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Evolutionary Mechanism with Respect to Host Specificity of Some Parasitic Plants Growing in Mithilanchal Areas of Bihar

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Abstract

Parasitism has been successful life strategy in the plants. The parasitic flowering plants were characterized by development of special organ called haustorium in multiple independent angiosperm clades. Host parasite interaction was investigated in detail by means of ethnobotanical studies in the Mithilanchal area of Bihar. The haustorium has the ability to accommodate anatomical and physiological differences between parasite and host plants. The evolution of haustorium has been documented considering four parasitic plant lineages. Several independent origins suggest the several ancestral plant lineages to meet the requirement of parasitic lifestyle such as the ability to recognize the host plant, an invasive haustorium and regulate the transfer of nutrient between two different plants. The family Orobanchaceae has been found to be unique among parasitic plant in this context. These plants exhibited a high degree of diversity in Mithilanchal areas. A few species of *Cuscuta* and *Loranthus* were found to be endemic. The members of Cuscutaceae and Loranthaceae family have a wide range of hosts.

***Key words*:** *Cuscuta,* Endemic, Haustorium, Parasitism, *Loranthus*

Parasitism is a highly successful life strategy and a theme that connects all kingdoms of life [1]. The coevolution along with high selection pressure influence the morphology and physiology of parasitic plants up to large extent enabling parasites important subjects for studying the diversity and evolution in phenotypic changes [2]. A parasitic plant is a plant that derives some or all of its nutritional requirement from another living plant. The parasitic plants constitute about 1% of angiosperm and are found in almost every biome. All parasitic plants have modified roots called haustoria, which penetrate the host plant connecting them to the conductive system -either the xylem, the phloem or both. About one percent of angiosperm are parasitic it means that they extract their food from other plants that is so called host. All parasitic plants possess a special organ called a haustorium which function in host attachment invasion and physiological redirection of host resources into the parasite [3]. Many have abundant photosynthesis that is hemiparasite and these are completely dependent on other plant for their existence while holoparasite lack photosynthetic activity and obtained all their food from haustorial connection with a host [4].

Parasitic angiosperms are the primary habitat of our ecosystem. They behave as prudent predators and are adapted to life cycle of their principal host [5]. Parasitic plants have been recognized as an entity for over 2000 years. On the basis of autotrophism, parasites were classified as holoparasite and hemiparasites. Again, another classification is on the basis of haustorial connection to the host i.e., they are stem and root parasites [6]. Furthermore, parasites were divided on the basis of presence or absence of chlorophylls i.e., they may be achlorophyllous or chlorophyllous [7]. The major lineage of recognized parasitic plant contains three hemiparasitic species and eight holoparasitic species. Only Orobanchaceae contain all the classification stages. Orobanchaceae provide a unique system to investigate the evolutionary origin and consequences of the plant evolving heterotrophic capacity [8].

Three genera of Orobanchaceae are very illustrative of the host change dependence. They are *Triphysaria*, *Striga* and *Orobanche*. Together they contain comparative framework for exploring the mechanism and significance of parasitism in plants. Parasitism originated in non-parasitic plants and the main aspects of evolutionary event was the origin of invasive haustoria. Haustoria made by the earliest parasitic Orobancheae were probably similar to those of hemi parasitic, facultative species. These species develop lateral haustoria on the side of their roots. In obligate parasite including *Striga* and *Orobanche* evolutionary event subsequent to lateral haustorium development resulted in the evolution of terminal or primary haustoria. The Terminal haustoria developed at the tip of the seedling radicle and no development of root until there is successful invasion of terminal haustorium and establishment in the host. The present paper accounts for the mechanism of evolution in parasitic plants with respect to specificity of host plants growing in Mithilanchal areas of Bihar, India.

MATERIALS AND METHODS

Mithilanchal areas comprise several districts of Northern Bihar of India (Fig 1). Regular visit to these areas were made to collect all host specimens which were parasitized by the two

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species of *Cuscuta*, *Viscum* and *Loranthus* for ascertaining their evolution. The survey of these parasitic plants was conducted in the year 2023. During fieldwork plant materials were collected for preparation of herbarium specimens and for biological and chemical testing [9]. Only few parasitic plants of different families were collected and identified with the help of flora of Darbhanga region. The results have been structured according to these categories: number of plants mentioned (with scientific Latin name, botanical families, host species and parts of host species [10]. To assess the degree of evolution in parasitic plants, these were compared with those reported in several works on ethnobotany, medicinal plants and phytotherapy [11].

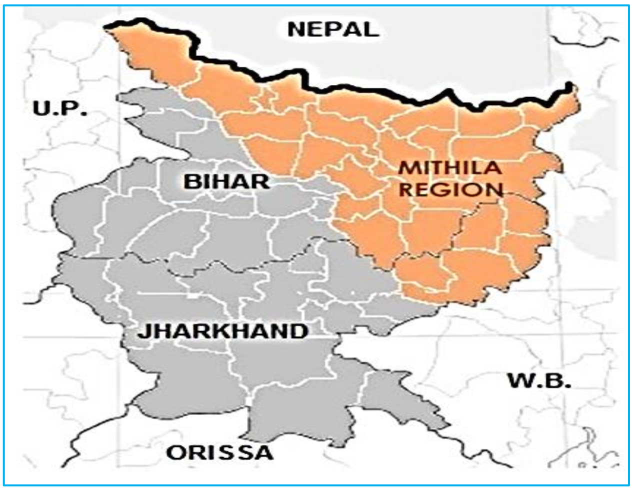

Fig 1 Map of Mithilanchal areas of Bihar, India

RESULTS AND DISCUSSION

The evolutionary event which gave rise to parasitism in plants was the development of haustoria. Parasitic plants are also divided as specialist and generalist plant parasite [12]. One of the most remarkable coevolutionary relationships that exist is the presence of one parasitic angiosperm upon another. Two forms of association can be distinguished, facultative and obligate. The defining structural feature of a parasitic plant is the haustorium a specialized organ that penetrates the host and forms a vascular union between the plants. There are two types of haustoria. The primary haustorium develops directly from the primary root apex and it is the only haustorium which function throughout the life time of the parasite. When only a primary haustorium is present the parasite is considered evolutionary more advanced. Evolution of the primary haustorium made holoparasite possible, since the generally small seeded holoparasite need water and nutrients from a host immediately after germination [13]. Secondary haustoria develop on lateral and adventitious roots. They are often short lived, sometime only a few months, but may occur up to several hundred per plants. Plants capable of supporting the growth of parasite to maturity are considered hosts, and within host species, levels of resistance to parasitism can vary.

Convolvulaceae and Lauraceae are the only two families where the majority of species are autotrophic plants and only one genus in each family is parasitic, *Cuscuta* and *Cassytha* (Fig 1-2). These two genera are so much alike regarding vegetative morphology and mode of parasitism that they represent a classic example of convergent evolution. They are winding, stem parasites with only secondary haustoria. Host range is high for most species but often difficult to determine; since the haustoria attach to any subject within reach [14]. However, many haustoria only develop a holdfast. *Cuscuta* species are fast growing. This may in part be explained by more efficient nutrient translocation since the xylem bridge is accompanied by phloem, a unique feature, elsewhere only reported from one species of *Orobanche* [15-16], (Fig 6).

Table 1 List of host plants with their botanical name, parasitizing part and nature

Botanical name of host plant	Parasitizing part	Nature of host plant
Abutilon indicum	Stem	Shrub
Acacia nilotica	Stem, leaf	Tree
Achyranthus aspera	Stem, leaf	Shrub
Boerhaavia diffusa	Stem	Herb
Caesalpinia crista	Stem	Shrub
Calotropis procera	Stem, leaf	Shrub
Capparis spinosa	Stem	Shrub
Cassia tora	Stem, leaf	Shrub
Coccinia grandis	Stem, leaf	Climber
Commelina benghalensis	stem, leaf, flower	Herb
Cassia occidentalis	Stem	Shrub
Corchorus aestuans	Stem, leaf, flower	Herb
Euphorbia neriifolia	Stem, leaf	Shrub
Ipomea fistulosa	Stem, leaf	Shrub
Lablab purpureus	Stem, leaf, flower	Climber
Luffa acutangula	Stem, leaf, flower	Climber
Momordica charantia	Stem, leaf, flower	Climber
Pennisetum typhoides	Stem, leaf, flower	Herb
Physalis fraternus	Stem, leaf, flower	Herb
Polyalthia longifolia	Stem, leaf	Tree
Ruellia tuberosa	Stem, leaf, flower	Herb
Sida acuta	Stem, leaf	Shrub

Fig 1 *Cuscuta chinensis* growing on host plant

Fig 2 *Cuscuta reflexa* growing on host plant

Fig 3 *Dendrophthoe falcata* growing on host plant

Fig 4 *Viscum album* growing on host plant

Fig 5 *Viscum articulatum* growing on host plant

Fig 6 *Loranthus odoratus* growing on host plant

Most of our understanding of parasitic plant evolution comes from studies of the Orobanchaceae that includes the full range of trophic capabilities including non-parasitic species as well as hemi and holoparasitic. Facultative hemiparasites have evolve from nonparasitic relatives and are the first step in the transition to parasitism. Holoparasitism has evolved multiple times from hemi parasitic Orobhanchaceae. Numerous changes have occurred along the transition to increased parasitic dependency including loss of autotrophic function, a general trend towards large genome sizes, major gene loss from the chloroplast and an increasing occurrence of horizontal gene transfer.

What evolutionary conditions might favour the development of parasitism in plants? Root parasitism confers certain advantages, especially for annual plants. When the parasite seeding forms a haustorium, it obtains a mature, functioning root system by "assuming" the root system of its host plants. Facultative hemi parasite have transpiration rates higher than their hosts and so they are most often found in open, sunny areas. But these areas also often have dense ground cover vegetation and competition for resources in the rhizophere is parasitism.

The stem parasitism in *Viscum* spp. also exceed their host transpiration rates (Fig 4-5). Given this, it is not surprising that *Viscum* spp. are most abundant in areas where access to sunlight is not limited, such as savannas and at the top of forest canopies where shading is avoided [17]. Diversification in Loranthaceae occurred during the Oligocene, a time when temperate deciduous woodlands and grasslands were displacing tropical biomes (Fig 3). The aerial portion of woody plants certainly represented an unexploited niche that offered opportunities for colonization by such early *mistletoes*. It has been known for several years that the members of Orobanchaceae develop haustoria when grown in the presence of another plant. It is now evident that these develop haustoria in response to chemical and tactile stimuli provided by the root of host [18].

Fig 7 *Orobanche crenata* infecting pea

The term host range versus host preference describes different aspects of the parasitic relationship. Host range refers to the total number of different species that can be parasitized. Host preference, referring to the choice of the most desirable host for optimal growth, typically is much narrower [19]. *Cuscuta* (dodder) species usually have extremely broad host ranges, and can even attach to many different hosts at once. But in nature, they are found regularly on few hosts and the parasite can often be located by first finding the preferred host.

The competence to form invasive haustoria in the earliest parasitic plants must have been followed by their abilities to separate their own roots from non-self-potential host. This distinction is the first move towards developing host specificity. The evolutionary rationale for a vegetative self-recognition system in root parasite seems obvious-a plant would receive nutritional benefits by parasitizing its own roots. The interaction between host and parasite occurs between cells of the haistoria of parasite and root of the host. The ability of the parasite to form and maintain a union with the host ultimately determines its success. The stem parasitic dodders (*Cuscut*a) provide intriguing models for host selection because they have nastic movement (in response to a host stimulus) that allow them to move towards hosts. The remarkable observation has been made that *Cuscuta pentagona* uses volatile chemicals cues to select hosts with the highest nutritional status [20].

CONCLUSION

Parasitic behaviour evolved in angiosperms is classical example of convergent evolution. Roughly 1% of all angiosperms are parasitic with a large degree of host dependence. Orobanchaceae is the only family that contains members of both total and partial parasites making it a model group for studying the evolutionary rise of parasitism. All other groups contain only partial parasites or total parasites. The members of Orobanchaceae develop haustoria when grown in the presence of another plant. *Cuscuta* (dodder) species usually have extremely broad host ranges, and can even attach to many different hosts at once. Unlike many other parasitic plants with limited host ranges, Cuscuta species exhibit remarkable adaptability, often possessing broad host ranges. They can even simultaneously attach to multiple hosts, reflecting their versatility in exploiting diverse plant species for sustenance.

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