauna (Tomialojc, 2007; Grimm *et al*., 2008; Moller *et al*., 2015). Urbanization becomes the ideal system for the invasion of animal communities by alien species (Croci *et al*., 2008; Evans, 2010; Díaz *et al*., 2011; Moller *et al*., 2015). The index of fauna synanthropization is an important indicator, as an increasing number of bird species are adapting to inhabit the human settlements. At the present stage of synanthropization, many hemysinanthropic species in different regions form synanthropic and natural populations. For example, synanthropic (sedentary) and natural (migratory) subpopulations of the blackbird (*Turdus merula*) live in Kyiv, while only a natural population live in Kharkiv. The Syrian woodpecker (*Dendrocopos syriacus*) in Kyiv nests only as a synanthrope in the courtyards of residential areas, city parks, and transformed biotopes of forest parks, and in the Kharkiv region, it is also noted in natural biotopes. From the end of the ninteenth century, the Syrian woodpecker entered the European countries from Turkey through the Balkans (Munteanu and Samwald, 1997). These birds were first recorded in Ukraine in 1948. By the mid-sixties of the last century, the Syrian woodpecker settled up to 50^o n. l., i.e., its breeding range reached Kyiv and Kharkiv almost simultaneously. Now it is an ordinary widespread species nesting in transformed biotopes. The tendency of the Syrian woodpecker to synanthropization allows for the prediction of its further relocation in the northern and eastern directions (Zavyalov *et al*., 2008). The proportion of stenotopic native species demonstrates how favorable the state of biotopes is for preserving the natural avifauna of the region (Shupova, 2017).

Thus, in different regions within the same natural-geographical zone, the same species may be present at nesting with a different status. As a result of the synanthropization index calculation, it was found that in the east of the forest-steppe, the nesting bird communities are more synanthropized. This picture was formed as a result of the fact that the list of species living in the forest parks of Kyiv is wider and includes mostly non-synanthropic bird species. The presence of alien bird species is an important indicator of disturbances in the natural ecosystem (White *et al*., 2009).

The dominant species in all forest parks are the great tit and chaffinch (*Fringilla coelebs*). In the forest parks, there are high numbers of the chiffchaff (*Phylloscopus collybita*), robin (*Erithacus rubecula*), song thrush (*Turdus philomelos*), blackbird (*Turdus merula*) and nuthatch (*Sitta europaea*). All of them are common species of forest ecosystems in the study area.

It was noted that forest parks providing nesting habitats for birds require secluded areas. The list includes: the goshawk (*Accipiter gentilis*), the sparrowhawk (*Accipiter nisus*), the common buzzard (*Buteo buteo*), the green sandpiper (*Tringa ochropus*), the redshank (*Tringa totanus*), the nightjar (*Caprimulgus europaeus*), the black woodpecker (*Dryocopus martius*), the tree pipit (*Anthus trivialis*), the great grey shrike (*Lanius excubitor*), the lesser grey shrike (*Lanius minor*), and the red-breasted flycatcher (*Ficedula parva*). The territorial plot of the observed pairs is located within the city of Kyiv, although the distance to the nearest buildings is also about 400 m. The aforementioned birds do not nest in well-groomed parks in the central part of the cities and are peculiar for the natural biotopes of the region. The process of habitat fragmentation can also contribute to this **(**Gardner *et al.*, 2019). In small fragments of the natural environment, rare bird species have fewer opportunities for meeting a sexual partner, and, therefore, there are less chances for breeding (Norton *et al.*, 2000; Zannette, 2001; Belisle and Clair, 2002; Brotons *et al.*, 2003; Caplat and Fonderflick, 2009). Therefore, in the case of the continuing urbanization of the territories of megacities, it is likely to expect the disappearance of the populations of small-in-number bird species (Batary *et al.*, 2014).

Conclusions

In the forest-parks of the megalopolises' forest-steppe zone in Ukraine, the list of bird species nesting in the forest parks decreases eastwards. Most representatives of the species composition of bird communities in the forest parks of the cities are common for the faunas of the compared regions. The absence of some species in any of the forest parks is due to the fact that individuals of the population in this region select forest sites located outside the city for nesting. The share of eurytropic species in the east is higher; and the degree of synanthropy of the nesting bird communities of the forest park zone in the east region is higher.

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The Reproductive Ecology of *Boerhavia diffusa* L. and *Boerhavia erecta* L. (Nyctaginaceae)

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Abstract: *Boerhavia diffusa* and *B. erecta* occur commonly and grow well displaying vegetative, flowering, and fruiting phases either simultaneously or alternately throughout the year in various habitats. In both species, the flowers open at dawn by unfolding the petaloid perianth during which the stamens, with dehisced anthers, and the style and stigma in a receptive state, gradually uncoil to become erect; in this process, autogamous self-pollination occurs. The flowers that failed to self- or cross-pollinate autonomously during the process of anthesis or by vector-mediation in open condition have the option to resort to autogamous self-pollination during the process of the closing of the petaloid perianth covering the sex organs within. Both species attract bees, wasps, flies, and butterflies to their flowers, but only bees and butterflies act as appropriate pollinators, while the other insects act as additional pollinators. The fruit is a one-seeded indehiscent anthocarp with mucoidal secretions which is adapted for zoochory, anthropochory, ornithochory, and hydrochory. Seeds are non-dormant and germinate immediately after dispersal. Furthermore, these species also multiply asexually through the fragmentation of the rhizome. In these plant species, the functionality of sexual and asexual reproduction modes enables them to invade new habitats and form prolific populations. Since these plant species control soil erosion by covering the soil effectively, they can be considered for the eco-restoration of ecologically damaged and deteriorated habitats and ecosystems.

Keywords: *Boerhavia diffusa*, *Boerhavia erecta,* Bees, Butterflies, Zoochory, Anthropochory, Ornithochory, Hydrochory.

Introduction

The genus *Boerhavia* was named after an eighteenth-century Dutch botanist, Hermann Boerhaave, at the University of Leiden, Germany. The generic name is often written in the literature as *Boerhaavia* (Hiruma-Lima *et al.,* 2000), but Linnaeus Latinized Boerhaave's name to Boerhavius and adopted the spelling *Boerhavia*, which is the correct spelling to be used (Spellenberg, 2004). The distribution and the number of genera and species in the genus *Boerhavia* have been reported differently by different authors. Hutchinson and Dalziel (1954) reported that the genus *Boerhavia* is distributed mainly across tropical America and in small numbers in the tropics and subtropics of the Old World. An anonymous publication (1988) confirmed that the genus has forty species, which are widely distributed in China, Egypt, Pakistan, Sudan, Sri Lanka, South Africa, USA, India, and several Middle East countries. Spellenberg (2000) stated that *Boerhavia* species are widespread, and their dispersal is mostly attributed to birds and human activity. Patil & Sanjivani (2016) confirmed that this genus is widely distributed in tropical, subtropical, and the temperate regions of the world including Mexico, America, Africa, Asia, Indian Ocean Islands, the Pacific Islands, and Australia. Douglas & Spellenberg (2010) noted that there about forty species worldwide, but

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*Corresponding author: solomonraju@gmail.com these species mostly occur in the south-western parts of North America. Chopra (1969) and Dev (2006) pointed out that six species of *Boerhavia*, *B. diffusa, B. repens, B. chinensis, B. erecta, B. elegans* (synonym: *B. rubicunda*), and *B. reniformis* (synonym: *B. rependa*) are found in India. Dutta *et al.* (2015) documented that *Boerhavia* is represented by four species, *B. crispa*, *B. diffusa*, *B. erecta*, and *B. rubicunda* in India. Chopra (1969) and Dev (2006) confirmed that most *Boerhavia* species possess worldwide medicinal uses; hence they have occupied positions in different systems of medicine including Indian Ayurveda, Siddha and Unani, Martinican medicine, African medicine, traditional Chinese medicines, as well as Indian and Brazilian pharmacopoeia. As for the *Boerhavia* genus, the species are annual or perennial herbs with a diffuse habit and produce campanulate flowers; the fruit is a 3-5 ribbed glabrous or glandular pubescent anthocarp (Bittrich and Kuhn, 1993; Jordaan, 2000). The *Boerhavia* flowers produce a narrow perianth tube and are melittophilous. They are suited for head pollination by small bees; they are fit for both bee and fly pollination (Bittrich and Kuhn, 1993). Spellenberg (2000) reported that in *Boerhavia coccinea, B. intermedia, B. spicata, B. torreyana* and *B. wrightii,* individual flowers open only for a portion of a day. The flowers open at dawn and their opening begins with the opening of the corolla-like perianth and the uncoiling of stamens and styles. With the progression of the morning, the filaments and style curl and the anthers haphazardly contact the stigma affecting autogamous self-pollination. The perianth closure begins in the late morning containing the stamens and style within and wrinkles by mid-afternoon of the same day. *B. coccinea* is visited by bees of *Scolia, Mellisodes,* by wasps of *Holopyga rudis* and *Ammophila,* and also by calliphorid, syrphid and muscid flies. *B. intermedia*, *B. torreyana* and *B. wrightii* are visited by *Mellisodes* bees and the *Holopyga rudis* wasp and also by the tachinid and syrphid flies. *B. spicata* is visited by *Scolia* and *Mellisodes* bees, *Ammophila* and *Ichneumonid* wasps, and also by calliphorid and syrphid flies (Spellenberg, 2000). *B. coccinea* is pollinated by social bees and social wasps in Caatinga in the northeastern Brazil (de Mendonca Santos *et al.,* 2010).

Bromilow (2010) noted that *Boerhavia diffusa* is native to South America, but Patil *et al.* (2016) stated that this species is found in the tropical, subtropical, and the temperate regions of the world. Struwig and Siebert (2013) mentioned that the specific epithet, *diffusa*, refers to the spreading or diffuse nature of the plant. Kirtikar and Basu (1933) reported that *Boerhaavia diffusa* is distributed throughout India and is extensively used in many parts of the country as a traditional medicine. Its utility as a drug to regenerate new cells in the body is promising and is well-known in Ayurvedic medicine. An anonymous publication (1988) confirmed that *B. diffusa* is an important medicinal herb indigenous to India. It grows well on wastelands and in fields during the rainy season. It grows in open sunlight and endures severe abiotic stresses such as UV exposure, high temperature, water, and nutrient deficiencies. In West Bengal, it is cultivated for its leaves for use in medicine. Bhardwaj and Sharma (2019) reported that *B. diffusa* has a tremendous potential of medicinal value and in fact has been traditionally used in various ailments such as syphilis, leukoderma, and blood disorders. In India, *B. diffusa* has a long history of therapeutic uses in the indigenous medicinal tribal communities and in the Ayurvedic system of medicine (Chaudhary and Dantu, 2014 and the references therein). Patil and Sanjivani (2016) stated that *B. diffusa* is extensively used by local people and medicinal practitioners for treatments of hepatitis, urinary disorders, gastrointestinal diseases, inflammations, skin problems, infectious diseases, and asthma in India. Chaturvedi (1989) reported that autogamous self-pollination is functional in *B. diffusa*, but hymenopterans and dipterans also pollinate the plant. Mwangi (2009) reported that *B. diffusa* is an important floral source for a diversity of bee species whichinclude *Apis mellifera, Ceratina* spp., *Lipotrichis* spp., *Macrogalea candida*, *Megachile* spp., *Pseudapis* spp., *Thyreus* spp. and *Xylocopa senoir* in the Arabuko Sokoke Forest, Nigeria. Mahale (2019) noted that *B. diffusa* is an important nectar source for the honeybees, *A. dorsata, A. cerana* and *A. florea* in the cultivated and uncultivated areas of Ahmednagar in the South-Eastern region of Western Ghats. Churi *et al.* (2020) noted that *B. diffusa* is a nectar plant for *Junonia lemonias, J. almana, Castalius risomon, Appias olferna, Eurema hecabe, Ypthima* spp., *Colotis amata, C. danae*, and *C. protractus* in South India.

Boerhavia erecta is native to the United States, Mexico, Central America, and western South America but is now cosmopolitan in tropical and subtropical regions of the world (Chen and Wu, 2007). The specific epithet, *erecta*, refers to the erection habits or upright inflorescences (Struwig and Siebert 2013). This herb is used in traditional medicine and as food in West and East Africa, where its leaves are eaten as a vegetable or are used in sauces (Schmelzer, 2006). Its roots are used for the treatment of various human diseases in traditional medicine (Nisha *et al.,* 2018). The plant powder is smoked as a cigarette once a day for one month to get relief from asthma (Shanmugam *et al.,* 2012). Despite the availability of the *Boerhavia* species and their medicinal and edible value, they have not been systematically investigated for any aspect of their reproductive ecology. Therefore, the present study was conducted to provide the details on the reproductive ecology of *Boerhavia diffusa* L. and *Boerhavia erecta* L. (Family: Nyctaginaceae; tribe: Nyctagineae) and to discuss relevant works on these two plant species published by others.

Materials and Methods

Study area

The wild pockets of *Boerhavia diffusa* and *Boerhavia erecta* in the scrub jungle deciduous ecosystem located on the outskirts of Visakhapatnam city (Latitude17.8909°N, Longitude 83.1908°E, altitude 209 amsl), Andhra Pradesh, India, were selected for the study between May 2018 and December 2019.

Floral morphology and biology

Twenty mature buds, four on five different plants of each plant species were marked to record anthesis and the anther dehiscence schedule. The anther dehiscence mode was also recorded by using a 10x hand lens. The flower morphological details such as flower sex, shape, size, colour, odour, perianth, stamens and ovary were recorded. The stamens were described regarding their number, origin, position, and whether they were exposed or hidden during the flower stage. Based on variation in the stamen number, the percentage of one-, two- and three-stamened flowers in each species was calculated by using 90 flowers collected randomly from different plants. The ovary details and its concealment by the lower part of perianth were carefully observed. The movements of sex organs, during the time of flower-opening and closing of the perianth, were carefully observed to find out whether spontaneous autogamy occurs or not. In case of occurrence, observations of whether it was absolute or not in one-, two- and three-stamened flowers were also made. For each plant species, ten mature buds with un-dehisced anthers were collected from different plants and were kept in a Petri dish. A single anther was taken out each time and was placed on a clean microscope slide (75 x 25 mm). These were crushed with a glass rod, and a small drop of lactophenol-aniline-blue was added to disperse the pollen grains equally to the fixed area on the slide and the pollen grains were counted under a compound microscope (40x objective, 10x eye piece). This procedure was followed for counting the number of pollen grains in one-, two, and three-stamened flowers. Based on the pollen counts of each anther, the mean number of pollen grains produced per anther was calculated. The mean pollen output per anther was multiplied by the number of anthers in the flower for obtaining the mean number of pollen grains per flower. At the same time, the pollen grains' characteristics were also recorded. Furthermore, the pollen-ovule ratio was calculated separately for one-three stamened flowers using the method followed by Cruden (1977). The protocols described by Mondal *et al.* (2009) were followed for the analysis and identification of amino acid types in the pollen of both plant species. The method described by Sadasivam and Manickam (1997) was followed for protein extraction from the pollen samples, while the method of Lowry *et al.* (1951) was followed for estimating the protein content in the samples. The Hydrogen peroxidase test described by Dafni et al. (2005) was used to record the commencement and duration of stigma receptivity.

Fruit set in spontaneous autogamy and open-pollinations

Eighty mature buds, eight from ten plants of each species were bagged and observed for three weeks to record the fruit set rate in spontaneous autogamy. Fifty flowers, five from ten plants of each species were tagged prior to anthesis and were observed for fruit set rate in open-pollinations.

Flower-visitors and pollination

Flowers were observed from morning to evening for four days to record flower-visitors to each plant species. The flower-visiting bees, wasps, and flies were identified according to the Zoological Survey of India, Calcutta, India, while the flower-visiting butterflies were identified with the help of the Field Guide of Butterflies book by Gunathilagaraj *et al.* (1998). The approach of flower visitors to flowers, flower-probing, the collected forage, and the contact between their body parts with the stigma and stamens, were carefully observed by standing close to the flowering patch and by using a field binocular to record their pollination role. The number of foraging visits made by the flower visitors was recorded at each hour for ten minutes from morning to evening for four days at fifty plants flowering profusely. The data collected on the foraging visits of these insects were tabulated and the mean number of foraging visits at each hour was calculated to know the foraging pattern of insects through time. The same data were also used to calculate the percentage of foraging visits made by each category of insects separately.

Fruit and seed aspects

Forty mature buds were tagged and observed for a period of three weeks to record fruit growth, development and maturation period. The fruit dehiscence mode and seed dispersal aspects were observed carefully. Fruit and seed morphological characteristics were described to understand fruit/seed dispersal modes. Field observations were made throughout the year on fruit/seed dispersal agents, seed germination, and the production of new plants.

Results

The plant and flowering phenology

Boerhavia diffusa is a perennial prostrate creeping herb (Figure 1a), while *B. erecta* is a perennial erect herb;the former grows well in wet and semi-wet areas, while the latter grows well in semi-wet and sandy soils. They form extensive mats of populations in open areas where ground flora is almost absent. *B. diffusa* dominates in areas where other low ground herbaceous species grow simultaneously but *B. erecta* has a scattered occurrence in areas occupied with several low ground mat-forming herbaceous species. In both, the stem is slender, woody towards the base, decumbent, greenish to purplish, and is many-branched from a tap root, but the branches are highly diffused with a prostrate form in *B. diffusa,* while they are slightly diffused with an erect form in *B. erecta*. Leaves are petiolated, arranged oppositely in unequal pairs, broadly ovate, entire, and

Figure 1. *Boerhavia diffusa:* a. Habit, b-d. Different stages of buds, e-g. Flowers, h-j. Autogamy taking place during anthesis due to gradual uncoiling of style during which the capitate stigma gets coated with pollen from dehisced anthers, k. Ovule, l. & m. Early stages of seed development, n. Fruits.

smooth. The plants of both species grow throughout the year if the soil is moderately wet, but they show prolific growth during the rainy season with a profuse flowering between July and September (Figure 3a). In both species, the perennial underground tap root sprouts to produce new growth and repeats its sexual cycle if the soil has sufficient moisture and nutrients. The inflorescence is a cymose panicle borne in axillary and terminal positions in both species. In *B. diffusa*, the inflorescence has a long peduncle composed of several cymes and each cyme produces 8.3 ± 3.01 pedicellate flowers. In *B. erecta*, the inflorescence has long primary and short secondary peduncles, and both types are covered with minute hairs. The secondary peduncles consist of two to four pedicellate flowers (Figure 3b). In both species, all flowers of individual cymes open on the same day.

Flower morphology

In both species, the flowers are actinomorphic and bisexual. They are 3-4 mm long in *B. diffusa* and 2-3 mm long in *B. erecta*. In both species, the perianth is gamocorolline representing the calyx and corolla. The lower part of the perianth is sepaloid, green, glabrous, clavate, tubular, and five-ribbed enclosing the ovary. The upper part of the perianth is petaloid, funnel-shaped extending at the rim into five lobes and each lobe is bifid and glabrous. The petaloid perianth, however, is red to violet in *B. diffusa* and is white with pink-stripes in *B. erecta*. In both species, the stamens vary in number from one to three. In *B. diffusa*, the three-stamened flowers account for 74%, the two-stamened ones, for 21%, and the one-stamened for 5%. In *B. erecta*, the corresponding percentages are 67%, 29% and 4% respectively. In both species, the stamens are free, slender, exserted, and their filaments are filiform and fixed at the base of the petaloid part of the perianth; anthers are creamy white, two-celled, monomorphic, and dorsifixed. The stamens are 3 mm long in *B. diffusa* and 1.5-2 mm long in *B. erecta*. In both species, the ovary has one carpel with one locule consisting of a solitary ovule in basal placentation (Figure 1k, 3i). The style is slender, terminal, filiform, and glabrous; it is light purple and 2 mm long in *B. diffusa*, while it is white and 1.3-1.5 mm long in *B. erecta*. In both species, the stigma reaches slightly above the top of the petaloid perianth; it is 1.5 mm long, light purple and peltate in *B. diffusa,* while it is 1 mm long, white and discoid in *B. erecta* (Figure 3h).

Floral biology

In both species, the buds mature slowly and open between 6:00- and 6:30 am (Figure 1b-g, 3c-e), and anther dehiscence occurs by longitudinal-latrorse slits simultaneously. Their opening begins with the opening of

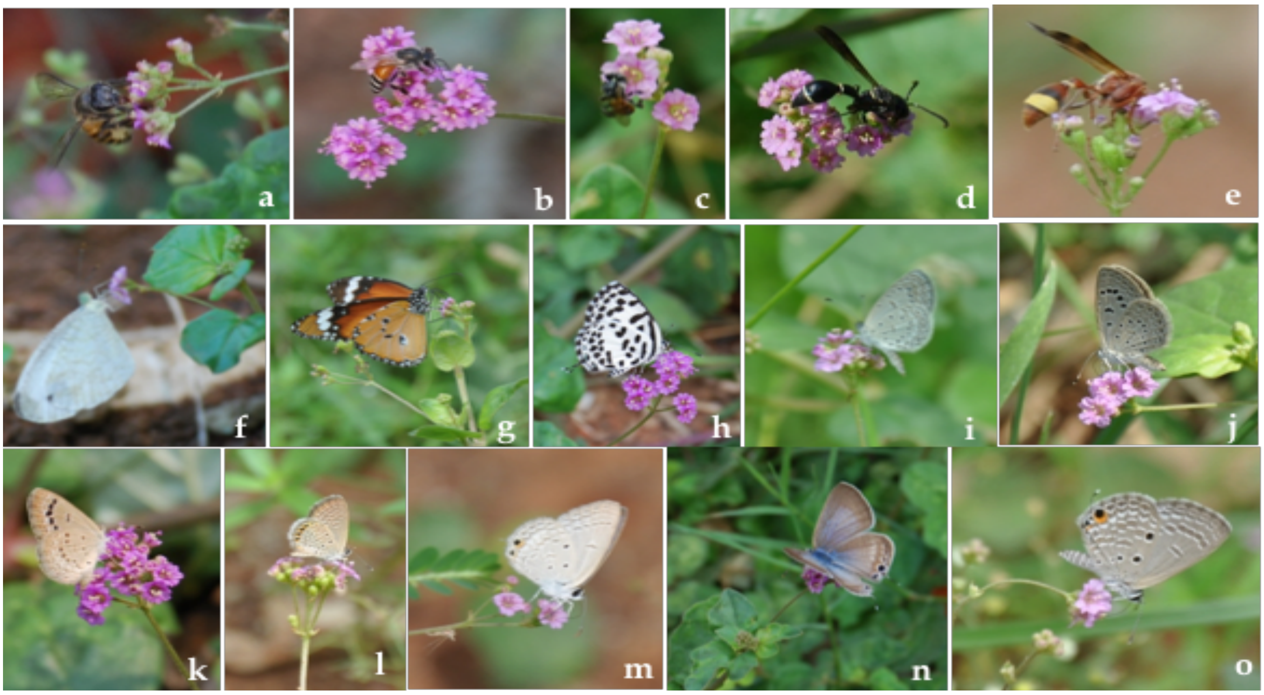

Figure 2. *Boerhavia diffusa*: a. *Apis cerana*, b. *Apis florea*, c. *Trigona iridipennis*, d. *Rhynchium* sp., e. *Polistes* sp., f. Pierid, *Leptosia nina*, g. Nymphalid, *Danaus chrysippus*, h-o. Lycaenids – h. *Castalius rosimon*, i. *Zizula hylax*, j. *Zizeeria karasandra*, k. *Zizina otis*, l. *Freyeria trochylu*s, m. *Euchrysops cnejus*, n. *Everes lacturnus*, o. *Chilades pandava*.

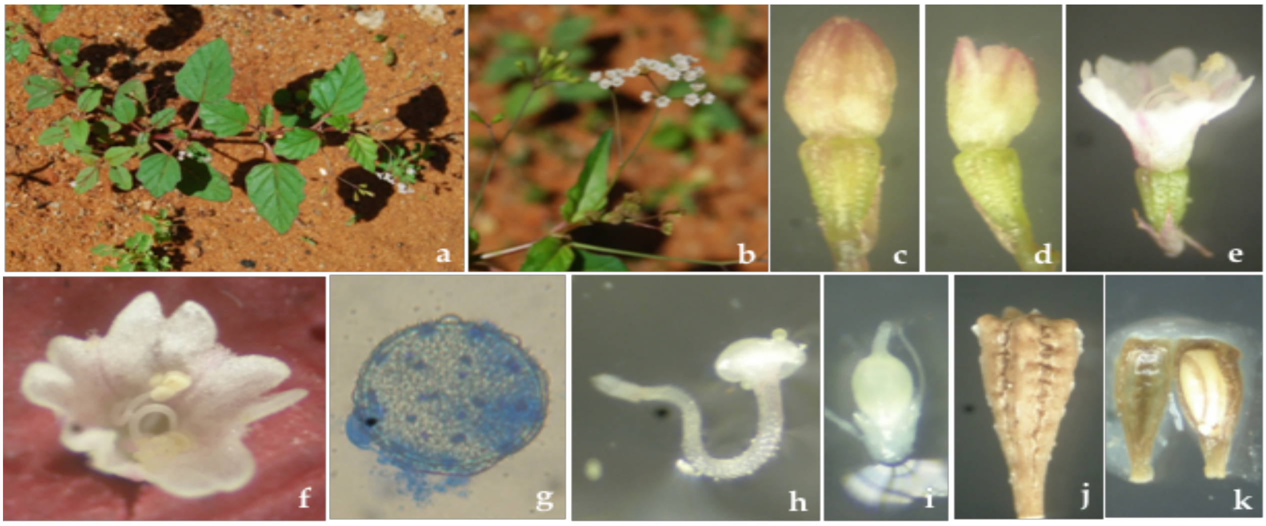

Figure 3. *Boerhavia erecta:* a. Twig in flowering phase, b. Flowering inflorescence, c. Mature bud, d. Anthesing bud, e. Flower, f. Position of stamens in open flower, g. Pollen grain, h. Style with discoid stigma, i. Ovule, j. Fruit, k. Seed.

the upper petaloid perianth and the uncoiling of stamens, style and stigma (Figure 3f). As the anthers present pollen during anthesis, the style in the process of uncoiling enables the peltate stigma to haphazardly contact the anthers. Then, the pollen from the anthers transfers to the stigma, and as a result autogamous self-pollination occurs (Figure 1h-j). The occurrence of this autogamous pollination was found to be certain in the three-stamened flowers but was not certain in neither the two-stamened nor in the one-stamened flowers. In the three-stamened flowers, the stigma during the process of uncoiling surely contacts the anthers due to the presence of a narrow space between them. Whilst in the two-stamened flowers, the additional space, created by the absence of the third stamen, reduces the chances for the uncoiling stigma to contact the anthers which results in autonomous autogamy. Similarly, in the one-stamened flowers, the chances for the uncoiling stigma to contact the anthers are further reduced and the autonomous autogamy occurs only when the stigma uncoils facing the solitary anther, and upon contact with the latter simultaneously. After the complete opening of the petaloid perianth, the stamens, style and stigma become erect and spatially separated; the anthers are placed at or slightly above the perianth rim, while the stigma stands above the top of the perianth. The petaloid perianth remains open until 1400 h, and thereafter the perianth lobes gradually close back by 1600 h. Prior to the initiation of perianth closure, the stamens and terminal part of the style and stigma coil downwards to enable the perianth lobes to close back. In this process, if the anthers still have pollen and are still facing the coiling stigma, then, autogamous self-pollination occurs. The chances for the occurrence of autogamous self-pollination during perianth closure are much higher in the three-stamened flowers than in the two- and one-stamened flowers. The color of the pollen grains is creamy white, spheroidal and pantoporate with spinulose thick exine and tubuliferous tectum; they are 58.1 µm in size in *B. diffusa* and 63.13 µm in size in *B. erecta* (Figure 3g). In both species, the pollen production rate per anther is constant in the one-, the two, - and the three-stamened flowers; it is 119.8 ± 7.02 in *B. diffusa* and 112.6 ± 9.74 in *B. erecta*. In *B. diffusa*, the pollen/ovule ratio was 120:1 in the 1-stamened flowers, 240:1 in the two-stamened flowers and 360:1 in the three -stamened flowers. In *B. erecta*, the pollen/ovule ratio was 113:1 in the one-stamened flowers, 226:1 in the two-stamened flowers and 339:1 in the three-stamened flowers. In both species, the pollen contains five essential amino acids and six non-essential

Table 1. Essential amino acids present in the pollen of *Boerhavia diffusa* and *Boerhavia erecta*

Essential amino acids			Non-essential amino acids		
Amino acid type	*Boerhavia diffusa*	*Boerhavia erecta*	Amino acid type	*Boerhavia diffusa*	*Boerhavia erecta*
Threonine	+	+	Alanine	+	+
Valine	+	+	Amino butyric acid	-	-
Methionine	-	-	Aspartic acid	-	-
Leucine	+	+	Cysteine	+	+
Iso leucine	+	+	Cystine	+	+
Lysine	+	+	Glutamic acid	+	+
Phenyl alanine	-	-	Glycine	-	-
Histidine	-	-	Hydroxy proline	+	+
Arginine	-	-	Proline	+	+
Tryptophan	-	-	Serine	-	-
			Tyrosine	-	-

amino acids. The essential amino acids are threonine, valine, leucine, isoleucine, and lysine. The nonessential amino acids include alanine, cysteine, cystine, glutamic acid, hydroxy proline, and proline (Table 1).

The total protein content per 1 mg of pollen is 190.45 µg in *B. diffusa* and 176.85 µg in *B. erecta*. In both species, the nectariferous tissue is continuous at the base of the filaments and expands close to the base of the free parts of filaments. Nectar is produced at the base of petaloid perianth just above the ovary; it is secreted in trace amount only. The stigma is receptive at the time of the unfolding of the petaloid perianth and remain receptive until the evening of the same day. The petaloid perianth together with sex organs falls off by the afternoon of the next day.

Foraging activity and pollination

The flowers *B. diffusa* and *B. erecta* were indiscriminately foraged by different insect categories during day light hours. Both species were foraged by bees, wasps, and butterflies, but *B. erecta* was also foraged by the fly *Musca* sp (Figure 4h,i) (Table 2). The bees were *Apis cerana* (Figure 2a, 4a), *A. florea* (Figure 2b), *Trigona iridipennis* (Figure 2c, 4b), and *Ceratina* sp. (Figure 4c) (Apidae); the first three species were common to both plant species, while the last bee species confined its visits to *B. erecta* only. The wasps included *Rhynchium* sp. (Figure 2d) and *Polistes* sp. (Figure 2e) (Vespidae), *Campsomeris annulata* (Scoliidae) (Figure 4d,e) and *Sphex* sp. (Sphecidae) (Figure 4f,g); the first two species visited the *B. diffusa* flowers only, while the other two species confined their visits to *B. erecta*. In both species, all insect foragers began their foraging activity at 0700 h, and gradually increased their activity towards noon paying maximum visits at 1000-1200 h; their foraging activity decreased towards evening. Their foraging activity ceased for the day at 1400 h in *B. diffusa* and at 1300 h in *B. erecta* (Figure 5,7). The butterflies included *Leptosia nina* (Pieridae) (Figure 2f), *Danaus chrysippus* (Nymphalidae) (Figure 2g), and *Castalius rosimon* (Figure 2h), *Pseudozizeeria maha, Zizula hylax* (Figure 2i, 4k), *Zizeeria karsandra* (Figure 2j, 4m), *Zizina otis* (Figure 2k, 4l), *Freyeria trochylus* (Figure 2l, 4n), *Euchrysops cnejus* (Figure 2m), *Everes lacturnus* (Figure 2n), *Jamides celeno, Chilades pandava* (Figure 2o), *C. laius* (Figure 4o) and *Leptotes plinius* (Figure 4j) (Lycaenidae). Of these, the pierid and nymphalid butterflies visited the *B. diffusa* flowers only. Among the lycaenid butterflies, *C. rosimon, P. maha* and *C. pandava* confined their visits to the *B. diffusa* flowers, while *C. laius* and *L. plinius* confined their visits to the *B. erecta* flowers only. All other lycaenids visited both of the *B. diffusa* and *B. erecta* flowers. In both plant species, the butterflies began their foraging activity at 0700 h, gradually increasing their flower visiting rate and paying maximum visits between 1000-1100 h. They then decreased their visits and terminated the foraging activity at 1300 h (Figure 6,8). In the *B. diffusa*, bees made 24%, wasps 16% and butterflies 60% of the total foraging visits. In *B. erecta*, bees made 43%, wasps 9% and butterflies 48% of the total foraging visits. In both plant species, the forage collected by bees included both pollen and nectar, while that collected by the wasps, the fly, and the butterflies included only nectar. Bees and butterflies were regular and consistent foragers, while wasps and the fly were irregular and inconsistent foragers even during the phase of the prolific flowering of the plant. Among butterflies, the nymphalid butterfly, *D. chrysippus* was an occasional forager on *B. diffusa* flowers.

In both plant species, the flowers, with the small petaloid tube consisting of nectar and situated just above the ovary, were found to be promiscuous for visitation by different insects. The nectar although seated at the ovary base was found to be accessible by small-tongued bees, wasps, and butterflies with small proboscis. The placement of anthers at or slightly above the rim of the petaloid perianth was found to be facilitating easy access for the pollen-collecting bees. The production of minute nectar and a small

Table 2. List of insect foragers on B*oerhavia diffusa* and *Boerhavia erecta*

Order	Family	Insect species	*B. diffusa*	*B. erecta*	Forage sought
Hymenoptera	Apidae	*Apis cerana* F.	+	+	Pollen and Nectar
		Apis florea F.	+	+	Pollen and Nectar
		Trigona iridipennis Smith	+	+	Pollen and Nectar
		Ceratina sp.	-	+	Pollen and Nectar
	Scoliidae	*Campsomeris annulata* F.	-	+	Nectar
	Sphecidae	*Sphex* sp.	-	+	Nectar
	Vespidae	*Rhynchium* sp.	+	-	Nectar
		Polistes sp.	+	-	Nectar
Diptera	Muscidae	*Musca* sp.	-	+	nectar
Lepidoptera	Pieridae	*Leptosia nina* F.	+	-	Nectar
	Nymphalidae	*Danaus chrysippus* L.	+	-	Nectar
	Lycaenidae	*Euchrysops cnejus* F.	+	-	Nectar
		Castalius rosimon F.	+	-	Nectar
		Leptotes plinius F.	-	+	
		Zizula hylax F.	+	+	Nectar
		Pseudozizeeria maha Kollar	+	-	Nectar
		Zizeeria karsandra Moore	+	+	Nectar
		Zizina otis F.	+	+	Nectar
		Freyeria trochylus Freyer	+	+	Nectar
		Everes lacturnus Godart	+	+	Nectar
		Chilades pandava Horsfield	+	-	Nectar
		Chilades laius Stoll.	-	+	
		Jamides celeno Cr.	+	+	Nectar

quantity of pollen by individual flowers was found to drive both pollen- and nectar-collecting insects to visit as many flowers as available in the flowering patch to meet their requirement for the day. In this process, these insects were found to make multiple visits to most of the flowers, and such a foraging behavior was considered to be promoting geitonogamy and xenogamy.

Being small-bodied, bees and flies approached the flowers in an upright manner, landing on the flat-topped umbels and inserting their tongues into the campanulate petaloid perianth of individual flowers to collect nectar. During the same visit, they also moved towards the anthers which are situated just above the perianth and collected pollen grains. All the three bee species loaded pollen into their corbiculae, and the pollen was also deposited on their ventral side and forehead. The ventral side of the bee body had contact with the peltate stigma and anthers during nectar and pollen collection and such a contact affected self- and/or cross-pollination. Being large-bodied, wasps approached the flowers in an upright way, landed on the same or adjacent umbels, and then inserted their straw-like tongues into the base of petaloid perianth to collect nectar; in doing so, they brushed the stigma and anthers with their ventral surface affecting self- and/or cross-pollination. Butterflies also approached the flowers in their upright position, landing on single or multiple umbels and inserting their proboscis to collect nectar. During that, they brushed the stigma and the anthers of the visited flower and also of the flowers of adjacent umbels with their proboscis, forehead, thorax, and abdomen. Such foraging behavior, used to collect nectar, was found to be affecting self- and/or cross-pollination. Furthermore,

Figure 4. *Boerhavia erecta*: a. *Apis cerana* collecting nectar, b. *Trigona iridipennis* collecting nectar, b. *Ceratina* sp. collecting pollen, d. & e. *Campsomeris annulata* collecting nectar, f. & g. *Sphex* sp. collecting nectar, h. & i. *Musca* sp. collecting nectar, j-o: Lycaenid butterflies collecting nectar: j. *Leptotes plinius* k. *Zizula hylax*, l. *Zizina otis*, m. *Zizeeria karsandra*, n. *Freyeria trochylus*, o. *Chilades laius*.

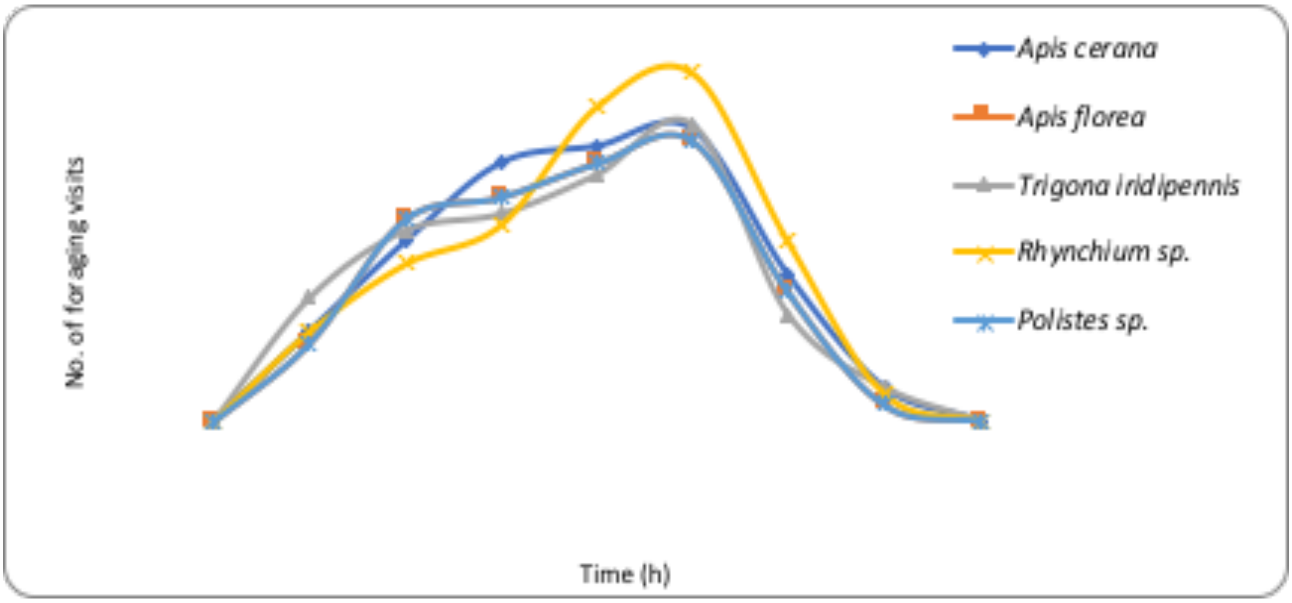

Figure 5. Hourly foraging activity of bees and wasps on *Boerhavia diffusa*

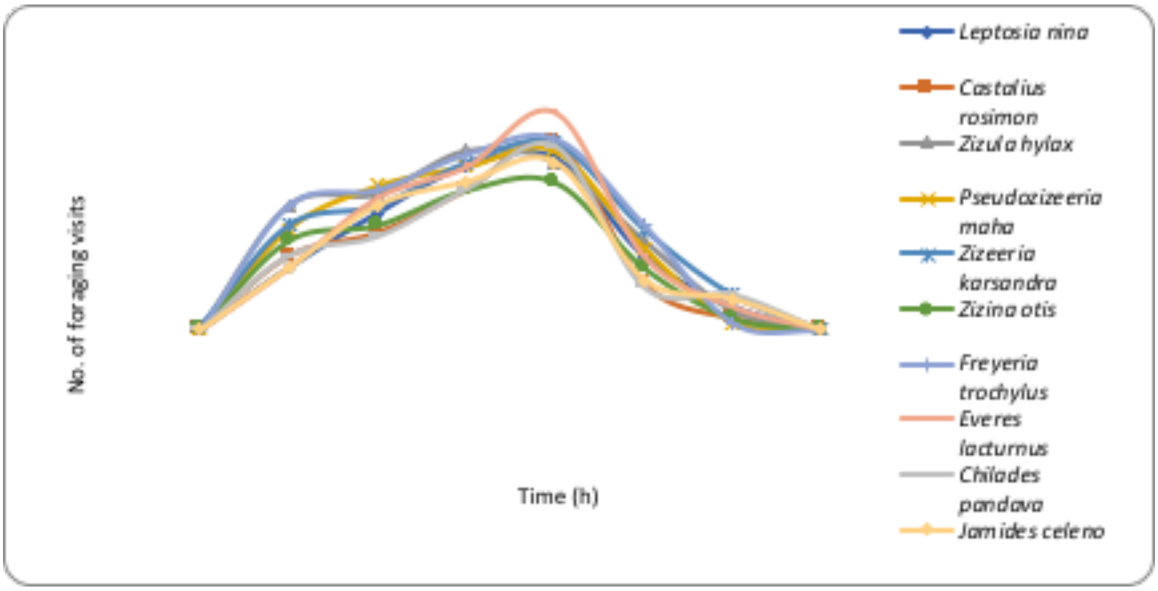

Figure 6. Hourly foraging visits of butterflies on *Boerhavia diffusa*

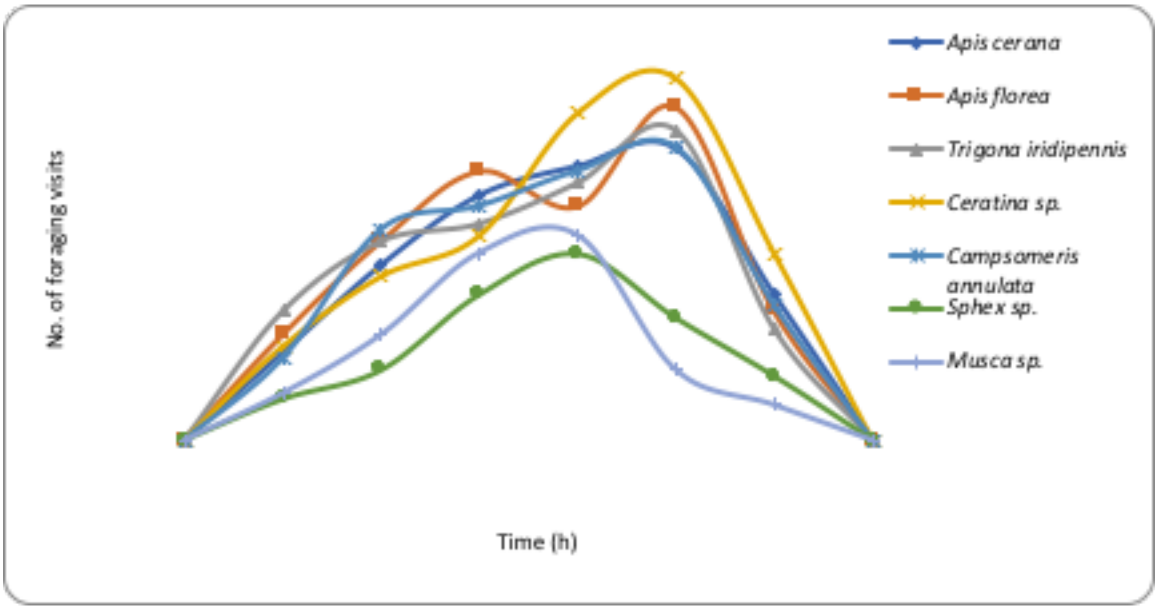

Figure 7. Hourly foraging visits of bees and wasps on *Boerhavia erecta*

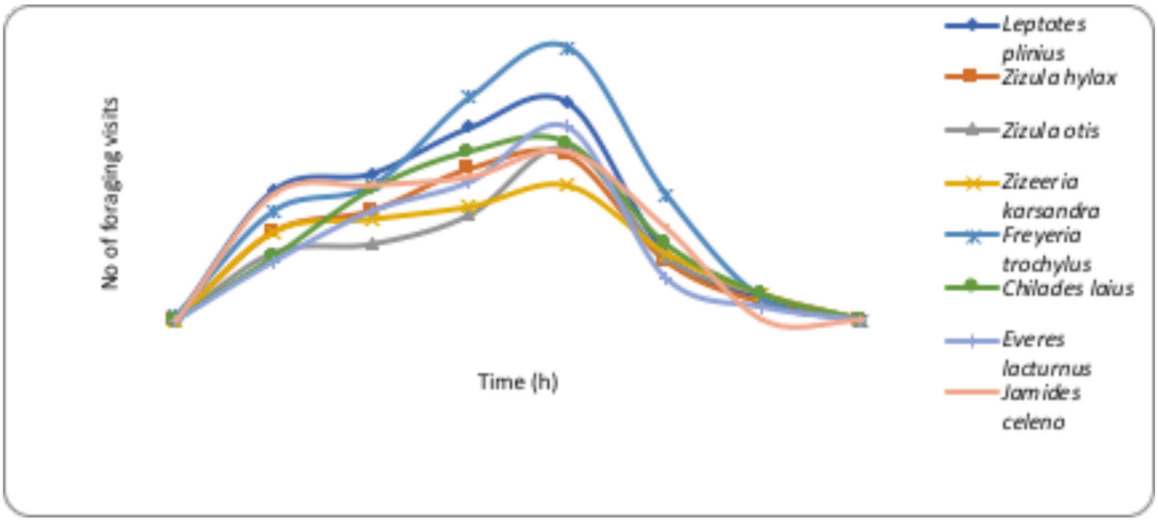

Figure 8. Hourly foraging visits of butterflies on *Boerhavia erecta*

the butterflies also collected nectar without landing on the umbels, but while holding the flowers with their legs in a hanging mode. In this foraging behavior, only the proboscis and/or their forehead had contact with the stigma and anthers which resulted in pollination. Therefore, being consistent and regular foragers to the plant, bees and butterflies were treated as the actual pollinators and wasps as additional pollinators.

Fruiting ecology and seed dispersal

In both species, the fertilized flowers produce fruits within one to two weeks. Fruit set rate in the bagged flowers was 78% in *B. diffusa* and 81% in *B. erecta*. In open-pollinations, fruit set rate was 92% in *B. diffusa* and 89% in *B. erecta*. In both, fruit is a one-seeded indehiscent anthocarp in which the lower part of the perianth remains attached to the fruit (Figure 1n, 3j). It is simple, sessile, 3 mm long, ellipsoid clavate-shaped, sticky, and pentangular with a slight indentation at the apex and is covered with glandular hairs. Furthermore, it secretes a hygroscopic mucoidal substance produced in the columnar cells of the ribs. Seeds are minute, five-sided, wedge-shaped, white and truncate at top (Figure 1l,m, 3k); they are 2.5 mm long, 1.5 mm wide in *B. diffusa,* and 1.5.-1.8 mm long and 1.2 mm wide in *B. erecta*. In both species, the sticky fruit with the mucoidal secretion appeared to be an adaptive trait to facilitate dispersal upon contacting with animals and humans because the fruit readily adheres to the objects they touch and detaches itself from the plant. The fruits of both species were also dispersed by birds, namely, *Acridotheres tristis* (Indian Myna), *Turdoides caudatus* (Common Babbler) and *Turdoides striatus* (Jungle Babbler). Furthermore, the fruits were found to be dispersed through rainwater. The seeds were non-dormant and germinate almost immediately upon the decomposition of perianth residue and fruit pericarp in the vicinity of parental sites provided that the soil has moisture. In addition to seed propagation , both species also multiply by the fragmentation of the rhizome to expand their population size. The function of both sexual and asexual modes enables them to propagate continually and display vegetative phase, flowering and fruiting phases either simultaneously or alternately throughout the year in the habitats where the soil is continually moist or wet.

Discussion

The genus *Boerhavia* represents four species, *B. crispa, B. rubicunda, B. diffusa* and *B. erecta* in India (Dutta *et al.,* 2015), of which *B. diffusa* and *B. erecta* are widespread and distributed throughout the country (Kirtikar and Basu, 1933: Chen and Wu, 2007). *B. diffusa* grows well in open sunlight and endures severe abiotic stresses such as UV exposure, high temperature, water and nutrient deficiencies (Anonymous, 1988). The present study shows that both *B. diffusa* and *B. erecta* occur commonly and grow well displaying vegetative, flowering and fruiting phases either simultaneously or alternately throughout the year in various habitats with wet to semi-dry soils. However, they show prolific growth, flowering and fruiting during the rainy season; they carpet the soils with their profuse growth in open habitats exposed to direct sunlight, high temperature, water and nutrient deficiencies. However, *B. diffusa* is widespread in wet to semi-set soils, while *B. erecta* is widespread in semi-wet and well-aerated sandy soils indicating that these species have different preferred habitats for their propagation and population expansion. These species can be easily identified through habit, inflorescence, and floral color characters in the field. In *B. diffusa*, the branches are prostrate and diffused with a long peduncle comprising of several cymes of pedicellate flowers with a red to violet petaloid perianth. In *B. erecta*, the branches are slightly erect spreading with long primary and short secondary peduncles; the latter type comprises several cymes of pedicellate flowers with a white petaloid perianth with pink stripes. In both species, all flowers in a cyme open on the same day and at the same time making them attractive to their pollinating insects.

Spellenberg (2000) reported that in *Boerhavia coccinea, B. intermedia, B. spicata, B. torreyana*, and *B. wrightii,* individual flowers open only during a portion of a day. The flowers open at dawn and their opening begins with the opening of the corolla-like perianth and the uncoiling of stamens and styles. As the morning progresses, the filaments and style curl, and the anthers contact the stigma affecting autogamous self-pollination. The perianth closure begins in the late morning containing the stamens and style within and wrinkles by mid-afternoon of the same day. Chaturvedi (1989) reported similar autogamous self-pollination and a perianth closing function in *B. diffusa*. In the present study, the flowers of *B. diffusa* and *B. erecta* open at dawn by unfolding the petaloid perianth during which the stamens with dehisced anthers, and the style and stigma in a receptive state gradually uncoil; in this process, the stigma brushes the anthers, and then the pollen grains transfer to the stigmatic surface resulting in autogamous self-pollination. The occurrence of autogamy by the movement of sex organs during flower-opening is almost certain in the three-stamened flowers as there is a very narrow gap between anthers and the style and stigma, but it is not so in either of the two - and the one-stamened flowers as there is a wider gap between the sex organs because of non-production of one stamen in two-stamened flowers and two stamens in one-stamened flowers. Most of the flowers produced by both plant species possess three stamens that facilitate autogamous selfing. However, the production of the two- and one -stamened flowers in both species appears to be an evolved trait to regulate autogamous selfing in order to facilitate vector-mediated autogamy, geitonogamy, or xenogamy during the open state of the flowers. Furthermore, the production of nectar and the vividly colored petaloid perianth are additional adaptations to attract insect pollinators to mediate pollen transfer within and between conspecific plants. The flowers that failed to self- or cross-pollinate autonomously during the process of anthesis or by vector-mediation in open condition have the option to resort to autogamous self-pollination by the brushing of the inward coiling of the stigma and style against the anthers bending inwards simultaneously, but this mode of pollination is subject to the availability of pollen in the anthers at that time. Moreover, the inward coiling of the sex organs is compulsory for the perianth to close back completely. The *B. diffusa* and *B. erecta* flowers govern themselves in autogamous self-pollination during the opening and closing process of the perianth lobes, while they facilitate vector-mediated self- and cross-pollination during the open condition of the perianth lobes. The flowers require only a few pollen grains for pollen and subsequent fertilization since the ovary contains only a single ovule. The movement of sex organs during the closing process of the perianth lobes and the duration of the open state of the perianth provide ample opportunities for the occurrence of self- or cross-pollination. In both plant species, pollen/ovule ratios indicate the functionality of facultative autogamy (Cruden, 1977); however, their ratios are higher than the ratios prescribed for facultative autogamy by Cruden (1977) suggesting that the high ratio is required to promote cross-pollination by insect pollinators and also to compensate for pollen loss resulting during the pollen collection activity of bee pollinators. Despite the functionality of spontaneous and vector-mediated pollination, the fruit set rate is not 100% in both plant species. Therefore, *B. diffusa* and *B. erecta* with a facultative autogamous mating system regulate spontaneous self-pollination and allow a certain percentage of cross-pollination in order to maintain genetic variation which enables them to adapt to different habitats, and to produce seed prolifically and expand their distribution range from plain lands to hill tops (Adahl *et al.,* 2006).

Bittrich and Kuhn (1993) reported that the *Boerhavia* flowers are melittophilous and are suited for head pollination by small bees;

they are fit for both bee and fly pollination. Spellenberg (2000) reported that *B. coccinea* is visited the bees of *Scolia, Mellisodes,* the wasps of *Holopyga rudis* and *Ammophila,* and also by the calliphorid, syrphid and muscid flies in New Mexico, United States of America. de Mendonca Santos *et al.* (2010) reported that *B. coccinea* is pollinated by social bees and social wasps in Caatinga in the northeastern Brazil (de Mendonca Santos *et al.,* 2010). Spellenberg (2000) also reported that *B. intermedia*, *B. torreyana, B. wrightii* and *B. spicata* are visited by bees, wasps, and flies. Chaturvedi (1989) reported that *B. diffusa* is pollinated by bees, flies, ants, and butterflies in North India. In this study, both *B. diffusa* and *B. erecta*, with a minute volume of nectar and pollen consisting of some essential and nonessential amino acids and protein content, attract bees, wasps, flies, and butterflies to their flowers. However, only bees and butterflies act as actual pollinators due to their regularity and consistency in their visits, while other insects act as additional pollinators. As the flowers are very small with a minute volume of nectar and a small amount of pollen, the insects are compelled to visit as many flowers as available in the habitat and in this process, they promote cross-pollination. In both plant species, the pollen grains are large and spinulose; these are the characteristics of insect-pollinated species (Nowicke, 1970). Therefore, both *B. diffusa* and *B. erecta* are entomophilous involving bees and lycaenid butterflies as principal pollinators.

Struwig and Siebert (2013) reported that the shape of the anthocarp, presence of ribs or wings, and the presence or absence and the position of glandular hairs are diagnostics of the *Boerhavia* species in South Africa. In this study also, anthocarp fruit characteristics can be used as diagnostic characters to differentiate *B. diffusa* from *B. erecta*. In these species, the upper part of the perianth is petaloid, while the lower part of the perianth is sepaloid. The petaloid perianth detaches by abscission after fertilization, while the sepaloid perianth containing the ovary enlarges and develops into a protective structure around the fruit which is termed as the anthocarp (Vanvinckenroye *et al.,* 1993; Hickey and King, 2000). In both species, the one -seeded indehiscent anthocarps secrete mucoidal substance in their columnar cells in the ribs, and this secretion enables them to be sticky and adhere to the objects which contact them. This character is an adaptive trait to facilitate the dispersal of anthocarps by animals, humans, and birds. Additionally, the anthocarps also disperse through rainwater. Therefore, both *B. diffusa* and *B. erecta* are zoochorous, anthropochorous, ornithochorous, and hydrochorous. These multiple dispersal modes ensure these plant species to migrate and spread across various uncultivated and cultivated habitats in tropical and sub-tropical areas around the world.

In this study, it was found that both *B. diffusa* and *B. erecta* propagate predominantly by seeds. Since seeds are non-dormant, they immediately germinate as soon as they are dispersed and produce several batches of populations if the soil has sufficient moisture and nutrients. Additionally, these species also multiply asexually through the fragmentation of the rhizome. The dual modes of regeneration enable these plant species to occupy diverse habitats and become invasive. In these plant species, the characters such as year-long flowering and fruiting, spontaneous autogamy, entomophily, the production of non-dormant seeds, the function of multiple seed dispersal modes and propagation by the fragmentation of the rhizome constitute weed characteristics and hence *B. diffusa* and *B. erecta* are treated as prolific and invasive weeds (Baker, 1965; 1974).

Mwangi (2009) reported that *B. diffusa* is an important floral source for a diversity of bee species in the Arabuko Sokoke Forest, Nigeria. Mahale (2019) noted that *B. diffusa* is an important nectar source for honeybees in the cultivated and uncultivated areas of the Ahmednagar in South-Eastern region of Western Ghats. Churi *et al.* (2020) noted that *B. diffusa* is a nectar plant for *Junonia lemonias, J. almana, Castalius risomon,* *Appias olferna, Eurema hecabe, Ypthima* spp., *Colotis amata, C. danae*, and *C. protractus* in South India. The present study adds that both *B. diffusa* and *B. erecta* are important pollen and nectar sources for bees, and constitute nectar sources for wasps, flies, and butterflies in all areas where these plant species occur.

Conclusions

The *Boerhavia diffusa* and *Boerhavia erecta* flowers open at dawn by unfolding the petaloid perianth during which the stamens with dehisced anthers, and the style and stigma in a receptive state gradually uncoil to become erect; in this process, autogamous self-pollination occurs. This mode of autogamy is almost certain in the three-stamened flowers, but it is not so in neither of the two- and the one -stamened flowers. The production of nectar and vividly colored petaloid perianth are additional adaptations for insect pollination. The flowers that fail to self- or cross-pollinate autonomously during the process of anthesis or by vector-mediation in the open condition have the option to resort to autogamous self-pollination during the process of the closing of the petaloid perianth covering the sex organs within. Despite the functionality of the spontaneous and vector-mediated pollination, the fruit set rate is not 100% in both plant species which means that they regulate spontaneous self-pollination and allow a certain percentage of cross-pollination to maintain genetic variation which for sure makes them adapt to different habitats, enables them to produce seed prolifically, and which expands their distribution range. In both species, bees and butterflies act as actual pollinators, while the other insects act as additional pollinators. In both species, zoochory, anthropochory, ornithochory, and hydrochory are functional. Seeds are non-dormant, germinate immediately after dispersal and produce several batches of populations provided that the soil environment is favorable. Moreover, these species also multiply asexually through the fragmentation of the rhizome. The year-long flowering and fruiting, the spontaneous autogamy, entomophily, the production of non-dormant seeds, the function of multiple seed dispersal modes and the propagation by the fragmentation of rhizome make them prolific and invasive weeds. The study suggests that both plant species are ideal pioneer species and can be useful in the restoration of ecologically disturbed and damaged habitats or ecosystems because they have the ability to grow in habitats with semi-wet and sandy soils. Furthermore, by establishing huge populations in such habitats these plant species play an important role in controlling soil erosion, and in the sequestration of carbon dioxide in addition to supporting certain local insect fauna by providing pollen and/or nectar during flowering period.

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Scorpions from the Tabuk Province, Saudi Arabia

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Abstract: Eight species of scorpions belonging to two families (Buthidae and Scorpionidae) are reported from thirteen localities in the Province of Tabuk. The family Buthidae is represented by seven species in seven genera (*Androctonus*, *Compsobuthus, Leiurus, Parabuthus, Orthochirus*, and *Trypanothacus*), while the family Scorpionidae is represented by a single species, *Scorpio kruglovi.* The present data extend the distribution range of *Trypanothacus buettikeri* and *Parabuthus leiosoma* further to the northwestern coastal region and the known range of *Compsobuthus setosus* to include western Saudi Arabia.

Key words: Tabuk, Saudi Arabia, Buthidae, Scorpionidae.

Introduction

The scorpion fauna of Saudi Arabia has been subject to several studies over the past fifty years (Vachon, 1966 and 1979; Levy *et al*., 1973; Kovařík, 2003; Kovařík and Whitman, 2005; Hendrixson, 2006; Lourenço and Qi, 2006; Al-Asmari *et al.,* 2007, 2009a, b, 2013; Desouky and Alshammari, 2011; El-Hennawy, 2009; Lowe *et al.,* 2014; Alqahtani *et al.,* 2019). Amr *et al.,* (2021) listed thirty-one species within four families, while recently, Alqahtani and Badry (2021) listed only twenty-six species of scorpions from Saudi Arabia. A new species, *Compsobuthus khaybari*, collected from Ain El-Hamah, Khaybar area was described (Abu Afifeh *et al.,* 2021). Fragmentary records from Tabuk were listed by Hendrixson (2006) and Al-Asmari *et al.*, (2013).

The present study aims at investigating the scorpion fauna of the Tabuk Province in Saudi Arabia based on a recent collection of scorpions.

Materials and Methods

Scorpions were collected from thirteen localities in the Tabuk Province (Table 1) either by flipping stones or by using ultraviolet torches at night. Specimens were photographed while alive, and then preserved in 75% ethyl alcohol with glycerol for further identification. The species were identified based on taxonomic keys according to Hendrixson (2006) and Alqahtani and Badry (2021).

Results

In this study, eight species of scorpions belonging to two families (Buthidae and Scorpionidae) were reported from thirteen localities in the Tabuk Province.

Family Buthidae

Androctonus crassicauda (Olivier, 1807) (Figure 1A).

Material examined: Magna, May 2011. ♂, Hisma, 23.6.2012. 1 Juvenile, Taima (Al Gharb farms), 2.7.2013. Qala'at Al Azlam, 25.6.2013. 1 Juvenile Um Luj-Al Gabaya farm, 25.6.2013. 3 Juveniles, Al Beda'a, 27.6.2013.

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Table 1. Localities from which scorpions were collected.

Locality	Coordinates	
	N	E
Al Beda'a	28° 26' 28.00"	34° 49' 26.00"
At-Tubayq	29° 47' 05.21"	37° 25' 26.53"
Bajdah	28° 20' 50.55"	35° 47' 16.03"
Harat Al Rahah (Ain Al Akhdhar)	27° 38' 20.76"	36° 49' 19.61"
Harat Al Rahah (Wadi Rashdan)	27° 49' 58.00"	36° 33' 05.00"
Halat Ammar	29° 09' 05.98"	36° 05' 28.47"
Hisma	29° 00' 11.35"	35° 30' 10.35"
Magna	28° 23' 46.35"	34° 45' 00.78"
Qala'at Al Azlam	27° 02' 21.88"	36° 01' 13.25"
Quraeah	28° 47' 05.35"	36° 00' 14.93"
Taima (Al Gharb farms)	27° 38' 10.00"	38° 32' 49.00"
Taima (Alnofood Alkabeer)	27° 25' 26.00"	39° 03' 26.00"

Figure 1. A. *Androctonus crassicauda.* **B.** *Compsobuthus setosus.* **C.** *Leiurus haenggii.* ***D.*** *Parabuthus leiosoma.* **E.** *Orthochirus* sp. **F.** *Scorpio kruglovi.*

Diagnosis: Colour of adults is golden brown to nearly black, pale yellow in juveniles; metasomal segment III wider than long; pedipalp manus broad and stout; outer tooth of basitarsal spur on leg IV generally not bifurcated, mesosomal tergites I and II with at most three carinae (Hendrixon, 2006).

Remarks: This is a widely distributed species across Saudi Arabia (Hendrixon, 2006; Alqahtani and Badry, 2021). Its distribution range extends across all of the Middle East and reaches as far as Armenia and Azerbaijan (Hendrixon, 2006).

Compsobuthus setosus Hendrixson, 2006 (Figures 1B and 2)

Material examined: 2 ♂, Halat Ammar, 2.7.2013.

Diagnosis: Pectinal teeth 19-19 for the two males, moveable fingers of pedipalps with 10 rows of denticles, pedipalp chela fingers without outer accessory granules. Metasomal segment: I with 10 carinae, II with 8 carinae and 5-6 granules, III with 8 carinae and 2-3 granules, IV with 8 carinae.

Remarks: This species is endemic to Saudi Arabia. It was originally described from Khashm Khafs and Riyadh in Eastern Saudi Arabia and near the Jordanian borders in the north (Hendrixon, 2006).
This species belongs to the "*acutecarinatus*" group and is characterized by having fingers without outer accessory granules. Occasionally, there may be external granules present at the basal two or three rows, but these granular rows are *mostly* nonexistent in this species . The present record expands the distribution range of this species further to the west of Saudi Arabia.

Leiurus haenggii Lowe, Yağmur and Kovařík, 2014, 2014 (Figure 1C).

Material examined: Manga, 23.5. 2011.
Diagnosis: Mesosomal tergites I and II with five carinae, pedipalp patella in females with L/W less than 3.20, Fs less than 23; female sternites III–IV with weak to obsolete median carinae (Lowe *et al.*, 2014).

Remarks: Lowe *et al.*, (2014) revised the genus *Leiurus* ; all previous records of *Leiurus quinquestriatus* (Ehrenberg, 1828) in Saudi Arabia describe it as either: *Leiurus brachycentrus* (Ehrenberg, 1829) known along the Red Sea coast, reaching as far as the southwest of Makkah, and *Leiurus arabicus* (Lowe, Yağmur and Kovařík, 2014)

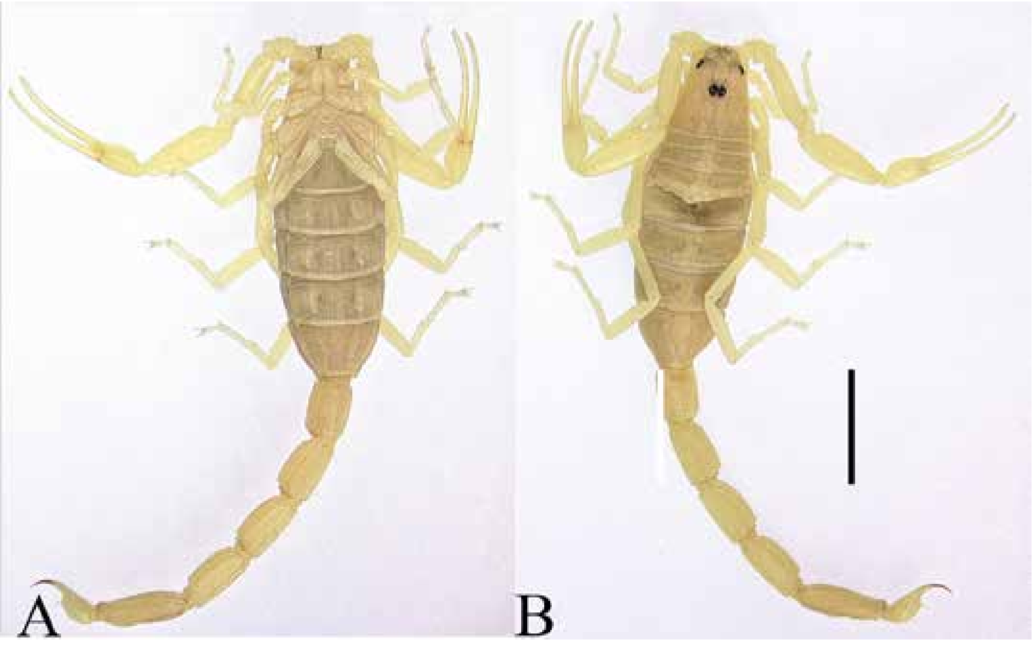

Figure 2. *Compsobuthus setosus*. **A.** Ventral aspect. **B.** Dorsal aspect. Scale bar = 5 mm.

distributed across eastern Saudi Arabia, or *Leiurus haenggii* known along the Red Sea coast.

Leiurus jordanensis **Lourenço, Modry and Amr, 2002 (Figure 3).**

Material examined: Quraeah, 1.10.2018. At-Tubayq, 21.9.2018.

Diagnosis: Mesosomal tergites I and II with five carinae, base colour dark brown to black, ventrolateral carinae of metasomal segment V with spinoid denticles (Hendrixon, 2006).

Remarks: It was collected from Al Jawf (Alqahtani and Badry, 2021). This is the second record from Saudi Arabia. It was originally described from Al-Mudawwarah, Jordan, close to the Tabuk Province (Lourenço *et al*., 2002).

Orthochirus **sp. (Figure 1E)**

Material examined: Bajdah, 2.7.2013

.

Diagnosis: Small scorpion; carapace and tergites densely granular; metasomal segment V punctate (Hendrixon, 2006).

Remarks: Hendrixon (2006) maintained that the genus *Orthochirus* is represented by *Orthochirus innesi* (Simon, 1910). This species, *O. innesi,* is confirmed only in North Africa. The taxonomic status of this genus is still unclear due to its morphological variability.

Parabuthus leiosoma **(Ehrenberg, 1828) (Figures 1D and 4).**

Material examined: ♂, Um Luj-Al Gabaya farm, 25.6.2013

Figure 3. Male *Leiurus jordanensis.*

Diagnosis: Pedipalp femoral trichobothria arranged in alpha-configuration; a stridulatory patch present on the dorsal surface of metasomal segments I-III (Hendrixon, 2006).

Remarks: This species is known in western Saudi Arabia. Its distribution extends across north-eastern Africa, Yemen, and western Saudi Arabia (Hendrixon, 2006).

Trypanothacus buettikeri **(Hendrixson, 2006) (Figure 5)**

Material examined: ♂ and ♀, Qala'at Al Azlam, 25.6.2013. ♂ and ♀ Ain Al Akhdhar, 5 July 2021.

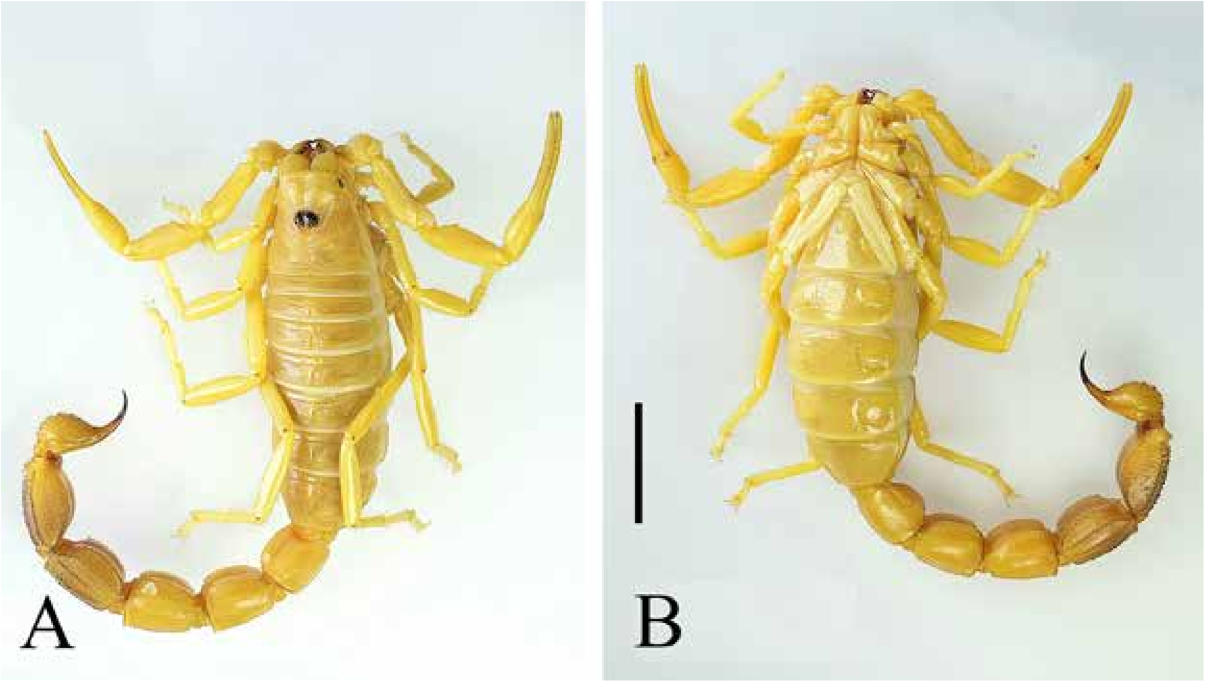

Figure 4. *Parabuthus leiosoma.* Male: **A.** Dorsal aspect. **B.** Ventral aspect. Scale bar = 10 mm.

Diagnosis: The male of this species is yellow and the female exhibits a reddish-brown coloration. The male has nine rows of denticles on the movable finger, trichobothrium e_2 distal to d_5 on the femur of pedipalp, pectinal teeth 25-25, while dentition in females shows nine to six on the fixed finger, pectinal teeth 21-21 (Hendrixon, 2006).

Remarks: This species is endemic to Saudi Arabia with records from Ha'il, Al Madinah, Ash Sharqiyah, and Asir (Hendrixon, 2006; Alqahtani, and Badry, 2021). The present record extends its distribution to northwest Saudi Arabia.

Family Scorpionidae

Scorpio kruglovi Birula, 1910 (Figure 1F)

Material examined: Hisma, 22.6.2013. Harat Al Rahah (Ain Al Akhdhar), 28.6.2013. Harat Al Rahah (Wadi Rashdan), 28.6.2013.

Diagnosis: Pediplaps lobster-like; metasomal segments I–IV with two axial carinae in the ventral part; a cheliceral movable finger with a single denticle (Alqahtani and Badry, 2021).

Remarks: Hendrixon (2006) described the species of this genus as *Scorpio maurus* sp. However, Alqahtani and Badry (2021) listed three species belonging to the genus *Scorpio*; *Scorpio fuscus* (Ehrenberg, 1829), *Scorpio palmatus* (Ehrenberg, 1828), and *Scorpio kruglovi* Birula, 1910;the latter was recorded from Tabuk.

Discussion

This is the first documentation of scorpions from the Tabuk Province presenting records of eight species. All species have been recorded from Saudi Arabia, however, the records of *T. buettikeri* and *P. leiosoma* extend their distribution range further to the northwestern coastal region (Alqahtani and Badry, 2021), while the record of *Compsobuthus setosus*extends its known distribution range to include western Saudi Arabia.

The variety of habitats in the Tabuk Province offers several living conditions suitable for sand-dwelling species such as *T. buettikeri, S. kruglovi* and *P. leiosoma,* in addition to *L.*

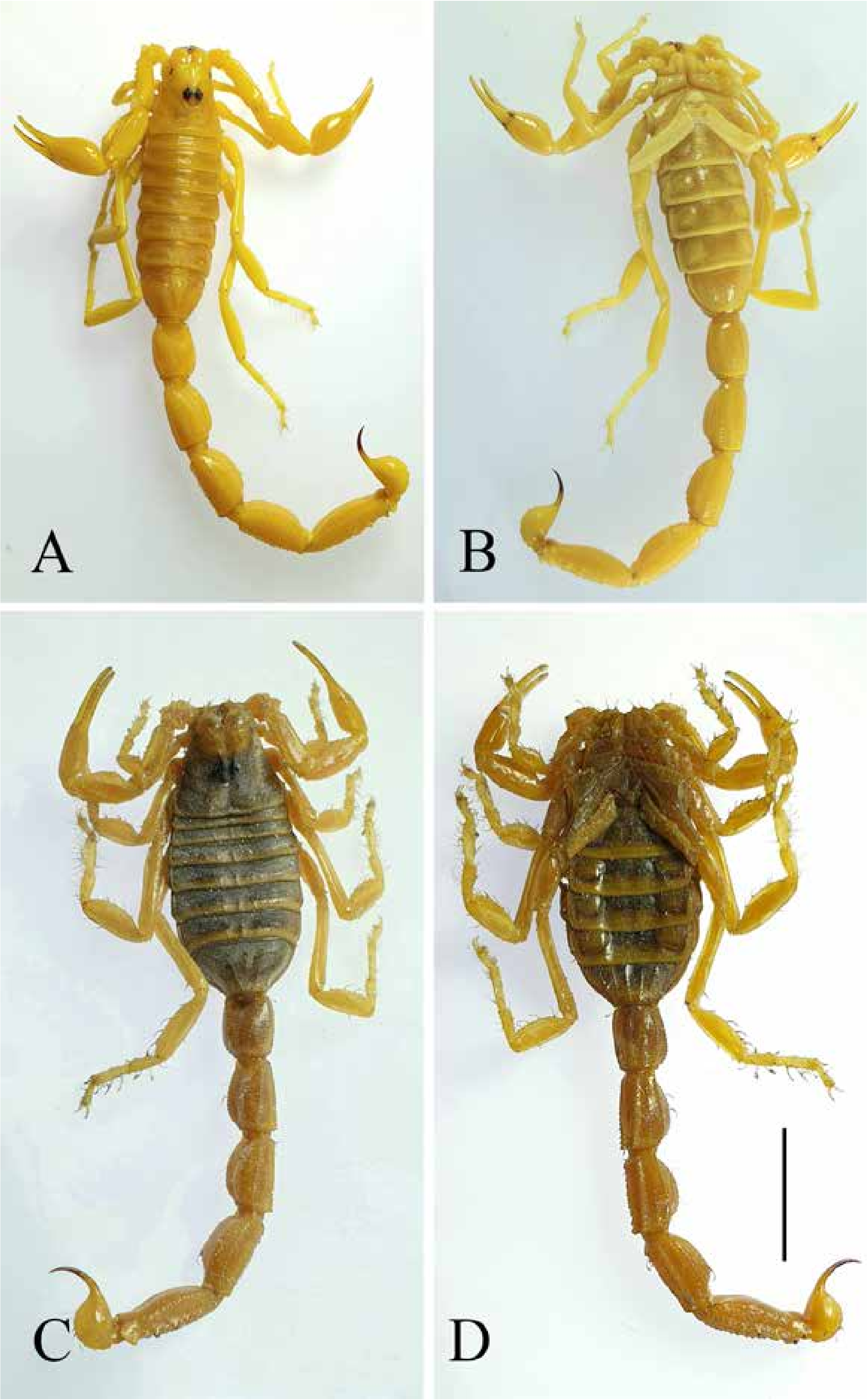

Figure 5. *Trypanothacus buettikeri.* Male: **A.** Dorsal aspect. **B.** Ventral aspect. Female**: C.** Dorsal aspect. **D.** Ventral aspect. Scale bar = 10 mm.

haenggii and *L. jordanensis* which inhabit the rocky areas.

Further studies are recommended to investigate the scorpion fauna of the Tabuk Province both at the molecular and morphological levels.

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Jordan Journal of Natural History, 8 (2), 2021 Pages 118-120

Short Communication

New Data on Digger Wasps, *Sceliphron curvatum* (F. Smith, 1870) and *Trypoxylon figulus* Linnaeus, 1758 (Hymenoptera: Sphecidae) as hosts of *Amobia oculata* Robineau–Desvoidy, 1830 (Diptera: Sarcophagidae) in Ukraine

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Abstract: *Amobia oculata* was reared from the nests of sphecid wasps *Sceliphron curvatum* (F. Smith, 1870) and *Trypoxylon figulus* Linnaeus, 1758 in Kyiv and Poltava regions of Ukraine. *S. curvatum* is a new host for this fly.

Keywords: Solitary wasps, Miltogrammine flies, Inquilines, Kyiv, Poltava

Introduction

This work is a continuation of the previously initiated (Verves & Protsenko, 2019) study of inquilines of solitary wasps in Ukraine. Thread-waisted or digger wasps (Hymenoptera: Apoidea, Sphecidae) consist of nearly 7700 species of solitary or semisocial insects (Pulawski, 2019). The female (sometimes together with male) build underground burrows for nesting, or aerial nests on the stems of grasses and shrubs (so called "clay jugs"), or mud nests in attics, carports, etc (so called "mud-dauber wasps"). Each nest includes from one to 40 brood cells. The adult females capture prey that they paralyze with a sting or kill and place it in a cell along with an egg. Predatory larvae feed on cicadas, aphids, bugs, grasshoppers, caterpillars, larvae and adult beetles, hymenopterans and other insects, or spiders). Adults of all known species usually feed on the nectar and (rarely) pollen of flowering plants (O'Neill, 2000).

Mud-dauber wasps, *Sceliphron curvatum* (F. Smith, 1870) build aerial nests using mud collected from humid-soil sources and carried to the nest in the form of spherical mud-balls (Chatenoud *et al*., 2012). *Sceliphron curvatum* is an invasive species in Ukraine. The native area of *S. curvatum* include Iraq, East Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, Pakistan, East India and Nepal (Hensen, 1987; Gülmez & Can, 2015). The expansion of this species has been noted in Europe since 1979 (Van der Vecht, 1984), and in Georgia and Turkey from the beginning of XXI century (Gülmez & Can, 2015). In Ukraine, *S. curvatum* reached Kharkiv region in 1999; Crimea in 2000; and Zakarpattia in 2001 (Shorenko, 2003, 2005). The modern analysis of museum collections and other materials suggests, that *S. curvatum* appears almost throughout the territory of Ukraine, except of the most of Polissia (Tymkiv *et al*., 2015). Today this species is found at territories of following 25 European countries(Schmid-Egger, 2005; Bitsch & Barbier, 2006; Ertürk & Taş, 2021): Austria (since 1979), Belarus (2014), Belgium (2014), Bulgaria (2005), Croatia (1996), Czech Republic (2004), France: mainland and Corsica (2001), Germany (2001), Greece (2005), Hungary (1998), Italy: mainland and Sicily (1995), Lithuania (2016), Luxembourg (2014), Montenegro (2004), Netherlands (2004), Poland (2009),

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Portugal (2006), Romania (2014), Russia: European part (2010), Serbia (2004), Slovakia (2003), Slovenia (1995), Spain: mainkand and Balearic Is. (2006), Switzerland (2001), Ukraine (1999). *Sceliphron curvatum* has also appeared in Neotropical region: Argentina (Compagnucci & Roig Alsina, 2008) and Chile (Barrera-Medina & Garcete-Barrett, 2008). Since 2017, this species has been registered in Utah State of USA. The analysis of expansion dynamics indicates a gradual settling of *S. curvatum* in Europe, but it is limited up to north by 53°N, what can be explained by thermophilicity of this species (Schmid-Egger, 2005). The preys are paralyzed spiders from 23 genera and 10 families, mainly Araneidae, Salticidae, and Philodromidae. Female places 2–40 spiders per cell (Fateryga & Kovblyuk, 2013; Gülmez & Can, 2015; etc).

Trypoxylon figulus (Linnaeus, 1758) is distributed throughout the Holarctic region (Bitsch et al., 2001). In Ukraine, this species is known from Cherkasy (Gorobchishin, 2006), Crimea (Shorenko, 2005), Kharkiv (Shorenko & Konovalov, 2010), Khmelnytskiy (Shorenko & Konovalov, 2010), Kyiv (Gorobchishin, 2006), Luhansk (Shorenko & Konovalov, 2010), Lviv (Shorenko & Konovalov, 2010), Sumy (Shorenko & Konovalov, 2010), Ternopil (Gorobchishin, 2006), Vinnytsia (Gorobchishin, 2006), Zhytomyr (Shorenko & Konovalov, 2010) regions and Kyiv City (Gorobchishin, 2006). This species nests in holes in dead wood, walls, stems etc, and abandoned earth nests of wasps, and boreholes of beetles; the preys are different paralyzed aphids or spiders of small sizes (Abraham, 1982).

Materials and Methods

The nests of the wasps *Sceliphron curvatum* and *Trypoxylon figulus* were selected as objects for the study. The field studies by second author took place in Kyiv region, Obukhiv district, Ukrainka town, 50°09′N, 30°44′ E. The nests of *S.curvatum* were placed at a height of one meter on the wall of the apartment on the 8th floor. Insects flew in and out freely through the open window. The pupae of *A. oculata* were collected from nests in November 2019; adult flies emerged in April 2020. The pupae of *A. oculata* were collected from nests of *T. figulus* in Poltava region, Pyriatyn district, outskirts of Leliaky village, 50°20'N, 32°30'E, in October 2018; adult flies emerged in April 2019. Laboratory investigations of the hymenopteran nests were performed by second author in the Biology and Medicine Institute Science Educational Center of Taras Shevchenko National University of Kyiv, and the determination of the flies was made by senior author at the Institute for Evolutionary Ecology, National Academy of Sciences of Ukraine, Kyiv.

Results.

AMOBIA OCULATA (Zetterstedt, 1844)

Material examined

2♀. Kyiv region, Obukhiv district, Ukrainka town, inside of building, 50°09′N, 30°44′E, pupae collected in November 2019 from nest of *Sceliphron curvatum*, emerged in April 2020.
3♀. Poltava region, Pyriatyn district, outskirts of Leliaky village, 50°20'02"N, 32°30' E, bottomland, forest instillation in April 2018, pupae collected in October 2018 from nest of *Trypoxylon figulus*, emerged in April 2019.

Distribution

Ukraine: Cherkasy, Chernigiv, Dnipro, Donetzk, Kyiv and Poltava regions; Kyiv City. The detailed review of general distribution (Holarctic and northern part of Oriental regions) and a list of hymenopteran hosts of this species were given in our previous publication (Verves & Protsenko, 2019).

Comment: This is the first record of *Sceliphron curvatum* as a host of *A. oculata*.

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Jordan Journal of Natural History, 8 (2), 2021 Pages 121-125

Short Communication

A Yellow-headed Gecko *Gonatodes albogularis* (Duméril and Bibron, 1836) with Bifurcated Tail in the Caribbean Lowlands of Costa Rica

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Abstract: Autotomy is an escape mechanism in lizards, follow by subsequent tail regeneration. Tail loss initiates a spontaneous epimorphic regenerative program, resulting in a fully functional replacement. Sometimes there are complications and the result is a bifurcated tail that can have negative consequences for the lizard. On 27 July 2019 at about 1000 h we found an adult male yellow-headed gecko with a bifurcated tail at Gandoca-Manzanillo Wildlife Refuge, Limón, Costa Rica. The last portion of its right side tail had a small rod apparently regenerated, but its seems difficult to determine if any of the bifurcated tails is product of regeneration. An individual without the white tip of the tail could have more difficulties to show up and defend its territory. We discuss this case based on similar cases found elsewhere.

Key words: appendage loss, autotomy, regeneration, reptiles, Spherodactylidae.

Introduction

Appendage regeneration in reptiles is usually restricted to the replacement of the tail, basically in lizards that can self-amputate the tail as a defensive behavior (Clause and Capaldi, 2006; Cortada, *et al*., 2017). In fact, autotomy is one of the most spectacular escape mechanisms in lizards, follow by subsequent regeneration (Pianka and Vitt, 2003). In response to a predatory presence or attack, the lizard voluntarily detached the tail at a specific fracture plane in vertebrae (Pelegrin and Muniz Leão, 2016). The lizard releases its tail by means of powerful muscle contractions (Vitt and Caldwell, 2014), and it immediately begin to thrash violently supported metabolically by anaerobic respiration, and it continues to thrash for extended time periods (Pianka and Vitt, 2003). The shed tail distracts the predator from any further attack and provide the individual with time to flee to safety (Arnold, 1988), leaving it holding a thrashing and expendable body part (Vitt and Caldwell, 2014). However, one of the most important steps following a successful autotomous escape is the regeneration of the tail (Clause and Capaldi, 2006). Tail loss initiates a spontaneous epimorphic regenerative program, resulting in a fully functional, although structurally non-identical replacement (Gilbert, *et al.,* 2013). Regenerated tails can be smaller, similar to, or larger than original tails (Vitt and Caldwell, 2014). Caudal autotomy is a mechanism that has been reported for 13 lizard families, although it can be absent in certain species (Bateman and Fleming, 2009).

Generally, the new tail replaces the autotomized tail, although sometimes there are complications (Hoefer and Robinson, 2020). There are many reports of bifurcated tails in lizards, with some recent reports by García-Vinalay (2017); Kolenda, *et al.,* (2017); Koleska, *et al.,* (2017); Maria and Al-Razi (2018); Ramadanović and Zimić (2019); Arango-Lozano and Patiño-Siro (2020); and Hoefer and Robinson (2020). There are even occasional cases of trifurcation or

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more (Hoefer and Robinson, 2020). Tail bifurcation is considered to be a frequent malformation among lizards and is recorded in several families (Koleska *et al*., 2017). Tails are useful for prehensility, counter balance, and distract predators (Pianka and Vitt, 2003). As a result, malformed tails could have negative consequences.

One of the groups of lizards with high capacity for autotomy are the geckos (Pianka and Vitt, 2003). The infraorder Gekkota includes Sphaerodactylidae, a highly diversified family with some 216 diurnal species (Leenders, 2019). There are six species of Sphaerodactylidae in Costa Rica (Leenders, 2019). Savage (2002) pointed out that these geckos are very small and difficult to distinguish between them, except the yellow-headed gecko *Gonatodes albogularis* (Duméril and Bibron, 1836). This is a diurnal and arboreal species with bright orange head, blackish to gray brown bodies with bluish lateral spots, a conspicuous blue line on the white supralabials, and a white tail tip (Savage, 2002). This gecko measures up to 113 mm total length with no sexual dimorphism in size; the moderate tail represents 50 to 58% of total length (Savage, 2002).

Yellow-headed gecko is a common lowland lizard found from southern Mexico and Central America to northern South America, from 2 up to 1,000 m elevation (Leenders, 2019). It was introduced to Florida and also occurs on adjacent islands of Colombia and western Venezuela, and Cuba, Jamaica, Grand Cayman, and Hispaniola (Savage, 2002). This lizard is often seen on palms, strangler figs, or other trees with deeply creviced bark (Leenders, 2019), but also in pastures, roadside fences, fallen logs, trash piles, and human-made structures (Savage, 2002).

Materials and methods

During a field trip to the Caribbean lowlands of Costa Rica we visited the Gandoca-Manzanillo Wildlife Refuge, Manzanillo sector in the Limón province on 26-28 July 2019. This refuge was created in 1985 and it encompasses both marine areas (4,436 ha) and coastal terrestrial areas (5,013 ha) with several residential areas designated for conservation in Talamanca County (Boza, 1988). Forest of Gandoca-Manzanillo is classified as a humid tropical rainforest, but the refuge encompasses several rare habitats like a lowland rainforest, a wetland of 400 ha with dense forest of Orey (*Campnosperma panamensis*) and Yolillo (*Raphia taedigera*), a mangrove swamp (mainly *Rhizophora mangle*), an area of 300 ha of Cativo (*Prioria copaifera*), a precious wood, and coral reefs (Boza, 1988). We walked the main trail of the refuge in the morning, afternoon and night on 27 July searching for amphibians and reptiles. We photographed every individual spotted without any other disturb and continued the hike.

Results

On 27 July 2019 at about 1000 h we found an adult male yellow-headed gecko with a bifurcated tail. The last portion of its right side tail had a small rod apparently regenerated, but its seems difficult to determine if any of the bifurcated tails is product of regeneration (Figure 1). However, the white final section of the tail is not well defined, the tip of the tail is not markedly white as in normal-tailed individuals. This gecko was at the base of the trunk of a big beach almond (*Terminalia catappa*) on the trail near the entrance of the refuge (9°38'15″N, 82°39'02″W). This introduced tree species is highly abundant in this area of the refuge. Yellow-headed gecko is very common in the area, and usually individuals are observed moving in low vegetation, especially on the trunks of large trees. We found 16 adult yellow-headed geckos (9 males and 7 females) that morning from the entrance of the refuge to the outlook point, a transect of about 500 m long and 10 m wide. None of all other observed individuals exhibited tail anomalies.

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Figure 1. A yellow-headed gecko (*Gonatodes albogularis*) with a bifurcated tail, note the regenerated section of the right tail. Gandoca-Manzanillo Wildlife Refuge, Limón, Costa Rica. Photo by José M. Mora

Discussion

Autotomy in the form of tail shedding is one of the most remarkable features of many lizards (Gordeev, *et al.,* 2020). Moreover, many species are able to regenerate the tail after self-amputation (Cortada *et al*., 2017). However, sometimes the new tail is malformed and this could have some negative consequences for the lizard. Loss of tails by lizards has potential energetic, social, and survival costs, and some individuals could suffer reduced social status, reduced mating success, and long term effects including reduced home range size and reduced access to females (Vitt and Caldwell, 2014). Sometimes the tail breaks but it still attached to the body, leading to a regenerated tail with two or even more tips (Pheasey, *et al.,* 2014). Tail bifurcation has been reported for many lizard families including geckos of Sphaerodactylidae (Montes-Gavilán, *et al*., 2018). Tail malformations in lizards, such as supernumerary tails, are usually associated with regeneration failures, a result of a previous injury as opposed to congenital malformations (Conzendey, *et al*., 2013; Koleska *et al*., 2017). An individual with multiple tails could reduce its fitness because the tail plays an important role in locomotion and can affect such activities as foraging, mating, and the ability to escape from predators (Passos, *et al.,* 2014).

Yellow-headed gecko occurs in greatest densities throughout the lowlands of its distribution range (Fitch, 1973 a). Adult males are territorial and chase smaller males away from a defended area, and spacing by an aggressive display in which they lower the tail directly forward over the back and wave it up and down in a jerky motion that emphasizes the white tail tip (Fitch, 1973 b). They also raise the body, lower the head, and twitch the head laterally. If these behaviors do not discourage an intruding male, the resident male may rush toward the opponent, striking him and trying to bite him (Savage, 2002). An individual without the white tip of the tail could have more difficulties to show up and defend its territory. Males with abnormal tails would have to go directly to chase and even bite other males because they have to skip the showing of the white tip of the tail as part of the territorial behavior sequence. Large trees such as figs (*Ficus* spp.) often have sizable colonies of ten to thirty or forty individual yellow-headed geckos (Fitch, 1973 a). As a result, the competence for space and other resources should be high, and a gecko with a bifurcated tail could be in disadvantage.

Tail loss costs have been evaluated in lizards regarding regrowth of single tails, however, no studies are available in literature about the costs of abnormal tail regeneration (Pelegrin and Muniz Leão, 2016). As a result, potential negative effects of multiple tails in lizards still remain unknown (Hoefer and Robinson, 2020). Also, despite being widespread, knowledge on frequency of tail bifurcation is still scarce (Kolenda, *et al.,* 2017).

Acknowledgements

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Jordan Journal of Natural History, 8 (2), 2021 Pages 126-131

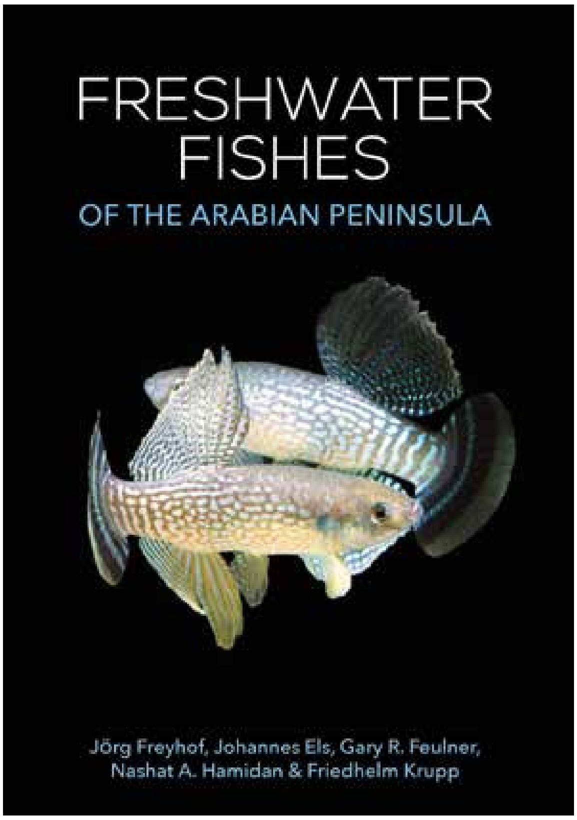
Book Review

The Freshwater Fishes of the Arabian Peninsula. Publishers. Dubai Motivate Media Group. 272 pp.

Freyhof, J., Els, J., Feulner, G.R., Hamidan, N.A., and Krupp, F. 2020.

Welcome to the world of fish biology (ichthyology), ecology and conservation (Lagler *et al*., 1962; Wootton, 1990). This book, first published in 2020, provides an up-to-date account of all the freshwater fish that have so far been recorded from across the Arabian Peninsula (AP) since records began. The project area (3.2 million km^2) includes at least seven different countries as well as a number of offshore islands within the Red Sea. Although the marine fish fauna of the AP is relatively well-known (Klausewtz, 1989; Gladstone *et al*., 2003) currently, there are few if any general books available which describe the freshwater fish present across the peninsula and how to identify them in better ways. However, where present, fish make an important contribution to the fauna of a region and deserve consideration in **biodiversity** and conservation assessments, post Rio (1992) (Abu-Zinada *et al*., 1989; Thouless, 1991).

Reasons for this apparent lack of information are complex, but probably include a general unfamiliarity with freshwaters across the AP and limited access to some of the more remote areas where such sites occur. There is also little general interest in sport fishing (angling) across the region, a factor which elsewhere can often drive interest in fisheries ecology and welfare. Previously, information of freshwater fish has largely been confined to technical journals unavailable to the general reader (Banister and Clarke 1977; Krupp, 1983; Hamidan and Shobrak, 2019). Thus, the main **aim** of this book is to develop a general interest in the theory and practice of fish biology and generate a greater appreciation and pride in the native fish fauna of the region and its '**natural heritage'** (page 18). The book was written by five main authors all well-known to science and experts in the fields of taxonomy and ecology, although many other people (fully acknowledged in the text) have contributed to the book especially in the production of the **distribution maps**.



In the distant geological past (ca. 100 million years), much of the region of the AP was covered by a network of river channels. Today most surviving freshwaters are largely confined to isolated wadis, mountain streams, lowland wetlands, and small reservoirs some of which continue to contain fish populations. Unfortunately, due to their isolation and small population size, many species have become threatened (endemic) with extinction due to a loss of habitat, reduced genetic diversity, limited 'connectance', high temperatures, seasonal drought, and climate change. Nevertheless, where present, fish play an important role in the ecology (structure and function) of freshwaters (Odum, 1959) even though they are rarely exploited for food or sport. Much of the book is designed to provide easily accessible identification keys for all those fish represented in the fauna (e.g., Maitland, 2004). Each fish species is illustrated in colour and is supported by distribution maps which help identify the local 'hotspots' of diversity and or endemism (Vitule, *et al.*, 2019).

The general structure of the book follows the regular format often used in similar guides (Lowe-McConnell, 1987; Maitland and Campbell, 1992; Skelton 1993; Davies *et al.*, 2004). It also includes an assessment of the conservation status of each of the species described (Jézéquel *et al.*, 2020). These **unique** assessments are based on criteria developed by the International Union for the Conservation of Nature (IUCN) situated in Switzerland, which is a respected non-governmental organisation (NGO formed in 1964) noted for the production of Red Data lists (de Nie, 1996) of threatened species. These lists (http:www.iucnredlist.org) can be used for the development of Management Plans for Species and Habitats throughout the world (Action Plans). Until recently (2004) however, fish were often excluded from such assessments due to a lack of affinity for this taxonomic group (amongst conservation agencies) and the difficulties of selecting suitable candidate species (charismatic 'flagship species') for funding initiatives. Happily, such disparities have now been overcome by the formation of a Fish Specialist Group within the IUCN which now actively promotes the status of fish throughout the world (e.g., Kottelat and Freyhof, 2007).

The book is divided into four main sections. Section One describes the methods used to sample fish in the field and the best ways of preserving them for later analysis in the laboratory. This also includes the collection and storage of DNA samples although no further details of molecular analyses are given (Carvalho and Pitcher, 1996). The introduction is followed by a description of the anatomy of fish and the main characters used in their identification. These include fin-ray counts and scale counts. This is followed by a brief review of the principles and protocols of fish taxonomy and systematics.

Section Two provides a review of the main theories which underpin the science of fish biology and the increasing importance of conservation. This includes a review of the geological history and plate tectonics of the region, and their collective role in shaping the origins and subsequent developments of the fish fauna, as well as the formation of the Red Sea. This review is particularly useful for readers unfamiliar with the region as many of the processes include species gains and losses from or to regions outside the AP including the 'mysterious' Levant to the north (Krupp and Schneider, 1989). Section Two concludes with a 'preliminary' assessment of the conservation status of each fish represented in the fauna (Table 1, page 100). This shows that approximately 50% of the fish fauna is currently directly threatened in a way that is sometimes linked to lack of data (being data deficient).

Most of the remaining sections (Three and Four) are given over to a detailed description of all the fish species represented in the fauna, sorted according to their assumed origins. Out of the total number of the forty-one species listed, thirty-one are conserved to be native. The remaining ten species are all thought to have been introduced to control disease vectors or in a few cases as a source of food. Non-native species can often pose serious threats to native species through competition (Copp and Fox, 2020). Collectively, the fish fauna consists of an eclectic mix of species and families probably caused by the turbulent history of colonisation and extinctions as explained above. Eleven different families are represented in the fauna; seven as natives and the other four as aliens or non-natives (See FishBase for listings of Fish Families).

Of all the fish families represented, the cyprinids (Cyprinidae) are the most diverse. Twenty different species are listed (Appendix 1, page 254) and include three species of Lotak (Genus Cyprinion), five species of

Barb and thirteen species of the Genus *Garra*. Barbs are often noted for increased sets of chromosomes or polyploidy. The Garra Genus is a complex group of fish widely distributed across the region and is highly adapted to the arid and unpredictable conditions found across the AP. Some have a 'mental' disc (Hashemzadeh-Segherloo, *et al*., 2017) under their lower jaw which provides attachment to the substrate. These fish often have extended breeding seasons which enable them to vary their spawning times to match the unpredictable nature of the seasons, an essential component of their life-history strategy. However, their taxonomy is complex and largely unresolved (see FishBase). The remaining families in the non-native fish group are the Anguillidae (two species), Leuciscidae (one species), Mugilidae (three species), Gobiidae (two species), Terapontidae (one species), and the Aphaniidae (three species of Killifish). The Killifish are perhaps the most well-known because they are often exhibited in commercial aquaria because of their unusual behaviours, bright colouration and sexual dimorphism (illustrated on the front cover of the book).

Fish within the non-native group include the cichlids Cichlidae (three species), Clariidae (one species), Loricariidae (one species) and the Poeciliidae (five species). The book concludes with a glossary of technical terms, a bibliography with 128 references, and an index.

In conclusion,

This book ticks most of the **aims** listed in the general introduction to the project. It provides an excellent overview of the science of fish biology and its relevance to the conservation and management of freshwater fish. Although currently, only forty-one species of fish occur across the AP, the book makes an important and **timely** contribution to the fauna of the region and its biodiversity. The authors are to be congratulated on the enormity of the project and their ability to establish cooperation amongst the various conservation agencies across the region. The book is richly illustrated and easy to read. It makes an excellent teaching resource with examples illustrating the complexities of **biogeography** and conservation.

In some ways however, the project remains incomplete as little information is presented on proposals for future research and the **management** of those sites which are found to be high in species diversity and endemism. Although much progress has been made in the research on some individual species (Ahmad *et al*., 2013; Borkenhagen, 2014; Alharthi 2020; Keivany *et al*., 2015; Abedi *et al*., 2011), there is an urgent need to revisit many of the sites listed to establish the current presence or absence of individual species and to better describe their status in terms of population numbers, disease profiles and **life-history traits** (Blanke *et al*., 2007; Mims *et al*., 2010). Without quantitative data of this kind, it is impossible to carry out long-term population viability analyses (PVAs) and make predictions about their ability to respond effectively to the future challenges posed by climate change and non-native species to name but two (Shuter and Post, 1990; Yamamoto *et al*., 2007). Long-term management over such large areas will obviously present significant logistical and political challenges.

Whilst the book provides essential reading for anyone considering a career in fish biology or conservation, many details in the book can also be useful for general consumption by colleges, schools, and interested naturalists. Fish are increasingly used as tools for a better understanding of the mechanisms by which species respond to changes in their environment through natural selection (Skelton, 1993). Such adaptations often involve variations in reproduction, behaviour, physiology, and genetic composition. Common examples are often drawn from tropical species including cichlids (mouth-brooders) and barbs (species flocks) where selection pressures can be particularly acute (Lévêque, C. 1997; de-Graaf, 2003; Skelton, 1993; Hauser *et al*., 2005). Similar extreme pressures undoubtedly occur across the AP region and await further description and analysis with respect to fish.

Therefore, we look forward to the second edition of the book which is likely to include several additional fish species identified through the application of more rigorous molecular screening techniques and further information on **management** schedules proposed for those regions which particularly have high levels of species richness and or endemism. In some cases, however, it may be necessary to develop Ex-Situ breeding programmes for critically endangered species using facilities as described in the United Arab Emirates (page 102) (e.g., McGregor-Reid 1995). Sadly, some of the most diverse regions are also located in politically sensitive areas of the world. This is where science can help to promote better understanding and communication through collaborative research projects.

In the second edition, one would also expect to see some reference to the risks of working in such remote areas of the world (risk assessment) and some tweaking of the index which in this edition rarely directs the reader to the correct page! On a positive note, it is wonderful to see that there are still areas of the world worthy of further exploration and discovery especially for younger members of the research community (e.g., McGregor-Reid, 1995).

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www.iucn.org/commissions/ssc-groups/fishes/freshwater-fish

https://www.unep-wcmc.org/about-us World Conservation Monitoring Centre Cambridge.

By: Chris Goldspink
The author (with hat) visiting one of the last artisanal pearl fisheries in the southern Red Sea, Saudi Arabia.

Abdulkader M. Abed (1943-2021)

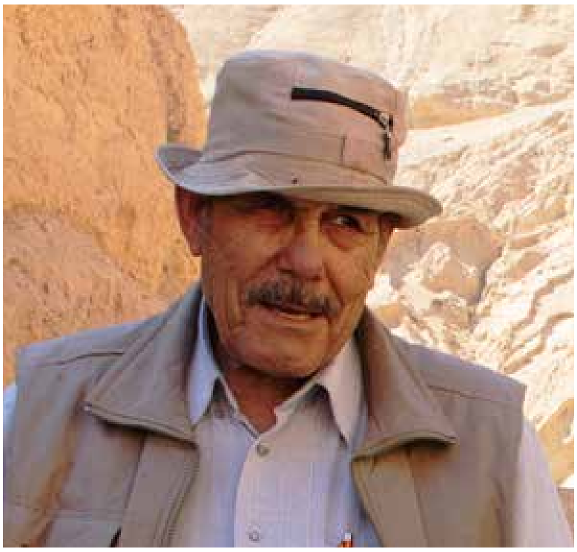
It is with great regret, all those involved with the Journal, as represented by its Editorial, Associate, and International Boards, were saddened by the news of Professor Abdulkader Abed death on the morning of 8th August 2021. He was one of the early founders of the Jordan Journal of Natural History and effectively contributed to its advancement.

Born in 1943, Abed grew up in Hatta village in Palestine, moving with his family to Jordan, where he finished his elementary and preparatory degree in Al Karameh (northern Jordan) in 1958, then the general school certificate in 1960.

His passion for geology started very early in his life when he used to collect oil shale rocks and wondered how they can give fire. He joined Damascus University in 1960 to study geology, he was one of the excellent students with high rank, he graduated in 1964, then joined Southampton University in the UK, to study Sedimentology and Sedimentary Geochemistry, and completed his PhD by the summer of 1972. At that time, he made his journey back to Jordan from the United Kingdom by train to enjoy the different eras of geological formations along his way back through Europe, Turkey, Syria then Jordan.

In 1974, he secured a place at King Abdulaziz University, in Jeddah / Saudi Arabia as an Assistant Professor. At that time Prof. Abed explored the basalt lava of the Medina, and engaged in teaching for 2 years, to move afterwards to the University of Jordan and established with his colleagues the Department of Geology. In this department, he built his academic advancement, engaged in teaching, supervising students, and sometimes chairing the department.

While he was teaching at the University, Abed started to explore the geology of Jordan, inspired by the knowledge gained from his PhD. Abed was enthusiastic about geology and was looking forward to empowering geologists in exploring the treasures of Jordan, water harvesting planning, infrastructures, education, and much more.



As a teacher, he was well known for his exceptional capabilities in transferring knowledge to his students, which he did with a delightful and passionate spirit that conveyed his own love of geology, geomorphology, and astronomy. He even was an active member in Jordanian Academy of Arabic being an excellent Arabic scholar, which allowed him to transfer a lot of knowledge in a simplified pure Arabic language “Fusha”. He never accepted to finish the basic geology course without having his students on the course field trip, where they enjoyed the practical knowledge and Abed’s distinguished companionship.

Professor Abed supported RSCN over many years. His involvement continued to the end of his life. He devoted much of his time to identify the geology of protected areas, preparing the designation file of Mujib Biosphere Reserve to be a global UNESCO Geopark, and helping jointly with his colleague Prof. Al Eisawi (1946-2020) in organising and supervising the annual scientific conference of RSCN.

His scientific legacy exceeded 150 publications and over 20 books including a Geology of Jordan, and a summary of the geology of Jordan jointly prepared with RSCN one year before his death. His last published book is: *The sky doom speaks Arabic* published in Arabic after his death.

In his academic life; he supervised many

Prof. Abed exploring a land crack in the Hammad Deseret in Ruwaished, at the southeastern border.

Masters and PhD students and build their capacities in many fields of geology. Some of them became professors in the geology department at Jordan University.

Professor Abed is well-known to international and highly esteemed geological associations such as Mineralogical Society (London, 1978), Society of Economic Paleontologists and Mineralogists (SEPM) 1981, International Association of Sedimentologists (IAS) 1985, Jordanian Geologists Association, Arab Geologists Association 1976, and Islamic Crescents' Observation Project 1998.

The family of the Jordan Journal of Natural History sends its deepest condolences to Professor Abed's family for their loss. Professor Abed will never be forgotten by his colleagues, his students, and the scientific community. We will treasure our memories of him and he will stay connected to our hearts forever.

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