



Review on: The services of ants-Hymenoptera-Formicidae in an ecosystem

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Abstract

An extremely diversified taxonomic category includes ants. They exhibit incredible social organization, which has allowed them to proliferate all across the planet. They account for about 10% of the animal biomass in the planet. By playing a significant part in plant pollination, soil bioturbation, bioindication and the control of crop-damaging insects, ants contribute to ecosystem services in agrosystems. Numerous researches on ant ecology have been conducted in recent years and the attention placed on tree cropping systems has increased the value placed on this knowledge. This review article provides a comprehensive summary of the knowledge regarding the functional roles that ants play in various fields, as well as the potential of various ant species to operate as biological control agents, bioindicators agents and ecological engineers.

Keywords: Ants, biological control agents, ecosystem engineering, bioindicators, functional role

Introduction

More than 12,500 species of ants have been formally identified and there may be another 12,500 species that are still undiscovered (Ward 2009). Ants are the most varied group of social insects. A prominent taxon of the terrestrial arthropod ecosystem, ants has inhabited nearly every continent since their emergence. Our knowledge of ants' real variety will continue to grow as new species are discovered and our comprehension of their evolutionary links is refined. In most terrestrial ecosystems, ants are also very prevalent and can make up significant portions of the overall animal biomass. (Holldobler al., 1990). The impact of anthropogenic activity on ecosystems and biodiversity is evident now. The effects of biodiversity loss must be carefully studied on a planet that is changing. Although ants are tiny, seemingly inconsequential species when viewed as a whole, they make up one of the major animal biomass subgroups on the planet, making up about 10% (Keller *et al.*, 2006) [35]. They are essential to the functioning of agro-ecosystems and offer a variety of services, including biological control (Offenberg, 2015) [36], plant pollination (Garcia *et al.*, 1995) [37], soil bioturbation (Jones 1994 [38]; Lavelle 1997 [39]) and bioindicators (Majer, 1983) [29], and helping to preserve animal and plant biodiversity (Keller *et al.*, 2006) [35]. The diversity of their roles is correlated with their group's high diversity when compared to other animal groups (Majer, 1983 [29]; Folgarait 1998) [42]. Ants are crucial in controlling insects that harm crops. The Millennium Ecological Assessment (MA) offers a broad framework for categorizing the many ecosystem services rendered by organisms. These include: provisioning services: products made available by an organism that have a direct impact on people's wellbeing; regulating services: products that control ecosystem processes or the inherent features of ecosystems that ensure their integrity sustaining services: services needed to maintain other types of ecosystem services, such as ecosystem functions; cultural services: benefits that come

from ecosystems that aren't material in nature. For some species, especially in horticulture, there is some understanding of their potential as biological control agents (Peng, *et al.*, 2004 [11]; Van Mele, 2008). In this review, we demonstrate that ants offer a variety of ecosystem services that fall under each of the categories of ecosystem, but they also contribute significant, expensive disservices that may compete with the services they do offer.

1. Role of Ants in Ecosystem Functioning

A variety of insects, whose capacity to pollinate flowers vary greatly in terms of both quality and quantity may pay visits to the blooms of insect-pollinated plants (Herrera, 1987 and 1989.) [44, 45] Ants' relatively small size in comparison to other pollinating insects, their typically smooth integument, their regular cleaning of their bodies or their antibiotic secretions (against pathogens), for which the co-evolution with pollen is frequently incompatible, are the reasons why ants are thought to be inefficient pollinators (Beattie, *et al.*, 1984) [46]. It has been suggested that the structure of some flowers is an adaptation to keep ants away (Peakall *et al.*, 1987) [47]. There was no difference in the quantity and weight of coffee berries between trees that were pollinated by ants or by flying insects (bees, wasps, butterflies, etc.). According to a research by De Vega and Herrera (De Vega, *et al.*, 2013), contact with yeasts carried by ants caused some chemical alterations in the sugars of flower nectars. According to the amount of yeast left behind, the flowers had higher fructose, glucose and sucrose concentrations and slightly higher temperatures than flowers that weren't visited by ants. This occurrence would seem to lessen the plant's chemical control over the different floral parts. The ability of such flowers to reproduce is frequently altered since the temperature increase (about 5–6 C) and the increased nectar sugars created would appear to draw in a lot more pollinators, such as bees (Whitney *et al.*, 2008).

Table 1: Role of Ants in Ecosystem Functioning

Sr.no.	Species	Activity	Area or country	Reference
01	<i>Atta taxena</i>	When digging their nests, leaf cutter ants damage the soil structure, which alters the soil's temperature and aeration.	Neotropical forest ecosystems	Amanda C. Swanson <i>et al.</i> 2018
02	General ants	Ants scavenge nectar from additional floral nectaries on the buds of the <i>Caryocar brasiliense</i> plant's apex.	south-east Brazil	Oliveira, P. S., 1997
03	<i>Iridomyrmex greensladei</i>	The mounds' soil porosity increased due to bioturbation activities, reaching roughly 200 cm down the soil profile. The effects of ant bioturbation and foraging activities on soil parameters were discovered to extend beyond the mound's perimeter and into the surrounding environment.	New South Wales in Australia	Nkem <i>et al.</i> , 2000.
04	<i>Trachymyrmex</i> sp. and <i>Camponotus</i> sp	due to burrowing activities, the accumulation of organic matter and other nutrients in the soil, which, in turn, alters soil physical, chemical and (micro) biological processes.	Columbia	Cammeraat <i>et al.</i> (2002), Decaëns <i>et al.</i> (2002)
05	<i>Aphaenogaster barbigula</i>	After a rain, the ants re-excavate their nest chambers, trapping any debris that lands close to the entrance and obstructing the path of debris that is being carried down a hill by overland flow processes.	semi-arid eastern Australia	Eldridge and Myers (1998) ^[13]
06	<i>Pogonomyrmex</i>	Competition with other granivores, seed dispersers and the favourable soil conditions they cultivate as a result of their digging	North America	MacMahon <i>et al.</i> 2000 ^[14]
07	<i>P. naegeli</i>	Each nest food items were gathered for an hour once a month using an A4 piece of paper as a tool to separate and capture the worker ants as they went about their business.	Brazilian savanna.	Anjos <i>et al.</i> , 2019 ^[15]
08	---	in host hackberry bushes (<i>Celtis spp.</i>) as a result of ants predated on butterfly larvae	southern United States	Hewitson, 1863
09	<i>L.sakagamii</i> or <i>F. japonica</i> , <i>L.niger</i> or <i>P.pungens</i>	Ants preyed most heavily on butterfly larvae in trees.	Japan	Kobayashi <i>et al.</i> 2008 ^[17]
10	<i>Lasius</i> , <i>Formica</i> , <i>Camponotus</i> , <i>Crematogaster</i> , <i>Myrmica</i> , <i>Tapinoma</i>	gather extra floral nectar or honeydew from heteropteran insects.	---	Pierce <i>et al.</i> , 2002 ^[18] , Fiedler, 2006
11	<i>Myrmica</i> spp	captures the interactions that are both direct and indirect.	Europe	Hochberg <i>et al.</i> 1994
12	<i>Myrmica</i> spp	past parasitism of <i>Myrmica</i> ant colonies by <i>Maculinea</i>	Vistula river valley.	Nowicki <i>et al.</i> 2007

2. Anta as Ecosystem Engineers

In particular, the soil fauna. The most notable soil-displacing creatures are earthworms, termites and ants because of the amount of soil they remove and the biogenic structures of organic/mineral aggregates they produce (worm castings, galleries, domes, etc.) (Jones, C.G.; Lawton, J.H.; Shachak, M.and, 1994^[38], 1997). The part of the soil fauna that moves the most soil is the ant, followed by earthworms (Decaën *et al.*, 2001). The earth is aerated by the galleries that ants excavate to construct their nests. In

comparison to some of the aggregates produced by earthworms and termites, some of these types of soil may come from relatively deep horizons and are frequently less rich in organic matter (Decaëns, *et al.*, 2001). Ants contribute significantly to the dynamics of organic matter by hastening the process of mineralization and improving soil qualities, particularly porosity, which affects water infiltration and circulation and lowers the likelihood of erosion (Lavelle *et al.* 1997^[39], 2008).

Table 2: Role of Ants in Ecosystem Engineers

sr.no.	Species	Activity	Area or country	Reference
01	leaf-cutting ant <i>Atta cephalotes</i>	Leaf-cutter ants affect the soil's structure when they excavate their nests, which changes the soil's temperature and aeration.	Atlantic Forest in Brazil	Meyer <i>et al.</i> 2013. ^[20]
02	<i>Myrmica rubra</i> And <i>Lasius niger</i>	In a field experiment, the presence and density of colonies of these two ant species were varied from the commencement of ant activity.	Lower Saxony, Germany	Sanders <i>et al.</i> 2011. ^[21]
03	yellow meadow ant (<i>Lasius flavus</i>)	Ant burrowing activity, soil mixing, aphid honeydew accumulation and decreased plant-derived nutrient inputs into nest-mound soil	New South Wales in Australia	Bierbaß <i>et al.</i> 2015 ^[22] .
04	General	Ant activity within a nest can affect soil nutrients and pH.	----	Cammeraat and Risch 2008 ^[23, 49]
05	<i>General ants</i>	Foraging activity among ants can also concentrate resources within a nest.	---	Lobry de Bruyn and Conacher 1990 ^[24]
06	<i>Pheidole fallax</i>	From each site, 15 nests were chosen for characterization of the organic debris in garbage heaps.	Department of La Guajira, in northern Colombia	Domínguez <i>et al.</i> 2022. ^[25]
07	leaf-cutting ant <i>Acromyrmex lobicornis</i>	Using a mixed-model ANOVA, the dry biomass of leaves and roots as well as the foliar contents of N and P as ant refuse were analyzed.	Nahuel Huapi National Park, Argentina	Farji-Brener. <i>et al.</i> 2010. ^[26]
08	<i>Lasius niger</i>	Ants safeguard aphids. observed how ants moved between their	Aarhus, Denmark,	Way 1963; Pontin

		nest and a group of aphids		1978
09	---	feeding different arthropods	---	Sanders and Platner 2007
10	<i>Lasius sakagamii</i> or <i>Formica japonica</i> , <i>Lasius niger</i> or <i>Pristomyrmex pungens</i>	Ants preyed most heavily on butterfly larvae in trees.	Japan	KOBAYASHI <i>et al.</i> 2008 [17]

3. Role of ant as Bioindicators Agents

To qualify as a good bioindicators, according to Oliver and Beattie (Oliver *et al.* 1996) [28], a taxonomic group must

meet four major requirements: it must be simple to sample, sufficiently diverse or of high biological value, have links with other taxonomic groups and be sensitive to

Table 3: Role of Ants as Bioindicator agents

Sr. No.	Species	Bioindicators for	Area or country	Reference
01	General ants	Resilience assessment in ancient mine sites	Australia	Majer. <i>et al</i> 1983, [29] Oliver. <i>et al.</i> 1996.
02	<i>Myrmica sabuleti</i> and <i>Lasius niger</i>	Calcareous grassland restoration success and, alongside information from the plant community	Temperate grassland	Fagan <i>et al.</i> 2010 [30]
03	<i>Aphaenogaster subterranea</i>	Restoration processes.	Italy	Ottonetti <i>et al.</i> 2006
04	<i>Camponotus fastigatus</i>	f environmental rehabilitation in areas impacted by mining activities	Brazil	Gollan <i>et al.</i> 2011 [32]
05	41 species from 12 genera	agricultural environments to assess the impacts of management practices in farmlands	Australia	Andersen <i>et al.</i> 2002 [33]
06	General ants	Ants are currently utilized to monitor degraded ecosystems after being used to detect pollutant concentrations in Australia and borealis forests.	Australia	José Renato <i>et al.</i> 2010
07	174 species from 24 genera	Investigated the validity of a streamlined ant assessment technique created to be practical for a variety of land managers.	Australia	ANDERSEN <i>et al.</i> 2002 [33]
08	General ants	Significant economies can be realized by streamlining the ant sorting process, according to research and these efficiencies can actually improve indicator performance rather than degrade it.	Australia	ANDERSEN <i>et al.</i> 2004
09	General ants	Ants are a great potential bioindicators category due to their immense diversity, extensive distribution in almost all environments and relatively ease of collecting.	Mine site, Australia	Majer, J.D, 1983 [29]
10	General ants	In Australia, ancient mining sites have long used ants as bioindicators for soil management and ecosystem assessment.	Australia	Majer, J.D, 1998
11	22 ant species from 13 genera	Due to their importance in agricultural contexts, they are increasingly recognized as a useful tool to assess the effects of management measures in farmlands.	Gujarat State), western India	Dolly Kumar & Archana Mishra, 2008 [34]
12	<i>Monomorium salomonis</i> and <i>Palothyreus tarsatus</i>	ant community composition in Senegalese mango-based ecosystems is influenced by orchard design and management practises.	Senegalese	Diamé <i>et al.</i> 2015 [41]

4. Biological Control Agent

Ants have close relation with many of the creatures in their habitat, particularly some plants with which they have mutualistic interaction relationships (Quinlan *et al.* 1977). In those interactions, both parties gain from one another's presence: Ants defend plants from herbivorous insects (leaf-eating, fruit-eating and xylophagy), while the plant offers the ants shelter, food supplies, or places to reproduce (Dejean *et al.*, 2009 and 2010). Predation, a repelling phenomenon, or a phenomenon that prevents the growth of plant harmful bacteria are the basis for the protective role of ants. The growth of fungi and bacteria that are plant pathogens is constrained by the presence of specific chemical compounds carried by ants (Buckley, 1987) [19]. The effectiveness of natural enemy predation at the ecosystem level is also influenced by the intricacy of natural enemy interactions (Casuala *et al.*, 2006 and Majer, J.D, 1983) [29]. The underlying principles of these phenomena are inspired by the complex secretions that ants deploy as a means of warfare. For instance, metapleural glands of ants release antibiotics. Although ants have 39 different glands that have been identified so far, most of these have distinct roles in the social structure of the colony (Hölldobler, B.;

Wilson, E.O), the production of alarm pheromones for colony defence, or as chemicals to retain group identity through kin recognition (Brown *et al.*, 1968). The effectiveness of natural enemy predation at the ecosystem level is also influenced by the intricacy of natural enemy interactions (Casuala *et al.* 2009). The best way to control herbivorous insects in an agricultural setting is through the colonization of habitats by dominant ant species organized into a "ant mosaic" (i.e., distribution of dominant species in patches so that the territories do not overlap) (Majer, J.D and Blüthgen, N, 1983) [29]. environmental changes. As a result of their ecological significance as predators, prey, detritivores, mutualists and herbivores as well as the relative steadiness of their motions as compared to other insects, ants have additional advantages. Ants have been utilized for a number of years as bioindicators for soil management and ecosystem assessment in old mining sites in Australia (Majer, J.D, 1998) as well as other regions of the world (Ottonetti *et al* 2006 and Gollan *et al.* 2011) [32]. They are increasingly being acknowledged as a helpful instrument to evaluate the effects of management strategies in farmlands, notably because of their significance in agricultural contexts (Dolly Kumar & Archana Mishra, 2008) [34].

Table 4: Role of Ants as Biological control agents

sr. no.	Species	Ecosystem or Crop	Area or country	Work on	Reference
01	<i>O. longinoda</i>	Citrus Orchards	Ghana	fruit flies	Afreh-Nuamah <i>et al.</i> 2012. [1]
02	<i>O. smaragdina</i>	Coconut	Northern Australia	plant bugs, caterpillars, weevils	Stapley, 1973 [2].
03	<i>S. invicta</i>	cotton and soybean	Alabama	insect pests and their natural enemies	Micky D. 2001
04	General	Maize	Nicargua	Armyworm and leafhopper	Ivette Perfecto, 1991 [3]
05	<i>S. invicta</i>	Collards	USA	diamondback moth and <i>Plutella xylostella</i>	Harvey <i>et al.</i> , 2004 [4].
06	<i>S. invicta</i>	cattle pasture	southern United States	<i>Beauveria bassiana</i>	Bextine <i>et al.</i> 2002 [5]
07	<i>A. steingroeveri</i> , <i>C. peringueyi</i> and <i>L. humile</i>	Vineyards	South Africa	<i>Planococcus ficus</i>	Mgocheki & Addison, 2009. [6]
08	<i>S. invicta</i> Buren	Stored honeybee comb	four South Carolina counties	wax moths	Taylor <i>et al.</i> 2003
09	<i>P. megacephala Fabricius</i> and <i>B. obscurior Forel</i>	orange jasmine hedge	University in Florida	<i>Diaphorina citri</i> Kuwayama	Navarrete <i>et al.</i> 2013 [8].
10	General	<i>Zea mays-Phaseolus vulgaris</i>	Nicaragua	<i>Spodoptera frugiperda</i> , Armyworm, <i>Dalbulus maidis</i>	Perfecto, & Sediles. 1992.
11	General	Coffee	Around the world	<i>Hypothenemus hampei</i>	Morris <i>et al.</i> 2018 [9]
12	<i>S. invicta</i> Buren	Ant mounds	West Indies	<i>Kneallhazia solenopsae</i>	Valles <i>et al.</i> 2015 [10].
13	<i>O. smaragdina</i>	<i>M. indica</i> and orchards	Darwin	<i>Selenothrips rubrocinctus</i>	Peng, & Christian. (2004) [11].

5. Interactions with natural agricultural pests

An important component of tropical agro-ecosystems are ants (Eubank *et al.*, 2007), with some native or invading species frequently attaining high densities and dominating other ant species (Hölldobler, B.; Wilson, E.O, 1990). Due to their aggressive nature, dominant ant species can diminish the diversity of natural enemies and the ecological stability of the trophic network by excluding those species from their territories and food sources (Gibb *et al.*, 2003). It can lead to asymmetric competition for the resource since omnivorous and generalist predators like weaver ants are competitors able to tolerate a low level or, to a certain extent, an absence of prey. Additionally, omnivorous

predators occasionally attack their intraguild rivals, which is referred to as intraguild predation behaviour, which enhances their superior competitor position. This is why the central concern of our research is the question of how *Oecophylla* sp. interacts with other natural enemies of agricultural pests. The investigations made since 2005 in Benin under natural orchard settings have yet to reveal an aggressive behaviour of *O. longinoda* towards parasitoids of the Tephritidae (J.-F. Vayssières, personal communication). It is also critical to remember that the disadvantages of intraguild interactions on biological control typically do not outweigh the advantages of grouping numerous natural enemies to control a pest (Janssen, *et al.* 2006).

Table 5: Role of Ants with natural agricultural pest

Sr.no.	Species	Interacting with	interaction	Area	Reference
01	<i>O. smaragdina</i>	Spider species <i>Oxyopes</i> sp.	competition	Australia	Peng and Christian. 2013
02	<i>O. longinoda</i>	fruit fly parasite <i>Fopius arisanus</i>	parasitism	Kenya	E.F. Appiah <i>et al.</i> 2014
03	Red imported fire ant	16 pest species	negative correlation	Alabama	Micky D. Eubanks. 2001
04	<i>Crematogaster striatula</i> , <i>C. clariventris</i> and <i>O. longinoda</i>	Major cocoa pest <i>Mirid</i>	negative correlation	West Africa	Leila Bagny Beihe <i>et al.</i> 20018
05	General ants	coffee berry borer	negative correlation	Brazil	Natalia <i>et al.</i> , 2017
06	7 different ant species	Banana weevil, <i>Cosmopolites sordidus</i>	negatively correlated with <i>C. sordidus</i> and positively correlated with <i>Formicinae</i> and <i>Ponerinae</i>	Cameroon, Central Africa	Anicet <i>et al.</i> 2015
07	General ants	<i>Hypothenemus hampei</i> 86 Ferrari	negative correlation	Matagalpa, Nicaragua)	Leila <i>et al.</i> 2019
08	<i>Pheidole</i> sp.	diamondback moth, <i>Plutella xylostella</i> and the black cutworm, <i>Agrotis ipsilon</i>	Positive association between plants with high larvae densities and negative connection between infested plants with low larval densities.	India	Agarwal <i>et al</i> 2007

Discussion

Agro-ecological management seems to be a method that combines several functional components of the agro-ecosystem with the goal of enhancing its ability for self-

regulation. This necessitates a greater appreciation of the diversification of arthropods found in various ecosystems and a better comprehension of the functions performed by various species as well as their relationships. It is generally

established that the animal component of an agro-ecosystem is a key factor in both biological control by natural enemies and plant output through flower pollination. Animal-plant interactions that result from herbivory can have both beneficial and harmful outcomes. An additional benefit supporting the use of ants as biological control agents in agro-ecosystems is their very real contribution to the recycling of nutrients, the decomposition of organic matter, the structuring of the soil and the restriction of disease development on plants. Insofar as the trophic interactions between biotic components of the environment are favoured, IPM programmes appear to offer a useful tool that is in keeping with an agro-ecological perspective, to the detriment of phytosanitary intervention based on very toxic chemicals. In most African fruit agro-ecosystems, this strategy has not been effectively adopted yet. It is feasible to encourage ant populations in tree cropping systems. One example of its successful application in biological control programmes in orchards is the introduction of *Oecophylla* or the conservation of its habitat in areas where it is endemic (Van Mele *et al.* 2007). When selecting a species of ant to be adopted or supported as a biological control agent in IPM programmes, certain factors must be taken into consideration. The ant fauna that is already present in the agro-ecosystem must first be identified. The taxon is not fully understood, as Hölldobler and Wilson (Hölldobler *et al.* 1990) noted and Ward (Ward, P.S, 2014) even hypothesized that there may be twice as many species as have been officially recognized. When selecting a species of ant to be adopted or supported as a biological control agent in IPM programmes, certain factors must be taken into consideration. The ant fauna that is already present in the agro-ecosystem must first be identified. The taxon is not fully understood, as Hölldobler and Wilson noted and Ward even hypothesized that there may be twice as many species as have been officially recognized. Thus, there is a critical need for research to more fully understand the role that specific ant species play in soil processes, interactions with soil fauna and relationships with all trophic chains—factors that are crucial for the health of tropical agro-ecosystems. However, important issues about ant effects in cropping systems remain unanswered. In order to better understand how ant bio-ecological research may be used to enhance tree crop production conditions, more research is required. A clarification of the differences between positive and negative effects on cropping systems should be considered one of several potential future initiatives in ant bio-ecology.

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