ACADEMICIA

ISSN: 2249-7137 Vol. 11, Issue 10, October 2021 Impact Factor: SJIF 2021 = 7.492

ACADEMICIA
An International Multidisciplinary Research Journal
(Double Blind Refereed & Peer Reviewed Journal)

DOI: 10.5958/2249-7137.2021.02222.9

THE DEVELOPMENT OF INSECT FARMING

Dr Pramod Kumar*

*Sanskriti University,
Mathura, Uttar Pradesh, INDIA
Email id: farm.agri@sanskriti.edu.in

ABSTRACT

Agriculture has developed separately in three insect orders: once in ants, once in termites, and seven times in ambrosia beetles. Agriculture has evolved independently in three insect orders. Despite the fact that these insect farmers are very distinct from one another in certain respects, they are surprisingly similar in many other aspects, which suggests that they have evolved via convergent evolution. All of them reproduce their cultivars as clonal monocultures inside their nests, and in the majority of instances, they propagate them clonally over several farmer generations as well. Despite the fact that long-term clonal monoculture presents unique challenges for disease control, insect farmers have developed a variety of strategies to manage crop diseases: they (a) isolate their gardens from the surrounding environment; (b) monitor gardens closely, controlling pathogens as soon as disease outbreaks occur; and (c) occasionally access population-level reservoirs of genetically variable cultivars, even while maintaining their own gardens. Rather of cultivating a single cultivar purely for nutrition, it seems that insect farmers produce, and potentially "artificially select" for, integrated crop-microbe consortia, which are then distributed across the field. It is possible that crop domestication occurred in the setting of coevolving microbial consortia, which may account for the agricultural success of insect farmers that has been documented for 50 million years.

KEYWORDS: *Agriculture, Evolution, Insects, Microorganism, Termites.*

1. INTRODUCTION

In the animal world, the cultivation of crops for food has occurred just a few times in the history of the species. The fungus-growing ants, the fungus-growing termites, the ambrosia beetles, and, of course, humans are among the most well-known and clear instances of this phenomenon. Agriculture has become increasingly important for humans, who began the transition from an ancestral hunter-gatherer existence to farming only about 10,000 years ago. In a global economy with projected food shortages, sustainable, high-yield agriculture has become critical for survival, and numerous research programmes are currently dedicated to the optimization of agricultural productivity in the context of growing environmental challenges. People have made significant advances in agriculture via a mix of intelligence, innovative planning, and a healthy dose of chance and good fortune, among other factors. Although nonhuman agricultural systems, such as fungus-growing insects, have been studied in the past, humans have not looked at them for potential insights for improving agricultural methods[1].

This lack of applied interest in insect agriculture is most likely due to a widespread assumption that human agricultural systems operate in a fundamentally different way than insect agricultural systems, which is unfounded. Humans, on the other hand, have gained a great deal of practical knowledge by studying the adaptive characteristics of other species closely, and similar issues such as crop diseases afflict all farmers, regardless of their phylogenetic positions or the crops they grow. It may be fruitful to examine the short- and long-term solutions that have evolved convergent in insect agriculture for possible application to human agriculture due to the universality of crop diseases in both human and insect agriculture due to the universality of crop diseases in both human and insect agriculture. The purpose of this review is to provide such a synthesis[2].

1.1 Behavioral and Nutritional Characteristics:

Agricultural practices such as insect fungi-culture and human farming have many similarities, including (a) the routine planting of sessile cultivars in specific habitats or on specific substrates, including the seeding of new gardens with crop propagules that are selected by farmers from mature gardens and transferred to novel gardens; (b) cultivation aimed at improving the growth conditions for the crop, or (c) cultivation aimed at improving the yield of the crop The insect farmers' obligate reliance on their cultivated crops may be easily shown via the experimental removal of their cultivated crops, which results in decreased reproductive output, higher mortality, or even the definite death of the cultivar-deprived insect (see Figure 1). Planting and harvesting are not required to be done with deliberate purpose according to our concept of agriculture. It is undeniably true that conscious planning, learning, and teaching have hastened the evolution of sophisticated agriculture in humans, but it seems unlikely that this has occurred in insects[3].

We have limited our review to fungi-culturists who specialize on ants, termites, and beetles. Aspects of hemipteran insect husbandry that are similar to human animal husbandry, such as the caring by ants of hemipteran insects, are not included in this study. Also excluded from consideration are cases that do not meet all four of the requirements of agriculture as defined above, such as the ant Lasius fuliginosus, which promotes fungal growth in the walls of its nest, because the fungus is apparently not grown for food, but rather for the purpose of strengthening the walls or providing antibiotic protection to the walls. On the same reasons, we rule out a number of potential instances of early agricultural development[4].

The snails of the genus Littoria, for example, may "proto-farm" fungus by producing plant wounds that get infected with fungal growth that is a component of their food supply, but they do not actively inoculate the plant wounds or otherwise cultivate the fungi. Invertebrates in particular are likely to have many more such proto-farming species yet to be discovered, and all known insect agriculturists are likely to have descended from proto-agricultural predecessors who were similar in many ways. The comparison of these proto-farming insects to “primitive” human agriculture is outside the scope of this study.

1.2 Understanding Agriculture:

We will examine agriculture as a form of strong co-evolutionary interaction, as described by the nutritional and behavioral requirements listed above, in which natural selection operates on both farmers and crops as interdependent lineages that are mutually reinforcing each other's development. When it comes to agriculture, our co-evolutionary approach takes into account not only the interactions between a specific farming insect and a single cultivated crop, but also the interactions between the insect garden insect and other pathogenic and mutualistic microbes that have recently been discovered in insect gardens. Some of these microorganisms, like the cultivars, are also controlled by the insect farmers for particular reasons, just as they are with the cultivars. A more accurate description would be that an insect garden is not a pure monoculture, but rather an ecological community that has been sequestered and designed to include various interacting microorganisms, some of which are helpful to the farmers and others that are harmful. The nature of insect-microbe interactions in gardens, the evolutionary origins of these interactions, and the convergence and divergence of evolutionary trajectories that culminated in the extant insect agricultural systems will all need to be investigated in order to gain a comprehensive understanding of the principles of insect agriculture[5].

1.3 Introduction to The Insect-Agriculture Systems:

Ants, termites, and beetles are the only three insect families that have been studied for their ability to develop behaviorally sophisticated systems of insect agriculture.

1.3.1 Ant Fungi-culture:

The fungus-growing ants are a monophyletic group in the tribe Attini, consisting of about 220 known species and many more undiscovered species. Attine ants are found exclusively in the New World and are at their most diverse in the wet woods of tropical South America, where they are thought to have originated in their supposed evolutionary home. When it comes to food, ant larvae and adults are obligate agriculturists. Their produced fungus is the only source of nutrition for the larvae and a significant source of nutrition for the adults. Despite the fact that adults may augment their meals by consuming plant fluids, the grown fungus are nutritionally adequate to sustain the ants even in the absence of extra nutrients from other sources such as plants. When daughter queens carry tiny pellets of natal-nest mycelium inside their infrabuccal pockets, which are pouches found in the mouthparts of all ants, garden fungus are transferred vertically through generations. Worker castes of the evolved leafcutter ants consist of a diverse group of workers with differing sizes and physical characteristics, each of which is trained to perform a specific job[6].

A number of distinct ant lineages grow their fungus on a variety of diverse surfaces. While the leafcutting genera Atta and Acromyrmex mainly utilize freshly cut leaves and flowers as their primary gardening substrate, the ancestral gardening substrate used by the so-called lower attines includes flower parts, arthropod frass, seeds, wood pieces, and other similar plant detritus. Although each attine system has its own set of symbionts, all attine systems include at least four of them: (a) fungus-growing ants; (b) their fungal cultivars; (c) mutualistic antibiotic-producing actinomycete bacteria; and (d) garden parasites from the ascomycete fungal genus Escovopsis. Additional bacteria and yeasts may be found in attine gardens, and they may work as mutualists, for example, by secreting digesting enzymes or antibotics to benefit one another.

1.3.2 Fungal Farming:

Of the more than 2600 species of termite known, approximately 330 species of the Macrotermitinae subfamily grow for food a specific fungus of the genus Termitomyces. Nests are usually established by the future queen and a single reproductive pair. They firmly lock themselves in a hard clay cell where they bring the first sterile workers' brood. In most termite species, a new colony has a fungal strain from windy sexual activity Termitomyces spores soon after nest establishment and starts building the first gardens. These spores originate from fruiting organisms (mushrooms) originating from mature thermite colonies. The production of the fungus seems to have been approximately timed with the period in which the first foraging workers emerge from a new nest a few months after the nesting phase. Termite gardens are developed on dead plants, which are only degraded partly, such as leaf litters, dead grass, dead woods, or dry leaves[7].

Termite Gardens are constructed of spore-containing faecal pellets in rooms constructed within the mound or distributed in the ground by the termites. Fecal pellets are continually added to the top of the comb and fungal mycelium quickly penetrates the new substratum. After many weeks, the fungus begins to form vegetative nodules, which the termites eat. These nodules are a rich nitrogen, sugar and enzyme source. The nodules are also coated with indigestible asexual spores (conidies), such that their consumption is used to inoculate the faeces with spores that pass through the intestine undamaged and are subsequently placed in new comb with the deposition of faecal material. Mature pebbles are also used, although nutritionally lower than nodules.

1.3.3 Beetle Fungal Farming:

About 3400 of the 7500 species in the weevil subfamily Scolytinae make up Ambrosia beetles. Although certain types are especially specialized in colonizing piths, big seeds, fruit and leaf petioles, most ambrose beetles build tunnel networks in tissue of the plants. The word ambrosia refers to fungus grown by beetles on gallery walls, where they eat as a sole or almost exclusive source of sustenance. The beetles rely on the fungus from which vital vitamins, amino acids and sterols are obtained.

In Xyleborini, a huge monophyletic tribe of about 1300 species, the most sophisticated fungicians are among the ambrosia beetles. We concentrate mainly on this group of ambrosian beetles in our review. While the lives of the Xyleborini vary widely, most have a number of fungal features. In the Xyleborini, there is a gendered division of labor; only women do horticultural chores, while men are short-lived and flightless. After mating, women scatter to the new host substratum and carry the fungus in specific pockets called mycangia. Once inside a new hostel, founders lay eggs and tender the resultant garden and brood on the walls of the dug tunnels. They are able to regulate the development of the fungal crop and, in some cases, the composition of its various fungal species, in ways not completely understood. If the woman dies, the garden is soon overtaken by polluting fungus and bacteria, leading to the death of the brood[8].

The ambrosian xyleborin beetle gardens are not, as previously thought, pure monocultures, but are usually made up of a mixture of mycelial fungi, yeasts and bacteria. These combinations were called multi-species complex academics, who proposed that the beetles can utilize weak substrate such as wood rather than any particular microorganism, as a whole. However, majority of the studies that followed showed that one "principal" fungus always prevails in kite gardens. Moreover, beetles usually only contain the main Mycangium fungus, and the cultivation effort of the female beetles tends to prefer the primary fungus that gives the most nutritional advantage. Some auxiliary fungus also assists the growth of beetles, although their survival alone is frequently severely decreased. The main fungus as the intended crop is affected by these findings while secondary fungi, yes and bacteria are contaminated by "weeds" or may be furthermore used in the gardens, alongside the predicted function of auxiliary bacteria and Yeasts in attine gardens.

1.4 Insect Agriculture Evolutionary Origins:

Phylogenetic analyses show nine distinct insect farming origins. In Amezzo, fungal production occurred just once, presumably in the rainforest of the Amazon. In termites’ fungal production also had a single genesis, in the African rainforest about Mya. In ambrosian beets, however, farming occurred seven times independently from Mya, six times in different nonxyleborin lines, and once in the Xyle-Borini ancestor around Mya. While macrotermitin and xyleborin common ancestors each domesticated a single, unique major cultivar clade to which their offspring have adhered throughout all subsequent development, attine ants have connections with numerous, independently domesticated crop lines. Interestingly, there are no documented instances of reversals in the nine agricultural insect lines from agricultural to non-agriculture, which suggests that the shift to fungal production is a dramatic, potentially permanent transformation that is very restrictive to future development.

For the autonomous development of insect agriculture, two major models have been proposed, the 'consumption first' vs the 'transmission first' models. In the first model of consumption, an insect lines start incorporating fungus into their more generalist diet, then become specialized fungi, and ultimately develop adaptations to grow fungi. In the first type of transmission, the insect lines begin to associate with a fungus as a carrier for the fungus and then nourishment is derived from it and then ultimately becomes a fungal cultivator. A third option is the development of an insect pulsation association, because the insects initially utilize fungus as a source of antibiotic substances, such as Reticulotermes speratus, which derives antibiotic protection against mixed-egg piles of fungal sclerotics. Finally, insect-associated fungi may undergo even more complex evolutionary processes from the exploitation of a pre-existing insect-pilon connection by one insect lineage in a common nest habitat. When these fungi adapted to insects are encountered. The evolutionary connections between beetle and ant fungi, however, are not supported in the latter theory and inconsistent with the estimated times of genesis of such insect fungal partnerships.

It is unknown for attine ants whether agriculture originated from a condition of ancestral fungal, antibiotic acquisition or fungal vectoring. The termite agriculture most probably came from the first consumption path, since many non-farming termed species seek and feed on fungal-infested wood, which indicates that non-farming predecessors of the farming termites may also have feed on fungi. Even before the formation of fungi, the non-agricultural ancestors of fungal beetles seem to have linked them, since many of their more primitive nongardening scolytines are fungal vectors without any apparent reliance on their fungal companions. This indicates that the fungi are not nutritionally dependent on the roots of fungal production in the different lines of the ambrosia beetle. However, a lot of non-ambrosian scolytines carry in mycangias fungus and feed on ungardened mycelium like larvae which colonize host plants and feed as new adults on spore layers which line the pupal panes. Some of the seven agricultural origins in beetles therefore seem to have been following the first path of transmission, while others followed the first route of consumption[9].

Insect farming is confined to growing of fungus instead of plants, predominant in human farming. While it is true that certain insects are specialized in host plants which they defend from other herbivores, none of them have all four agricultural components mentioned above. One may question whether circumstances led insects to develop fungal instead of plant farming. Indeed, fungal agriculture has many benefits over plant farming, and plant features may even prohibit simple cultivation. Firstly, unlike fungus, plants usually have strict light and space needs, excluding them in underground or otherwise confined nests of insects from cultivation. Such nesting behaviors may promote fungal growth via the protection of food crops from undesirable consumers and wind-dispersed pathogens. In addition, fungus may be kept continuously in a non-sexual mycelial form, which provides a more constant food supply, as opposed to plants, which typically need frequent pollination for long-term culture. Thus, although seeds and plants may be collected easily, fungi are probably more cultivable, which explains the prevalence of fungal rather than plant agriculture among insects.

Ant, termite, and the vast majority of beetle agriculturists are gregarious creatures. Each and every one of the ants and termites is eusocial, as shown by the distribution of reproductive labor among workers, cooperative brood care, and generational overlap. In the known ambrosia beetle world, only one species is considered eusocial; the others are sub-social, in which a single female is responsible for her brood, or communal, in which multiple fertile females work together to care for their broods and garden. Sociality may have aided in the development of agriculture because of the natural benefit that agriculture has in the division of labor, which allows for the partitioning of agricultural duties and the enhancement of agricultural efficiency, which is advantageous to agriculture[10].

Farmers of ants and termites, for example, divide their agricultural tasks into a series of conveyor-belt-like stages that are divided among different worker castes, each of which is specialized in a single main task: foraging; processing and cleaning substrate before incorporation into the garden; planting mycelium onto new substrate; monitoring and weeding of the garden; or disposal of diseased or senescent garden. Because of the logistical challenges associated with researching beetle behaviour in their hidden tunnels, task partitioning has not been studied in ambrosia beetles too far. Task partitioning is expected to improve efficiency in a variety of situations, including protection against nest and garden thieves, disease monitoring in gardens, and modifying optimum growing conditions for crops.

2. DISCUSSION

The development of clonal monocultures over an extended period of time is perhaps the most remarkable characteristic of insect agriculture. Monoculture increases agricultural efficiency through economies of scale, and clonality preserves the desirable properties of the crop by preventing sexual recombination. However, these advantages come at a cost of two things: one is the loss of genetic diversity, and the other is the loss of genetic diversity. Due to reduced genetic diversity in the crop, there is an increased susceptibility to the rapid spread of disease mutations, as well as a decreased resistance to fast-evolving diseases as a result of this increased vulnerability. Human and insect farmers are also subject to these economic trade-offs.

Instead of a single, “magic bullet” strategy, the insect farmers' solution to the monoculture-disease problem appears to be a combination of several strategies, including (a) crop sequestration, (b) intensive monitoring of crops for diseases, (c) access to a population-level reservoir of crop genetic variability, and (d) management of disease-suppressive fungi. Large-scale crop sequestration is the least practical of these techniques in human agriculture because human foods need exposure to sunlight and because greenhouse farming is prohibitively expensive in comparison to other methods. It is possible for some crops (for example, in greenhouse environments) to conduct intensive (e.g., daily) disease monitoring of every single crop plant; however, hourly monitoring of the kind carried out in insect agriculture appears to be prohibitively expensive for human agriculture as a whole, according to the authors.

Designing human agricultural systems that more effectively take use of microbial consortia that are known to have positive roles in crop nutrient absorption and disease resistance is a new strategy that is now being pursued. Microbes in the rhizosphere have long been recognized as important partners in the production of some crops and trees. Recent research has shown the existence of disease-suppressant bacteria that reside on the root exudates of crops and generate antibiotics that defend the crop against infections. Microorganisms from the phyllosphere and endophytic microbes have both been shown to have disease-suppressive effects on agricultural plants in studies. Research on rhizosphere, phyllosphere, and endophyte microorganisms of human crops is a relatively young area, and there are still many helpful microbes to be found and put to use in the agricultural sector in general.

3. CONCLUSION

Perhaps it is through methods like these that humans can gain the greatest insight from insect farmers, especially if disease-suppressant microorganisms are ever to be introduced into human agriculture. When developing these strategies, agriculturists should keep in mind that current human crops were not necessarily selected for their abilities to interact with auxiliary microbes during the domestication process, i.e., the alleles in the wild ancestors that were optimally mediating such interactions may have been lost during the domestication process. It is possible that studying the microbial consortia associated with the wild populations from which the ancestors of human-domesticated crops were initially originated would be necessary to conduct a thorough assessment of the potential applications of auxiliary microorganisms in agriculture. This kind of domestication within the context of coevolving microbial consortia may very well be the main factor explaining the insect farmers' 50-million-year-old agricultural success.

REFERENCES

1. J. D. Evans *et al.*, “The i5K initiative: Advancing arthropod genomics for knowledge, human health, agriculture, and the environment,” *Journal of Heredity*. 2013, doi: 10.1093/jhered/est050.

2. E. Crotti *et al.*, “Microbial symbionts: A resource for the management of insect-related problems," *Microbial Biotechnology*. 2012, doi: 10.1111/j.1751-7915.2011.00312.x.

3. A. Papanicolaou *et al.*, "The whole genome sequence of the Mediterranean fruit fly, Ceratitis capitata (Wiedemann), reveals insights into the biology and adaptive evolution of a highly invasive pest species," *Genome Biol.*, 2016, doi: 10.1186/s13059-016-1049-2.

4. D. Vanderpool, R. R. Bracewell, and J. P. McCutcheon, "Know your farmer: Ancient origins and multiple independent domestications of ambrosia beetle fungal cultivars," *Mol. Ecol.*, 2018, doi: 10.1111/mec.14394.

5. J. Gowdy and L. Krall, "The economic origins of ultrasociality," *Behavioral and Brain Sciences*. 2015, doi: 10.1017/S0140525X1500059X.

6. A. van der Meij, S. F. Worsley, M. I. Hutchings, and G. P. van Wezel, "Chemical ecology of antibiotic production by actinomycetes," *FEMS Microbiology Reviews*. 2017, doi: 10.1093/femsre/fux005.

7. F. O. Aylward *et al.*, "Convergent bacterial microbiotas in the fungal agricultural systems of insects," *MBio*, 2014, doi: 10.1128/mBio.02077-14.

8. A. R. I. Lindsey *et al.*, "Comparative genomics of the miniature wasp and pest control agent Trichogramma pretiosum," *BMC Biol.*, 2018, doi: 10.1186/s12915-018-0520-9.

9. L. M. Boykin, C. D. Bell, G. Evans, I. Small, and P. J. De Barro, "Is agriculture driving the diversification of the Bemisia tabaci species complex (Hemiptera: Sternorrhyncha: Aleyrodidae)?: Dating, diversification and biogeographic evidence revealed," *BMC Evol. Biol.*, 2013, doi: 10.1186/1471-2148-13-228.

10. C. J. Jackson *et al.*, "Structure and function of an insect α-carboxylesterase (αesterase7) associated with insecticide resistance," *Proc. Natl. Acad. Sci. U. S. A.*, 2013, doi: 10.1073/pnas.1304097110.