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Myrmecophytes – A Wonder in Mutualistic World

Ranjeet Kaur Parmar[1], Vikrant Arya[1], Amandeep Kaur Gill[2,*], Vinay Thakur[3]

Abstract

In nature, organisms have an inherent ability to interact with each other constructing the ultimate basis of simple to diversified relationships among themselves. Myrmecophytes emerge because of the complex association between plants and ants which coevolve over time. They develop specialized structures and mechanisms to interact with ants in a mutualistic manner. Ant's dispersal of seeds via myrmecochory, extrafloral nectaries, food bodies, and domatia are among several tools that make this mutualistic interaction possible. Myrmecophytes provide food and shelter to the ants; in return, ants shield them from predators and herbivores. These interactions help to facilitate their survival under the extremities of nature. Recently, the role of fungus in contributing to the existing knowledge of plant-ant interactions has also been reported which suggests the successful three-way symbiosis. From an ecological point of view, myrmecophytes have a significant role in maintaining the harmony of a particular niche. They have also been explored therapeutically, and several epiphytic Myrmecophytes (Myrmecodia) and other species have been reported to be pharmacologically active. In this paper, an attempt has been made to highlight this extraordinary species considering their ecological and therapeutic prospects.

Keywords: Adaptation, myrmecophytes, mutualism, myrmecodia, therapeutic prospects

INTRODUCTION

The coevolution of plants and insects brings about complex relationships that help their survival in nature [1]. This intimacy further aids in building adaptive characteristics in them which ensure their endurance against biotic and abiotic stresses [2]. The interdependent evolutionary relationships might prove beneficial or harmful to the species [3]. Representing obligate interactions among species, mutualism seeks associations from both organisms in such a way that both will benefit from concurrent existence [4]. The most cited example in this category is of bees and flowering plants. Bee's nectar requirements from angiosperms facilitate the reproduction process in plants [5]. Ants also existed in diversified and symbiotic relationships with plants [6] which date back to around 140 million years [7], particularly in the Mesozoic era when ground-dwelling predatory ants explored plants (trees) as an auspicious source of food [8]. Several plants often interact with ants and exist in a mutualistic relationship; these species were recognized as myrmecophytes. The word myrmecophytes is derived from the Greek word "*myrmeko*" meaning "ant" and "*phyton*" representing "plant" [9]. Historical records depict that the interactions between plants and ants were implicated by varying theories by different scholars having contrasting views. In 1874, Thomas Belt (a naturalist from Nicaragua) suggested the existence of a prominent relationship between ants and plants against herbivory. He along with German Biologist, JFT Muller propounded the "coherent theory of myrmecophily" explaining the complex interaction between plants and ants. Later, Herr O. Warburg, a Physiologist proposed to call ant-

***Author for Correspondence**
Amandeep Kaur Gill
E-mail: amansatnamgill@gmail.com

[1]Research Scholar, Department of Pharmaceutical Sciences, CT University, Ludhiana, Punjab, India
[2]Associate Professor, Department of Pharmaceutical Sciences, CT University, Ludhiana, Punjab, India
[3]Principal, Govt. Pharmacy College Kangra, Nagrota Bagwan, Himachal Pradesh, India

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loving plants "Myrmecophytes" (ant plants) and further classified them into Myrmecotrophic (supplies food to the ants), Myrmecodomous (affords shelter to ants), and Myrmecoxenous (provides both food and shelter to ants) as indicated in Figure 1 [10, 11].

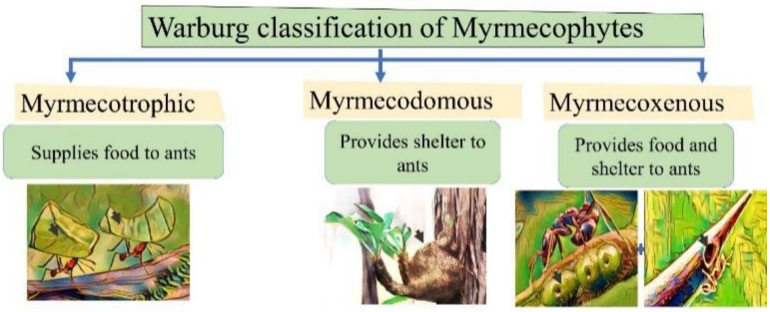

Figure 1. Classification of myrmecophytes.

MUTUALISTIC ASSOCIATION OF MYRMECOPHYTES

Myrmecophytes (ant-plants) have developed manifold adaptive features to establish a mutualistic relationship with ants as illustrated in Figure 2. The two commonly categorised mutualisms in which a plant-ant can be correlated are dispersal and defence. With the involvement of elaiosome (fleshy structures adhered to seeds), Myrmecochory represents the ant's dispersal of seeds or fruits [12]. Ant gardens also contribute towards seed dispersal via ant-dispersed epiphytes, particularly in the tropics [13]. Extrafloral nectaries (EFN) are involved in building an indirect defence of Myrmecophytes against several herbivores via attraction mechanisms. Ants are attracted by this carbohydrate-rich fuel, which is an instant energy source also [14]. Food bodies produced by distinct plants also serve as a food source for foragers. Apart from food, myrmecophytes also provide specialized nesting sites for ants known as Domatia [15]. In return, the ants shield the plant against diseases, rivals, and herbivores.

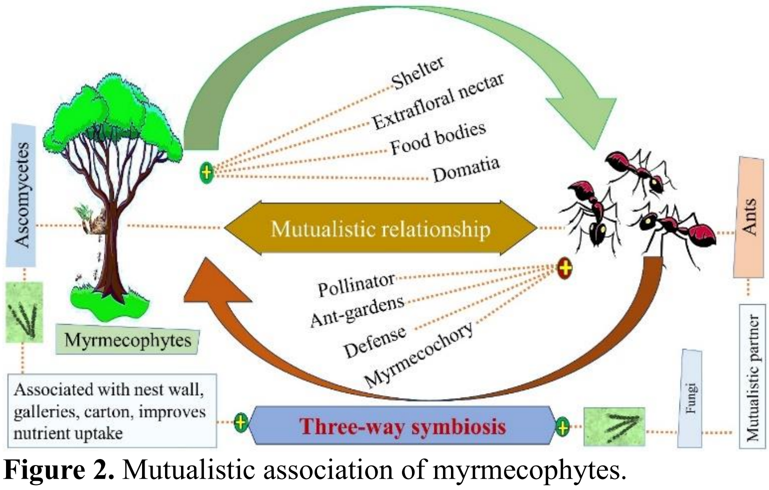

Figure 2. Mutualistic association of myrmecophytes.

MYRMECOPHYTES-ANT PARTNERS

Myrmecophytes and ants may have a mutualistic or commensalistic relationship as indicated in Table 1. Myrmecophytic-ant associations contribute towards adaptive evolutionary changes in both species. Several species of Genus Acacia *viz. A. hindsii, A. cornigera* existed in mutualistic relationship with arboreal ants *Pseudomyrmex ferruginea* [16]. Amazonian myrmecophytes (*Cordia nodosa* and *Duroia irsute*) showed symbiotic association with lemon ants (*Myrmelachista schumanni*) and *Azteca* (neotropical ant genus) respectively [17]. Ant-rewards (food, housing) offered by myrmecophytic tree *Vachellia velutina* towards *Pseudomyrmex spinicola* showed obligate mutualistic behavior [18]. *Turnera velutina,* a member of the flowering family Passifloraceae reported to have existed in a mutualistic relationship with patrolling ants *viz. Dorymyrmex bicolor, Brachymyrmex spp., Paratrechina longicornis* protecting extrafloral nectaries of myrmecophyte [19].

Trees belonging to *Macaranga spp.* showed a strong relationship between a heart-shaped abdomen ant *Crematogaster* [20]. *Leonardoxa africana,* a tropical tree showed a distinctive mutualistic relationship with *Aphomomyrmex afer* whereby providing a defence mechanism against herbivory [21].

Humboldtia brunonis, an evergreen myrmecophyte existed in a close mutualistic association with white-footed ant *Technomyrmex albipes* [22]. The extrafloral nectar (EFN) composition of Myrmecophyte, *Piper fimbriulatum* influences the mutualistic behaviour of *Pheidole bicornis* [23].

Table 1. Existence of myrmecophytes-ant partners.

S.N.	Myrmecophyte		Ant Species		Reference
	Genus	***Species***	***Genus***	***Species***	
1	*Acacia*	*hindsii*	*Pseudomyrmex*	*ferruginea*	[16]
2	*Acacia*	*cornigera*			
3	*Cordia*	*nodosa*	*Myrmelachista*	*schumanni*	[17]
4	*Duroia*	*hirsuta*	*Azteca spp.*	–	
5	*Vachellia*	*collinsii*	*Pseudomyrmex*	*spinicola*	[18]
6	*Turnera*	*velutina*	*Dorymyrmex*	*bicolor*	[19]
			Brachymyrmex spp	–	
			Paratrechina	*longicornis*	
7	*Macaranga spp.*	–	*Crematogaster spp.*	–	[20]
8	*Leonardoxa*	*africana*	*Aphomomyrmex*	*Afer*	[21]
9	*Humboldtia*	*brunonis*	*Technomyrmex*	*albipes*	[22]
10	*Piper*	*fimbriulatum*	*Pheidole*	*bicornis*	[23]

THERAPEUTICAL SIGNIFICANCE OF MYRMECOPHYTE

The epiphytic Genus of myrmecophytes “Myrmecodia” belongs to the Rubiaceae family encompassing some remarkable species displaying potent anticancer activities. They have modified inner chambers specially designed to house ants [24]. *Myrmecodia pendans* fraction was reported to exhibit antitumor activities when tested against colon cancer cell lines (Caco-2, HCT-116) in MTT assay [25]. ERK and STAT3 signaling pathways are inhibited by the methanolic extract prepared from the leaves of an ant-plant (*M. platytyrea*), which has antitumor effects on SK-Hep1, Huh7 (human hepatocellular carcinoma cells) [26]. *M. tuberosa*, an epiphytic Myrmecophytic species reported anticancer activities in vivo involving Sprague Dawley Rats. The active fractions were prepared from ethanolic extract modules TCD4+ and TCD8+ cell profiles [27]. The flowers obtained from an evergreen Myrmecophyte *Humboldtia brunonis* [22] manifest potential antioxidant and antibacterial activities in the DPPH and agar well diffusion methods [28]. Bark of Myrmecophyte *Acacia cornigera*, Fabaceae [16] reported anti-inflammatory activities when evaluated in *Croton tiglium* oil-induced ear dermatitis in mice [29]. In Silico molecular investigations (virtual docking) on Myrmecophytic Amazonian tree *Cordia nodosa* [17] showed promising antiophidic properties particularly in *Naja atra* (Chinese cobra), *Bothrops pirajai* (Piraja’s lancehead), *Bothrops asper* (Terciopelo) [30]. Myrmecophyte *Mallotus japonicus*, commonly known as food wrapper plant [31] exhibited antiviral properties due to the presence of complex secondary metabolites [32].

THREE-WAY SYMBIOSIS

The role of fungus as a mutualistic partner has been recognized by several researchers representing three-way symbiosis [33]. It is evidenced that several black fungal species *viz.* Ascomycetes (Chaetothyriales, Capnodiales) have a prominent role in nesting strategies (nest walls, galleries) [34].

Endophytic fungi are also reported to be associated with ant gardens to promulgate the growth of myrmecophytes [35]. Some more studies representing ant-plant and fungal associations are reported in the case of *Hirtella physophora* [36], *Cecropia* [37], *Caularthron bilamellatum* [38], *Mallotus japonicus* [31], and Acacia [39]. Apart from fungal associations volatile organic compounds [40–45] and the protective trichome's role in controlling ant's behavior toward mymecophytes is of great concern (Figure 3) [46, 47].

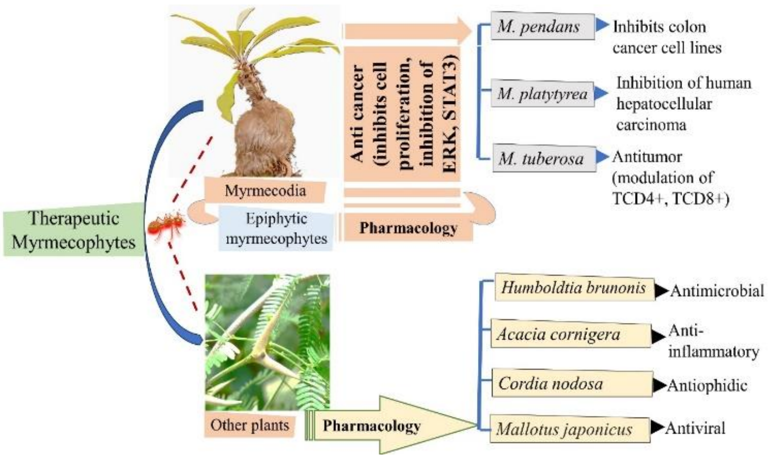

Figure 3. Pharmacological potential of myrmecophytes.

CONCLUSIONS

Representing one of the most diverse mutualistic relationships in nature, myrmecophytes tailored themselves to uphold their survival. By offering food and shelter to ants, they can generate a patrolling force against herbivory and other predators. Ascomycetes, endophytic fungus seems to play a vital role in maintaining the success of these plant-ant interactions. Not only from an ecological perspective they are important but when explored therapeutically these myrmecophytes exhibited a wide array of Pharmacological activities.

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