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HOST RANGE AND HOST PREFERENCE OF CUSCUTA SPECIES (CONVOLVULACEAE) IN KARAK, KOHAT AND BANNU DISTRICTS, KHYBER PAKHTUNKHWA, PAKISTAN

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Abstract

Cuscuta is a genus of parasitic plants that negatively impact crops and valuable timber trees. Ecological surveys are needed to improve our understanding of the *Cuscuta*-host relationships and to monitor such losses. In this study, Karak, Kohat and Bannu districts of Khyber Pakhtunkhwa province of Pakistan were explored to determine the host range and host preferences of *Cuscuta* species. Two species, *C. campestris* Yunck. and *C. reflexa* Roxb. were documented. *Cuscuta campestris* was found parasitic on 12 plant species representing 12 genera and nine families, while, *C. reflexa* was found parasitic on 11 plant species representing 10 genera and nine families. Both species are generalist species with Shannon Weiner Index values of 1.42 for *C. reflexa* and 2.22 for *C. campestris*. Rhamnaceae was the preferred host family for *C. reflexa* while Asteraceae had the highest number of host species for *C. campestris.* It is inferred that the two *Cuscuta* species have a diverse host range with little host overlap, clearly exhibiting taxonomic resource partitioning to minimize interspecies competition when they occur in sympatry.

Key words: *Cuscuta,* Convolvulaceae, Host range, Holo-parasite, Crops, Timber trees, Weeds.

Introduction

Parasitic angiosperms have evolved independently 12 times and comprise ca. 4750 species in 292 genera from 31 families (Nickrent, 2020; 2022). Parasitic plants can be "generalists" when parasitizing a wide range of unrelated hosts, or "specialists", sometimes utilizing a single host species (Sultan *et al*., 2018; Costea *et al*., 2020; García *et al*., 2018; Costea and Stefanović, 2009). Parasitic plants significantly impact the natural plant communities they inhabit, mainly due to the effect they exert on their hosts (Albert *et al*., 2008).

Cuscuta (Convolvulaceae; dodder) is a sub-cosmopolitan genus comprising over 200 species (Costea *et al*., 2015), with highest species diversity in the New World from Canada southwards to Chile (Yuncker, 1932; Stefanović *et al*., 2007). *Cuscuta* species commonly known as dodder, are obligate stem holoparasites (Kaiser, 2015) and some of them are among the most common invasive parasitic plants in the world (Riches and Parker, 1995; Costea and Tardif, 2006). Some *Cuscuta* species have important medicinal and pharmacological value, while others are a threat to natural ecosystems and agricultural crops (Riches & Parker, 1995; Jayasinghe *et al*., 2004). Pharmacological studies and traditional uses of these plants have showed that *Cuscuta* spp. are effective antibacterial, antioxidant, antiostioporotic, hepatoprotective, anti-inflammatory, antitumor, antipyretic, antihypertensive, analgesic and anti-hair fall agents (Noureen *et al*., 2019).

Cuscuta spp. possess rudimentary roots (Behdarvandi *et al*., 2015), reduced leaves and the vegetative portion is represented only by stems (Kuijt 1969; Albert *et al*., 2008). Physical and physiological connection between *Cuscuta* and the host is established by means of specialized organs, called haustoria, which connect the vascular tissues of parasite and host enabling withdrawal of water, carbohydrates and other solutes (Dawson *et al*., 1994; Albert *et al*., 2008). *Cuscuta* species typically exhibit broad host ranges and inflict serious damage to many crops, including forage legumes (alfalfa, clover, lespedeza), potato, carrot, sugar beets, chickpea, onion, cranberry, blueberry, and citrus (Riches & Parker, 1995; Dawson *et al*., 1994). Besides the reduction of yield in crops, native species play an important role in natural ecosystems where they contribute to the ecological equilibrium and diversity of plant communities (Press & Phoenix, 2005). *Cuscuta* species can also transmit a variety of viruses and mycoplasma-like organisms from diseased to healthy plants. Some viruses that were transmitted to plants by insect vectors may be retained by these parasites. Host weeds of dodder play a role as a virus-maintaining reservoir in both cases (Toth *et al*., 2006). Furthermore, *Cuscuta* spp. have emerged as one of the most significant constraints to crop yield in many regions of the world (Riches & Parker, 1995; Farah & Al-Abdulsalam, 2004; Costea & Tardif, 2006). For example, field dodder infestation lowered tomato yield by 50% to 75% (Lanini, 2004), and carrot yield by 70% to 90% (Bewick *et al*., 1988). Toth *et al*., (2006) reported that *C. campestris* infection reduced sugar beet weight from 21.6% to 37.4%, and sugar content from 12.0% to 15.2%.

Hosts of *Cuscuta* are numerous and belong to diverse families of Angiosperms (e.g., Gaertner, 1950; Costea & Tardif, 2006; Barath & Csiky, 2012). In Pakistan, 14

Cuscuta species have been reported (Rajput & Tahir, 1988). However, the *Cuscuta*-host studies have received little attention. Therefore, the current study aims at exploring the host range and host preferences of *Cuscuta* spp. in three districts of Khyber Pakhtunkhwa.

Material and Methods

Study area: This study was conducted in the plains of the three southern districts of Khyber Pakhtunkhwa Province: Karak, Kohat and Bannu. District Karak lies at latitude 33° 6' 37" N and longitude 71° 5' 29" E and at average elevation of 548 m. District Kohat lies at latitude 33° 35' 20" N and longitude 71° 26' 34" E and at average altitude of 488 m, while district Bannu lies at latitude 32° 54' 3" N and longitude 70° 38' 43" and at average altitude of 378 m. (Fig. 1).

Climate and vegetation of the study area: The annual mean and maximum temperatures, humidity and rain fall of the three districts (sourced from Agricultural Research Stations in the respective districts) is illustrated in Fig. 2. The climatic data indicate that Karak and Bannu were relatively hotter and more humid during the study period. The climate of Kohat, Karak and Bannu districts can be characterized as sub-tropical. The common vegetation of the study area comprises *Vachellia nilotica, Prosopis juliflora, Senegalia modesta, Olea ferruginea, Dodonea viscosa, Sideroxylon muscatense, Ziziphus spina-christi, Z. nummularia, Capparis decidua, Dalbergia sissoo* and *Cymbopogon jwarancusa*. *Salvadora oleoidies* and *Nannorrhops ritchieana* are found in Bannu and parts of Karak in extreme southern zone.

Exploratory surveys and plants collection: Different sites in all three districts were periodically visited during 2019-2020 (Table 1). Different areas were thoroughly surveyed for the presence of *Cuscuta* species, and at each site all the host-dodder combinations were carefully recorded, and herbarium specimens of *Cuscuta* species were collected along with their hosts.

Plant identification: *Cuscuta* species and their hosts were identified with the help of different volumes of Flora of Pakistan and were cross matched with herbarium specimens at National Herbarium of Pakistan (Stewart Collection) at National Agricultural Research Centre, Islamabad. An attempt was made to collect all the host plants during their flowering season. Herbarium vouchers were deposited at National Herbarium (RAW), Plant Genetic Resources Institute, National Agricultural Research Centre, Islamabad and Department of Botanical and Environmental Sciences, Kohat University of Science and Technology, Kohat.

Statistical analysis

Shannon Weiner Index was calculated to infer the relative host diversity and degree of host specialization of each *Cuscuta* species (Norton & de Lange, 1999).

Results and Discussion

Two *Cuscuta* species were recorded in the study area, *C. campestris* and *C. reflexa* (Figs. 3 and 4). *C. campestris* was found to be parasitic on a total of 12 plant species from 12 genera in nine families (Table 4), while, *C. reflexa* was found to be parasitic on a total of 11 plant species from 10 genera in nine families in the study area (Table 5). *C. reflexa* has a Shannon-Wiener index value of 1.43 and *C. campestris* has a Shannon-Wiener index value of 2.22. Both *Cuscuta* species are generalist species, however, *C. campestris* had a relatively wider host range in the study area compared to *C. reflexa*. *C. campestris*, has an almost worldwide distribution and has a wide host spectrum (Kaiser *et al*., 2015).

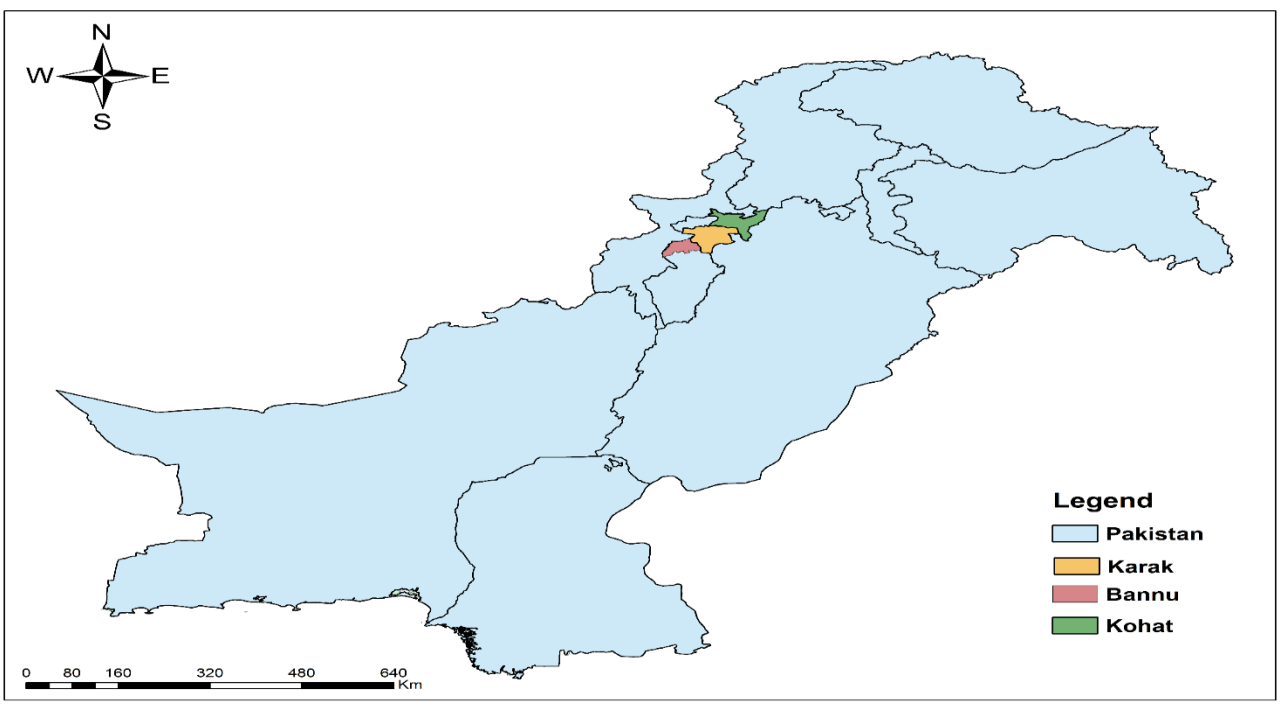

Fig. 1. Map of the study area.

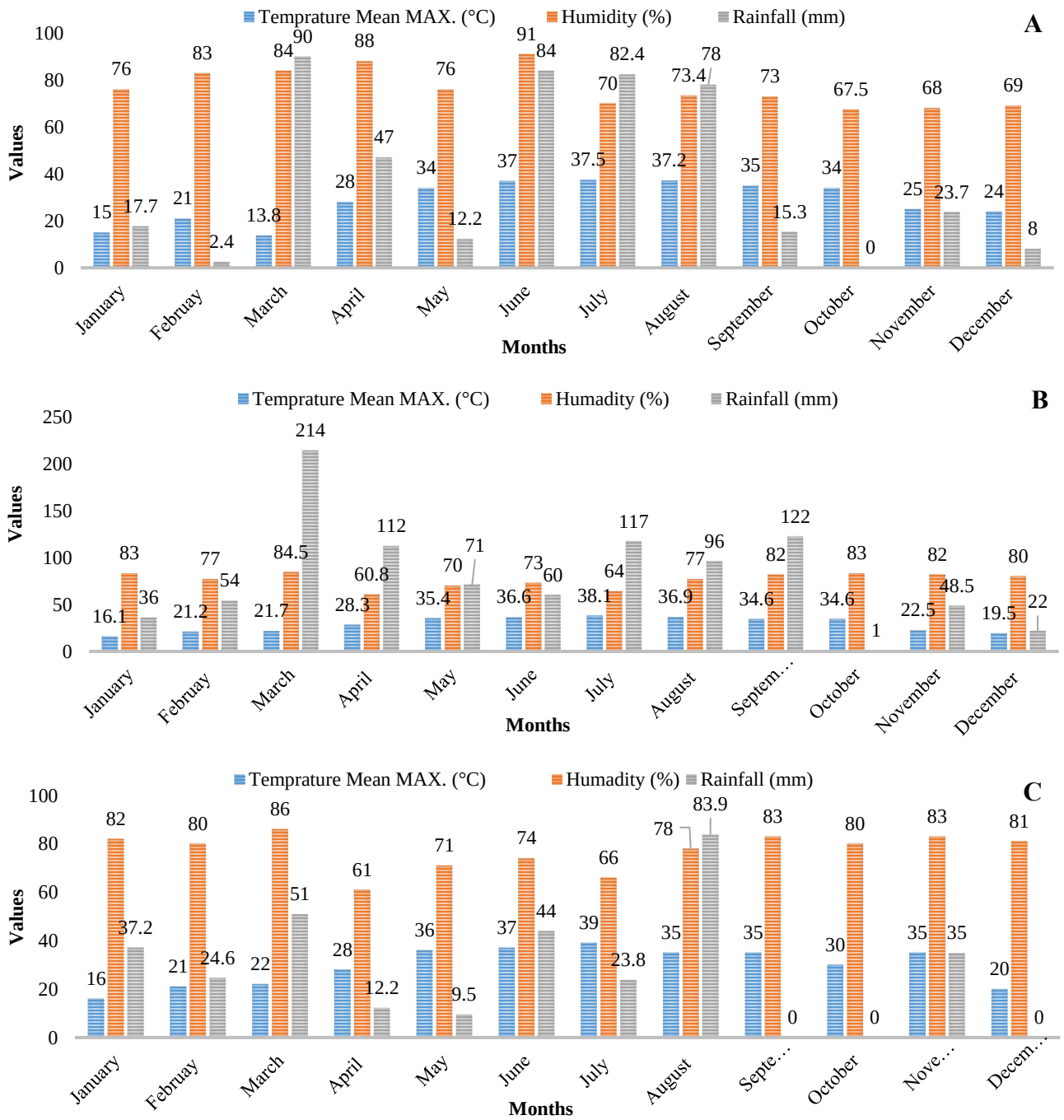

Fig. 2. Climatic data of the study area: A. Karak, B. Kohat, C. Bannu.

Table 1. Study sites, their GPS coordinates and altitude.

Locality	Tehsil	District	Coordinates	Altitude
Jandu Khel Wazir	Bannu	Bannu	32.59246/70.40713	336 m
Mahmand Khel Wazir	Baka Khel Wazir	Bannu	32.04602/70.66361	390 m
University of Science and Technology, Bannu	Domel Wazir	Bannu	32.02842/70.70042	361 m
Central Jail Bannu	Domel Wazir	Bannu	32.01327/70.71162	357 m
Shah Qaiser Banda	Takht-e-Nasrati	Karak	33.11532/71.08918	578 m
Ghundi Killa	Takht-e-Nasrati	Karak	33.04034/71.02242	474 m
Ahmad Wala	Takht-e-Nasrati	Karak	33.06457/71.03003	503 m
Sabir Abad	Karak	Karak	33.16591/71.31579	808 m
Karak Development Authority	Karak	Karak	33.12846/71.14258	652 m
Teri	Banda Daud Shah	Karak	33.29722/71.11528	621 m
Government Post Graduate College, Kohat	Kohat	Kohat	33.34259/71.28467	470 m

Key to *Cuscuta* species in Bannu, Karak and Kohat districts (adapted from Rajput & Tahir, 1988)

\+ Stems thick, succulent; flowers arranged in paniculate cymes (thyrses); infrastaminal scales reaching the middle of the corolla tube; style 1, thick, c. 0.5 mm long or obsolete; stigma conical; capsule, globose-conical, brown, not depressed, without an interstylar opening ..... *Cuscuta reflexa*

\- Stems thin; flowers in compact, glomerulate clusters, each with 2-8 flowers; infrastaminal scales slightly longer than the corolla tube; styles 2, linear; stigma rounded or capitate; capsule depressed-globose, membranous; with an interstylar opening ..... *Cuscuta campestris*

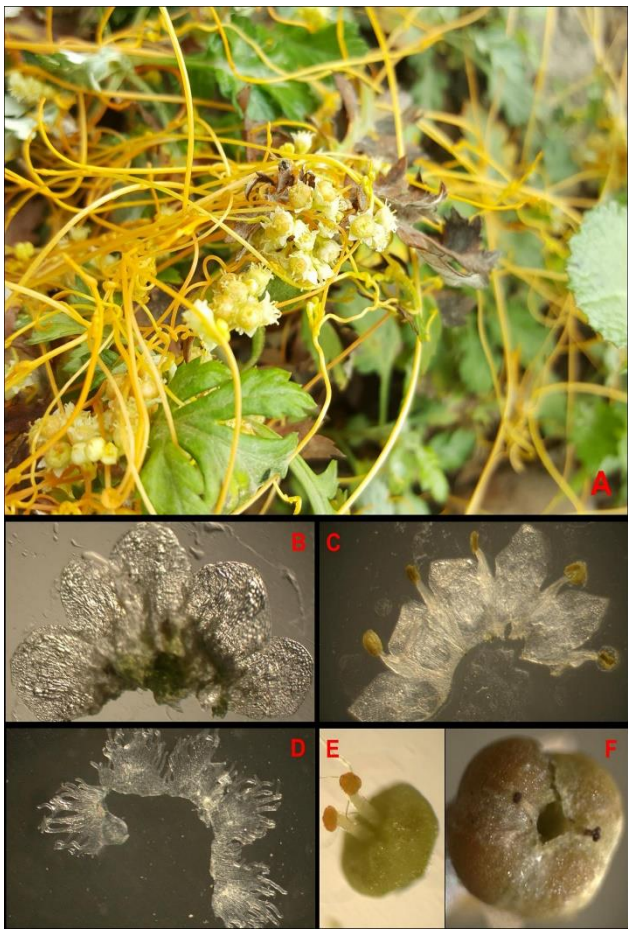

Fig. 3. *Cucuta campestris* A: habit, B: dissected calyx, C: opened corolla, D: infrastaminal scales removed from the corolla, E: gynoecium with two styles and capitate stigmas, F: fruit showing interstylar opening.

Fig. 4. *Cucuta reflexa* A: habit, B: flowers, C: developing fruits, D: dissected calyx, E: opened corolla showing infrastaminal scales, F: gynoecium with one reduced style and two conical stigmas.

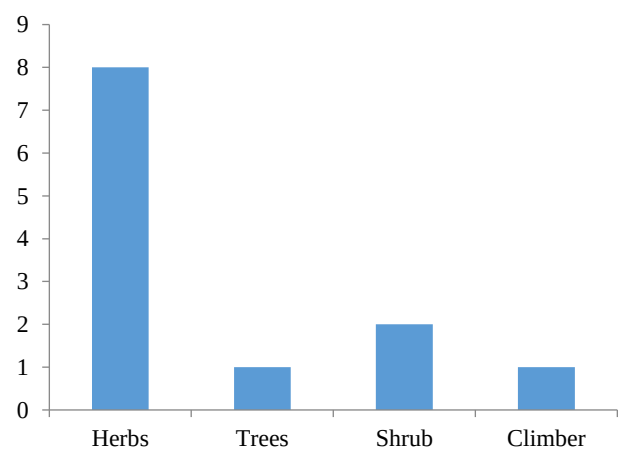

Fig. 5. Categories of host species infested by *Cuscuta campestris.*

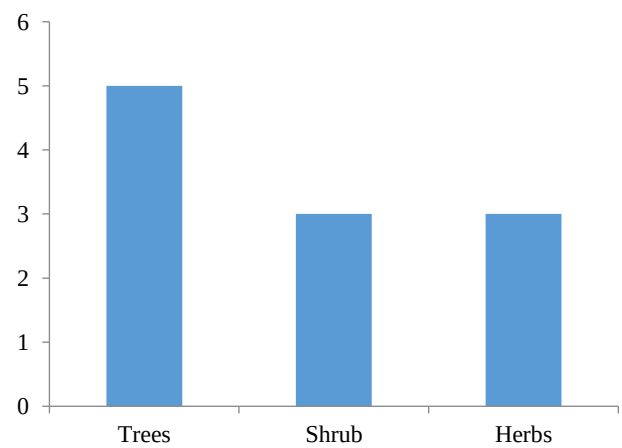

Fig. 6. Categories of host species infested by *Cuscuta reflexa.*

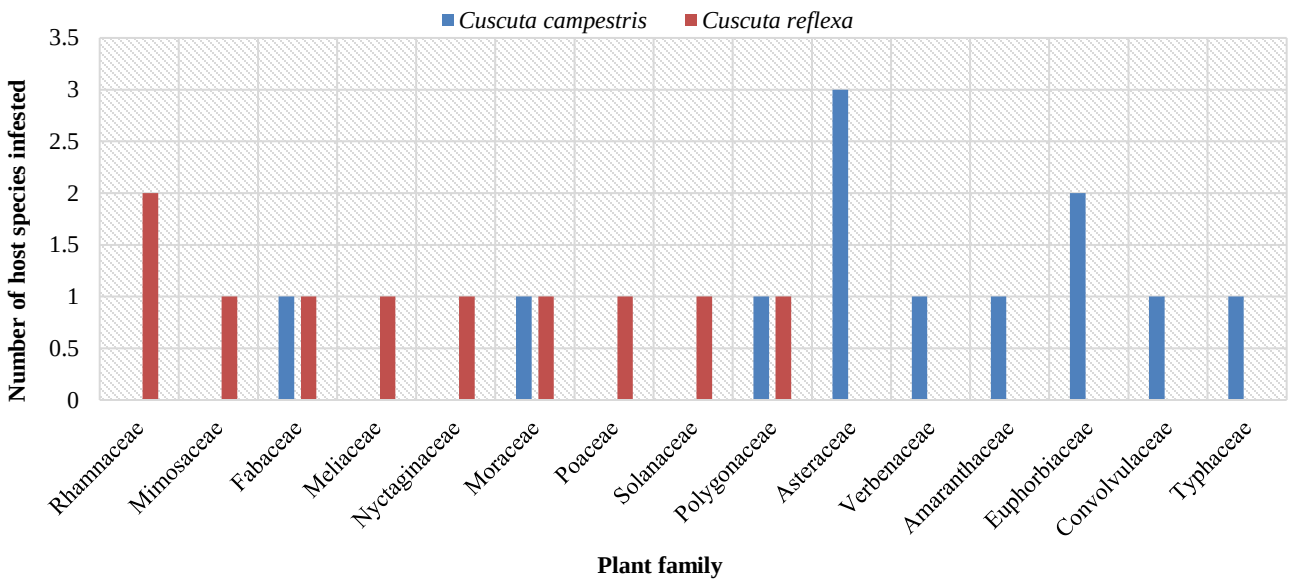

Fig. 7. Number of hosts species from different families infested by *Cuscuta campestris* and *Cuscuta reflexa*

The geographical distribution of parasitic flora is dependent on the availability and distribution of suitable host species (Sultan *et al*., 2018; García *et al*., 2018). According to Flora of Pakistan, *Cuscuta* is represented by 14 species (Rajput & Tahir, 1988) while an additional species, *Cuscuta pedicellata*, was reported more recently byMukhtar *et al*., (2012). However, the host range of *Cuscuta* spp. is not well-documented in Pakistan (Athar *et al*., 2007), therefore host range and host preferences of two *Cuscuta* species were investigated in different ecologies within the study area (Tables 1, 2 & 3).

No host overlap was observed between the two species. Although, *Cuscuta reflexa* is a generalist species, 74% of the total records were from *Ziziphus* hosts, but overall, 11 host taxa (10 genera in nine families) were recorded (Table 5; Fig. 7). Of the total *C. reflexa* hosts recorded, five were trees, two shrubs and two were herbaceous species (including one monocot) (Fig. 6). *Cuscuta campestris* is also a generalist species, parasitizing 12 taxa (twelve genera in nine families) (Table 4; Fig. 7). Asteraceae included the highest number of host species for *C. campestris*. Of the total *C. campestris* hosts recorded, 8 were herbs (including one monocot species), 2 shrubs, 1 climber, and 1was a tree species (Fig. 5). A total of 22 plants species belonging to 21 genera from 14 families and were observed as host plants for 2 *Cuscuta* species in Kohat, Karak and Bannu districts. Asteraceae accounted for the highest number of preferred hosts (showing high susceptibility) to dodder infestation in another study on host range and preferences of *C. campestris* in North America and Nigeria, respectively (Gaertner, 1950; Nwokocha & Aigbokhan, 2013). In the current study, hosts of *C. campestris* also comprised of mostly herbaceous plants (Fig. 5), while the hosts of *C. reflexa* were represented mostly by trees (Fig. 6). This may be explained by the thin, filiform stems of *C. campestris* compared to the thick and vigorous stems of *C. reflexa*, which has larger haustoria that are capable of penetrating the mechanical tissues of the woody hosts. The different host ranges may also be supported by the fact that *C. campestris* and *C. reflexa* belong to completely different subgeneric lineages, subgenus *Grammica* and *Monogynella*, respectively (Costea *et al*., 2015). Stems of the parasitic plant *Cuscuta subinclusa* were shown to discriminate among host species and invest in resource acquisition by selecting the host plant based on its quality (Kelly, 1990). Studies showed that *C. campestris* foraged and primarily parasitized the most rewarding hosts (Koch *et al*., 2004). Many species of parasitic plants have ability to parasitize different host plant species in a community. According to Iqbal *et al*., (2014) although *Cuscuta planiflora* parasitized berseem (*Trifolium*), 'ber' trees (*Ziziphus* spp.), canola and some native species in Pakistan, however its potential host range is considerably wider.

C. campestris is the most widely distributed dodder species globally and the most important *C.* species, attacking a wide range of species, including vegetables, forage legumes, ornamentals and only very rarely on woody plants (Costea and Tardif, 2006; Nwokocha and Aigbokhan, 2013). Besides the occurrence of *C. campestris* on ornamental species (e.g., *Chrysanthemum indicum, Duranta erecta*) in the current study, it has also been reported on chilli crops from Lahore (Mukhtar *et al*., 2011) and on berseem in Malka Hans area of Pakpattan district (RAW 102061). *Cuscuta reflexa* was recorded on important timber, fruit (jujube) and ornamental (*Bougainvillea*) species in the study area while there was a single occurrence on wheat in Mahmand Khel Wazir, Bannu.

A study on *Cuscuta* species conducted in the lowlands of Sri Lanka, found that the host range and host-parasite association of most populations were distributed in agricultural areas (mainly in the dry zone) along the irrigation channels, abandoned lands, roadside vegetations and adjacent to the cultivated fields (Jayasinghe *et al*., 2004). Occurrence of dodders along irrigation channels was suggestive of causing further infestation in agricultural fields, as irrigation channels are potentially a major dispersal source of dodders in dry zones (Jayasinghe *et al*., 2004). The occurrence of *C. campestris* on hydrophytes like *Typha* and *Persicaria* in the current study also suggests

that its seeds can be disseminated to cultivated fields by irrigation water (Costea & Tardif, 2006; Olszewski *et al*., 2020). *C. campestris* fruits float for a longer than the seeds and can be dispersed by water (Ho & Costea, 2018) while the seeds were also shown to be dispersed by waterfowl birds via endozoochory (Costea *et al*., 2016).

The susceptible weed hosts that sustained *C. campestris* growth until fruiting of the parasite were classified as the most preferred hosts (Nwokocha & Aigbokhan, 2013), thus their occurrence within and adjacent to the cultivated fields indicates that they can be used as alternate hosts during the off-season, as a consequence increasing the build-up of dodder seed bank. *Cuscuta* species can potentially disseminate plant pathogenic viruses to herbaceous hosts (Mikona & Jelkmann, 2010). *Cuscuta* infestations create limitation to wild life movement through their potential to shut off regions of bush with dense net like masses (Iqbal *et al*., 2014). The seed bank of *Cuscuta* species can be reduced through rotation with a non-host monocot crop for a long time period, moreover, as cool temperatures retard dodder spread, cautious timing of crop sowing can also reduce infestation levels (Dawson *et al*., 1994). The occurrence of *Cuscuta* on *Broussonetia papyrifera* and *Parthenium hysterophorus* in the current study is suggestive of their potential use as bio-control agents against these alien invasive species as suggested by Shen *et al*., (2011) in the case of *C. campestris* for *Mikania micrantha.*

Table 2. Locality wise occurrence of *Cuscuta campestris* on different hosts.

Locality	*Atriplex tatarica*	*Chrysanthemum indicum*	*Parthenium hysterophorus*	*Xanthium strumarium*	*Ipomoea cairica*	*Croton bonplandianus*	*Ricinus communis*	*Alhagi maurorum*	*Morus alba*	*Persicaria glabra*	*Typha latifolia*	*Duranta erecta**
Jando Khel Wazir, Bannu	+	−	−	−	−	+	−	+	−	+	+	−
Mahmand Khel Wazir, Bannu	−	−	−	−	−	−	−	−	−	−	−	−
University of Science & Technology, Bannu	−	+	−	−	−	−	−	−	−	−	−	+
Central Jail, Bannu	−	−	+	+	−	−	−	−	−	−	−	−
Shah Qaiser Banda, Karak	−	−	−	−	−	−	−	−	−	−	−	−
Ghundi Killa, Karak	−	−	−	−	−	−	−	−	−	−	−	−
Ahmad Wala, Karak	−	−	−	−	−	−	−	−	−	−	−	−
Sabir Abad, Karak	−	−	−	−	−	−	−	−	−	−	−	−
Karak Development Authority	−	−	−	−	−	−	−	−	−	−	−	−
Teri, Karak	−	−	−	+	−	−	−	−	−	−	−	−
Government Post Graduate College, Kohat	−	−	+	+	+	−	+	−	+	−	−	−

Table 3. Locality wise occurrence of *Cuscuta reflexa* on different hosts.

Locality	*Calotropis procera*	*Senegalia modesta*	*Vachellia nilotica*	*Melia azederach*	*Broussonetia papyrifera*	*Bougainvillea glabra*	*Triticum aestivum*	*Emex spinosa*	*Ziziphus spina-christi*	*Ziziphus nummularia*	*Withania somnifera*
Jando Khel Wazir, Bannu	−	−	+	−	−	−	+	+	+	−	+
Mahmand Khel Wazir, Bannu	−	−	−	+	+	+	−	−	−	−	−
University of Science &Technology, Bannu	−	−	−	−	−	−	−	−	−	−	−
Central Jail Bannu	−	−	−	−	−	−	−	−	−	−	−
Shah Qaiser Banda	−	−	+	−	−	−	−	−	+	−	−
Ghundi Killa, Karak	−	−	+	−	−	−	−	−	+	−	−
Ahmad Wala, Karak	+	−	−	−	−	−	−	−	−	+	−
Sabir Abad, Karak	−	−	−	−	−	−	−	−	+	−	−
Karak Development Authority	−	+	−	−	−	−	−	−	−	−	−
Teri, Karak	−	−	−	−	−	−	−	−	−	−	−
Government Post Graduate College, Kohat	−	−	−	−	−	−	−	−	−	−	−

Table 4. Hosts of *Cuscuta campestris* recorded in Kohat, Karak and Bannu districts, hosts followed by an asterisk are exotic hosts.

Family	*C. campestris* hosts	Frequency of occurrence on host	Herbarium vouchers
Amaranthaceae	*Atriplex tatarica*	3	RAW102083; RAW102084
Asteraceae	*Chrysanthemum indicum**	5	RAW102097
Asteraceae	*Parthenium hysterophorus**	4	RAW102079; RAW102080; RAW102081
Asteraceae	*Xanthium strumarium*	2	RAW102096
Convolvulaceae	*Ipomoea cairica*	1	RAW102089; RAW102090
Euphorbiaceae	*Croton bonplandianus*	4	RAW102088
Euphorbiaceae	*Ricinus communis*	1	RAW102092; RAW102093
Fabaceae	*Alhagi maurorum*	1	RAW102086; RAW102087
Moraceae	*Morus alba*	2	RAW102091
Polygonaceae	*Persicaria hydropiper*	8	RAW102082
Typhaceae	*Typha latifolia*	10	RAW102095
Verbenaceae	*Duranta erecta**	2	RAW102094
9 families	12 genera: 12 species		
Indigenous	9 genera: 9 species		
Exotic	3 genera: 3 species		

Table 5. Hosts of *Cuscuta relfexa* recorded in Kohat, Karak and Bannu districts, hosts followed by an asterisk are exotic hosts.

Family	*C. reflexa* hosts	Frequency of occurrence on host	Herbarium vouchers
Apocynaceae	*Calotropis procera*	1	
Fabaceae	*Senegalia modesta*	2	
Fabaceae	*Vachellia nilotica*	3	RAW101400; RAW101455
Meliaceae	*Melia azederach*	1	RAW101398
Moraceae	*Broussonetia papyrifera**	1	RAW101410
Nyctaginaceae	*Bougainvillea glabra**	1	RAW101547
Poaceae	*Triticum aestivum*	1	RAW101545
Polygonaceae	*Emex spinosa**	1	RAW101546
Rhamnaceae	*Ziziphus spina-christi*	26	RAW101454
Rhamnaceae	*Ziziphus nummularia*	6	
Solanaceae	*Withania somnifera*	1	RAW101399
9 families	10 genera: 11 species		
Indigenous	7 genera: 8 species		
Exotic	3 genera: 3 species		

Conclusion

Both *Cuscuta* species are generalists, however, most records of *Cuscuta reflexa* were from genus *Ziziphus* in the study area while *C. campestris* had a relatively broader host range. A total of 11 hosts from 10 genera in 9 families were attacked by *C. reflexa* and 12 hosts from 12 genera in 9 families were attacked by *C. campestris*. It was noted that both *Cuscuta* species are widely distributed in Bannu and in scattered patches in district Karak, while parasitize the least number of hosts in Kohat. Based on our key findings it is concluded that *Cuscuta* species have varied host range with little host overlap displaying taxonomic resource partitioning to limit interspecies competition when they occur in sympatry. Moreover, a tendency toward a particular host range can modulate the parasite's impact on the structure of plant communities.

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