TAXONOMIC REFLECTIONS ON THE PARASITIC ANGIOSPERMS OF PAKISTAN

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ABSTRACT

This is the first comprehensive listing of the flowering parasitic plants of Pakistan. A total of 50 plant species in 13 genera belonging to five plant families are reported from Pakistan. The largest number of parasitic plants are in Orobanchaceae (25 species) followed by Cuscutaceae (17 species). Scrophulariaceae had four species, Loranthaceae three and Balanophoraceae one. The majority of these parasitic plants occur in northern areas of Pakistan and Kashmir. Six species were found in Balochistan, and only two in Sindh. All the species of Scrophulariaceae, except *Centranthera hispida*, were found either in hilly areas or in the salt range.

KEY WORDS: Parasitic angiosperms, Pakistan

Approximately 1% (4000 species) of all angiosperms are parasitic, and attach themselves to other vascular plants by means of haustoria (Nickrentand and Press, 1999). These plants have continued

to be the focus of multidisciplinary research owing to their importance as agronomically significant weeds and as models for studying developmental, physiological and molecular processes (Albrecht et al. 1999, Boone et al. 1995, Stewart and Press 1990). Because of their intimate and complex interrelationships with host plants, parasitic angiosperms display evolutionary modifications at the biochemical, cellular, anatomical, and ecological levels that are novel among angiosperms (Nickrentand and Press, 1999).

Yoder (1999, 2001) and Yoder et al. (1999) have reported how plants communicate via chemical signals in the environment. In their studies on parasitic plants, they particularly focused on the genetic mechanisms governing the interaction of parasitic angiosperms and their plant hosts. Parasitic plants are interesting because their growth, development, and physiological behavior is modified in response to molecular signals exuded from neighboring plants (Estabrook and Yoder 1998, Matvienko et al. 2001, O'Malley and Lynn 2000). In addition, the study of parasitic plants is important because of the agricultural devastation caused by several of the more pernicious weedy species (Cubero and Moreno 1996, Habib and Rahman 1988, Press and Graves 1995, Torres et al. 2000). For example, the parasitic weed *Striga* Lour. is estimated to infect two thirds of crop plants on cultivated lands in sub-Saharan Africa where it can cause complete yield loses in critical staples such as maize, sorghum, millet and broad beans (Haussmann et al. 2001). The lives of over a 100 million Africans are negatively affected by this single plant pathogen alone (Haussmann et al. 2001). Although all parasitic plants have received much attention, the major emphasis has been on devastating crop pathogens such as *Striga* and *Orobanche* L. (Cubero and Moreno 1996). Press and Graves (1995) discussed modern topics such as the physiology of seed germination and haustorial initiation, mineral, carbon and nitrogen relations; and genome organization. However, there still exists a need to fully explore the cellular, biochemical and structural aspects of all parasitic plants.

More than 50% of Pakistan is mountainous, particularly its northern areas which includes high altitude mountain ranges, such as the Hindu Kush, Pamirs, Karakorams and Himalayas. These ranges are rich in flora and fauna, most of which are endemic, having temperate

paleo-arctic affinity, including species typical of the Sino-Japanese phytogeographical zone and Himalayas (Nasir and Rafiq 1995). Parasitic angiosperms have been mentioned in the *Flora of Pakistan* (Nasir and Ali 1972) and elsewhere (Nasir and Rafiq 1995). However, reports on their taxonomy, distribution and host plants are lacking. The present study was undertaken to compile a taxonomic list of parasitic plants and their distribution in Pakistan.

MATERIALS AND METHODS

This study is based on extensive on line and library and search study through MEDLINE, review articles and book reports to find out parasitic angiosperms of Pakistan (Nasir and Ali 1972, Nasir and Rafiq 1995). A list was compiled, and their taxonomic position determined. The distribution of these parasitic angiosperms in various parts of Pakistan is also described. The genera are arranged alphabetically within families. The nomenclature and classification follow Nasir and Ali (1972) and Nasir and Rafiq (1995), and author citations follow Brummitt and Powell (1992).

RESULTS AND DISCUSSION

This study is the first comprehensive survey of the parasitic angiosperms of Pakistan. A total of 50 species in 13 genera belonging to five families are reported from Pakistan (Table 1). It is interesting to note are are all dicotyledonous. The largest is found in Orobanchaceae (25 species) followed by Cuscutaceae (17 species). Scrophulariaceae had four species, Loranthaceae, three and Balanophoraceae one species (Table 1). The majority of these parasitic plants occur in northern areas of Pakistan and Kashmir. Six species were found in Balochistan and only two in Sindh (Table 1). All the species of Scrophulariaceae, except *Centranthera hispida* R. Br., are found either in hilly areas or the salt range.

Parasitic plants often use secondary metabolites secreted from the roots as chemical messengers to initiate the development of invasive organs (haustoria) required for heterotrophic growth (Keyes et al. 2000). Some of the most devastating parasitic plants of important food crops such as maize, sorgham, millet, rice and legumes belong to

Orobanchaceae, which typically invades the roots of the plants depriving them of water, minerals and essential nutrients (Yoder 1999). The hemiparasitic Orobanchaceae are characterized by a distinctive suite of ecophysiological traits (Phoenix et al. 2005). These traits have important impacts on the host plants and non-host plants, and influence interactions with other trophic levels. Ultimately, they can affect community structure and functioning. Phoenix et al. (2005) reviewed these physiological traits and discussed their ecological consequences.

The root hemiparasitic Orobanchaceae forms a convenient subset of the parasitic angiosperms for study because they are the most numerous and widely distributed group of parasitic angiosperms. Their physiological characteristics have been well studied. They are important in both agricultural and (semi)natural communities, and are tractable as experimental organisms (Estabrook and Yoder 1998, Phoenix et al. 2005, Riopel and Timko 1995, Torres et al. 2000). Key traits include: high transpiration rates; competition with the host for nutrients; and haustorial metabolism of host-derived solutes, uptake of host-derived secondary metabolites; dual autotrophic and heterotrophic carbon nutrition; distinct carbohydrate biochemistry; high nutrient concentrations in green leaf tissue and leaf litter; and small (often hairless and non-mycorrhizal) roots (Chang and Lynn 1986, 1987, Stewart and Press 1990).

Impacts of parasitic angiosperms on their hosts are detrimental, which can alter competitive balances between hosts and non-hosts and thus result in community change. Further impacts may result from effects on the abiotic environment, including soil water status, nutrient cycling and leaf/canopy temperatures. However, for non-host species and for organisms that interact with these (e.g. herbivores and pollinators) or for those that benefit from changes in the abiotic environment, the parasites may have an overall positive effect suggesting that at the community level, hemiparasites may also be considered as mutualists (Matvienko et al. 2001, Phoenix and Press 2005). It is clear that through their distinctive suite of physiological traits, hemiparasitic plants in Orobanchaceae have considerable impact on community structure and function, can have both competitive and positive interactions with other plants, and can affect other trophic levels (Phoenix and Press 2005). Many community level effects of

parasitic plants can be considered analogous to those of other parasites, predators or herbivores.

The goal of this study was to bring together the state-of-the-art research on parasitic angiosperms. Unlike most of the past publications, the main focus has been on the taxonomic and distributional aspects of the parasitic angiosperms of Pakistan. The results presented here will be of broad interest for plant scientists, and will provide information to specialists working on different aspects of parasitic plant biology.

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REFERENCES

Albrecht, H, J. I. Yoder and D. A. Phillips. 1999. Flavonoids promote haustoria formation in the root parasite *Triphysaria*. Plant Physiol., 119: 585-592.

Boone, L. S., G. Fate, M. Chang and D. G. Lynn. 1995. Seed germination. In: M. C. Press and J. D. Graves, eds. Parasitic Plants. Chapman and Hall, London. pp. 14-38.

Brummitt, K. R. and C. E Powell. (eds.). 1992. Authors of plant names. Royal Botanic Gardens, Kew, UK.

Chang, M. and D. G. Lynn. 1986. The haustorium and the chemistry of host recognition in parasitic angiosperms. J. Chem. Ecol. 12: 561-579.

Chang, M. and D. G. Lynn. 1987. Plant-plant recognition: chemistry-mediating host identification in the Scrophulariaceae root parasites. In: Allelochemicals: Role in Agriculture and Forestry (G.R. Waller, ed.), A.C.S. Symp. Ser. 330, Amer. Chem. Soc. Washington, D.C.

Cubero, J. I. and M. T. Moreno. 1996. Parasitic weed science: a quarter century. In: J. I. Cubero and M. T. Moreno, Coord. eds. Advances in Parasitic Plant Research. Córdoba, Spain, pp. 15-24.

Estrabook, E. M. and J. I. Yoder. 1998. Plant-plant communications: rhizosphere signaling between parasitic angiosperms and their hosts. Plant Physiol. 116: 1-7.

Habib, S. A. and A. A. Abdul Rahman. 1988. Evaluation of some weed extracts against field dodder on alfalfa (*Medicago sativa*). J. Chem. Ecol. 14: 443- 447.

Haussmann, B. I. G., D. E. Hess, G.O. OMANYA, B.V.S. REDDY, H.G. WELZ and H.H. GEIGER. 2001. Major and minor genes for stimulation of *Striga hermonthica* seed germination in *Sorghum*, and interaction with different *Striga* populations. Crop Sci. 41: 1507-1512.

Keyes, W. J., R. C. O'Malley, D. Kim and D. G. Lynn. 2000. Signaling organogenesis in angiosperms: xenognosin generation, perception, and response. Growth Regul. 19: 217-231.

Matvienko, M., M. J. Torres and J. I. Yoder. 2001. Transcriptional responses in the hemiparasitic plant *Triphysaria versicolor* to host plant signals. Plant Physiol. 127: 272-282.

Nasir, E. and S. I. Ali. 1972. An annotated flora of West Pakistan. Stewart Herbarium Gordon College, Rawalpindi and Department of Botany, University of Karachi, Pakistan.

Nasir, Y. J. and R. A. Rafiq. 1995. Wild flowers of Pakistan. Elite Publishers Ltd., Islamabad, Pakistan.

Nickrent, D. L. and M. C. Press. 1999. Current Research on Parasitic Flowering Plants. General Symposium for the XVI International Botanical Congress Aug. 1-7, 1999, St. Louis, Missouri.

O'Malley, R. C. and D. G. Lynn. 2000. Expansion message regulation in parasitic angiosperms: marking time in development. Plant Cell, 12: 1455-65.

Phoenix, G. K. and M. C. Press. 2005. Linking physiological traits to impacts on community structure and function: the role of root hemiparasitic Orobanchaceae (ex-Scrophulariaceae). J. Ecol. 93: 67-70.

Press, M. C. and J. D. Graves, (eds.). 1995. Parasitic plants. Chapman and Hall, London.

Riopel, J. L. and M. P. Timko. 1995. Haustorial initiation and differentiation. In: M. C. Press and J. D. Graves, eds. Parasitic Plants. Chapman and Hall, London. pp. 39-79.

Stewart, G. R. and M. C. Press. 1990. The physiology and biochemistry of parasitic angiosperms. Ann. Rev. Plant Physiol. Plant Mol. Biol. 41: 127-151.

Torres, M. T., M. Matvienko and J. I. Yoder. 2000. Agricultural genomics and its application to investigating subterranean plant-plant communications. J. Cellular Biochem. 80: 203-207.

Yoder, J. I. 1999. Parasitic plant responses to host plant signals: a model for subterranean plant-plant interactions. Curr. Opin. Plant Biol. 2: 65-70.

Yoder, J. I. 2001. Host plant recognition by parasitic Scrophulariaceae. Curr. Opin. Plant Biol. 4: 359-365.

Yoder, J. I., M. Matvienko, P. Richnavsky, D. Jamison, K. Kongkadee, A. Fisher, D. Day, J. Pelletier, Y. Godwasser and R. Wrobel. 1999. Parasitic plant responses to host plant signals. In: Biology of Plant-Microbe Interactions. (P.J.G.M. de Wit, T. Bisseling and W.J. Stiekema, eds.), International Society for Molecular Plant-Microbe Interactions, St. Paul, Minnesota, pp. 362-367.

Table1. Parasitic angiosperms of Pakistan.

Parasitic Species	**Distribution**
Balanophoraceae	
Balanophora involucrata Hook. f. & Thomson	Kashmir
Cuscutaceae	
Cuscuta approximata Bab.	Chitral and Kashmair
Cuscuta approximata Bab. var. *urceolata* (Kunze) Yunck.	Murree and Kashmir
Cuscuta australis R. Br. var. *cesatiana* (Bertol.) Yunck.	Kashmir
Cuscuta brevistyla A. Braun ex A. Rich.	Chitral
Cuscuta capitata Roxb.	Astor and Kashmir
Cuscuta chinensis Lam.	Kashmir
Cuscuta epithymum (L.) L.	Skardu
Cuscuta europaea L.	Astor
Cuscuta europaea L. var. *indica* Engelm.	Chitral and Swat
Cuscuta gigantea Griff.	Kalat
Cuscuta hyalin Roth	Karachi
Cuscuta kotschyana Boiss.	Balochistan
Cuscuta lehmanniana Bunge	Chitral
Cuscuta lupuliformis Krock.	Kalat and Chitral
Cuscuta monogyna Vahl	Balochistan
Cuscuta planiflora Ten.	Chitral and Kashmir
Cuscuta pulchella Engelm.	Chitral
Cuscuta reflexa Roxb.	Karachi, Chitral, Dir, Gilgit and salt range
Cuscuta tinei Inzenga	Kashmir
Loranthaceae	
Arceuthobium minutissimum Hook. f.	Swat, Kagan,
Viscum album L.	Kurram, Chitral

Viscum cruciatum Sieber ex Spreng.	Khyber, Swat
Orobanchaceae	
Aeginetia pedunculata (Roxb.) Wall.	Murree
Christisonia calcarata Wight	Sindh
Cistanche tubulosa (Schrenk) Hook. f.	Sibi, Las Bella, Mianwali
Lathraea squamaria L.	Kaghan, Dunga Gali, Murree
Orobanche aegyptiaca Pers.	Quetta, Chaman, Ziarat, Dargai
Orobanche alba Stephan	Miranjani, Poonch
Orobanche amethystea Thuill.	Ziarat, Chitral
Orobanche amoena C. A. Mey.	Chitral
Orobanche caesia Rchb.	Murree and Kashmir
Orobanche cernua Loefl.	Quetta, Chitral
Orobanche clarkei Hook. f.	Kurram, Chitral
Orobanche coelestis (Reut.) Beck.	Balochistan
Orobanche connata K. Koch	Chitral
Orobanche hansii A. Kern.	Kurram, Chitral
Orobanche hirtiflora (Reut.) Tzvelev	Kalat
Orobanche kashmirica C. B. Clarke ex Hook. f.	Kashmir
Orobanche kotschyi Reut.	Chitral

Orobanche lavandulacea Rchb.	Baluchistan
Orobanche orientalis Beck	Ziarat and Kashmir
Orobanche oxyloba (Reut.) Beck	Baluchistan
Orobanche psila C. B. Clarke ex Hook. f.	Kashmir
Orobanche solmsii C. B. Clarke ex Hook. f.	Swat and Kashmir
Orobanche stocksii Boiss.	Kurram
Orobanche vulgaris Poir.	Kurram
Xylanche himalaica (Hook. f. & Thoms.) Beck	Kashmir
Scrophulariaceae	
Centranthera hispida R. Br.	Mirpur
Striga asiatica (L.) Kuntze	Salt range
Striga gesnerioides (Willd.) Vatke	Salt range
Sopubia delphiniifolia (L.) G. Don	Hilly areas