ISSN: 2641-1784

Research Article

Advance in Environmental Waste Management & Recycling

Pathways of Aphids and Grasshoppers to Radiate From Stress to New Species

S. H. Hodjat*

Prof. Jalal Afshar Zoological Museum, Faculty of Agriculture, University of Tehran, Karaj, Iran

*Corresponding Author
S. H. Hodjat, Prof. Jalal Afshar Zoological Museum, Faculty of Agriculture, University of Tehran, Karaj, Iran.

Submitted: 2024, Nov 01; **Accepted:** 2024, Nov 28; **Published:** 2024, Dec 18

Citation: Hodjat, S. H. (2024). Pathways of Aphids and Grasshoppers to Radiate From Stress to New Species. *Adv Envi Was Man Rec, 7*(3), 01-04.

Abstract

Environmental stress can evolve new insect species by epigenetic inheritance and changes in their morphology and physiology. Recent phylogenetic research has emphasized that the adaptation of insects to feed on plants increased their diversity. Discovery of many fossil aphid species trapped in tree resins proved that they started with sexual or holocyclic life cycles by overwintering in the egg stage during the winter. Adelgidae and Phylloxeridae appeared about 200 Mya after Coccoidea. They were rapidly adapted to feed on trees and herbaceous plants after the acquisition of cyclical parthenogenesis life cycle 140 Mya. The economic importance of aphids and grasshoppers and aphid relation to their host is by direct damage or carrying viral plant diseases. Phylogenetic research indicates that Orthoptera radiated 300 Mya and grasshoppers radiated in the Pliocene of the Cenozoic period about 59.3 Mya. The radiation of 40 Orthopteran orders representing 15 super-families of monophyletic insect group is composed of Ensifera and Caelifera suborders. In this article, the possible route for speciation in aphids and Chorthippus grasshoppers is discussed. Two articles in the appendix describe specific information about Gomphocerinae and Chorthippus species of Iran.

1. Introduction

First, the short history of aphid historical evolution and the possibility of their genetic changes to surpass plant resistance preventing aphids from feeding on them is described. An example is given by the difficulties in Aphis species identification. Then Orthoptera phylogenetic and radiation by reference to Gomphocerinae radiation by female choice of copulation and the appearance of various plasticity and traits in their population is described. Taxonomic identification of *Chorthippus* is associated with female choice of copulation with special acoustic characteristics. Difficulties of *Chorthippus* of Iran identification are explained in attached articles.

The variation in aphid life cycles and their diversification on various host plants increased their number of species [1,2]. Aphids of Europe are composed of about 1600 species and subspecies with mostly holocyclic life cycles producing sexual morphs in autumn and females lay eggs on trees to overwinter cold winter conditions. They spend summers on trees and reproduce parthenogenetically on herbaceous summer hosts or on crops. They are adapted to the environmental stressful conditions and hymenopteran parasitoid wasps that have some effects to reduce their population. Many aphid species are attended by ants that are attracted to their sweet secretions or they are crop pests and resistant to insecticide. Their winged parthenogenetic forms spread on crops and affect them by viral diseases [3]. In Iran a list of 324 aphid species with short descriptions of their biology, host plants and distribution or migration in the summer is described [4]. Aphids' host plant change occurs by increased temperatures and lack of rainfalls.

Stress-induced changes in the biology of aphids and grasshoppers on crops are evolutionary processes for agricultural insect pests (AIPs) causing outbreaks or escaping the stressors during their life period. Resistance to pesticides, diapause, acclimatization, migration, and the number of their generations are adaptations to increase the insect pest fitness on crops. The rapid evolution of AIP increases their damage to crops. The following processes give extra chances to AIP that by genetic evolution and insect radiation increase their damage to crops

- Stress induces variation to specific genomic sites to increase insect population and adapt them to farm conditions.
- Genomic change linked to AIP increasing fitness.
- AIPs exposed to various stressors show homothetic physiological response to heritable DNA methylation by histone modification.

• Transposable elements (TE) regulation and mobilization effects on morphogen.

Genotypes of *A. gossypii* by mutation or recombination can produce genetic variable strains by asexual reproduction. Variable genotypes by mutation or recombination have different potentials in viral pathogen transmission to plants. Viral transmission genes produce plant responses for defense called gene-for-gene interaction. Interspecific genetic and phenotypic variability in *A. gossypii* was measured in 49 clonal lineages against plant defense genes or gene-for-gene interaction. It was found that the level of genetic melon aphid polymorphism in various clones is associated with the phenotypic variability of aphid genotypes responding to plant defense. It is concluded that environmental stress in aphid can shape plant resistance to viral infestation by aphis [5].

I-APHIDS

• Phylogeny and History of Evolution

Protein complex that is active in mitochondria and functions as riboproteins are intercellular structures made of both RNA and protein for protein synthesis in the cell ribosome or nucleosome. The ribosome reads the messenger RNA (mRNA) sequence and translates the genetic code into a specified string of amino acids. Post-transcriptional diversity in riboproteins highlights similarities and differences of proteins studied molecular evolution and phylogenetic inference in Precambrian divergence by ribosomal DNA (rDNA) sequences in a number of living organisms [6]. Pairs of primers were selected to facilitate the analysis of rRNA. Analysis was carried out and aligned for sequences of four nuclear rDNA and two mitochondrial ribosomal (rRNA) genes. Identified regions of test genes are likely to give information to identify closely related species of organisms in relation to food or their distribution. rDNA array in 15 sections by use of PCR (Polymerase Chain Reaction) are primers that can be selected in relation to the analysis of divergence of the rRNA genes to answer systematic problems in the hierarchy of food and geographic distribution . By using allozyme and microsatellite markers it is found that *Acyrthosiphon pisum* collected from pea, clover, and alfalfa plants were genetically divergent. Therefore, there are some host-associated genetic differences between biotypes [7].

• Aphid Biotypes and Pathway To Radiation

The main aphid radiation is recorded about 80 MYA when they selected a holocyclic life cycle producing sexual morphs on trees and, in the spring, fundatrix produced parthenogenesis morphs of winged and wingless and migrated to herbaceous plants. These aphids, if faced with stressful conditions, migrate to new hosts. Adaptation to new hosts sometimes produces new species, which is radiation with phylogenetic branching for speciation. Host changing usually produces similar aphids called biotypes. Biotypes with similar morphology are also called biological species with different traits. They may have different genetic compositions with little morphological and physiological differences from the main population. The detailed lists of aphid biotypes are published.

Morphological differences between *Hyalopterus pruni* and H. amgdali are in the length-width ratio of the cornicle (Siphunculi) of the wingless parthenogenesis forms. The ratio is less in H. amgdali than H. pruni. The morphology alone is not a suitable character for the separation of the two aphid species. The differences in the two species are clearly seen after sexual morph production on their different host plants with different sexual morphs on each host [8]. In Iran, H. pruni is collected from apricots, peaches, prunes, and almonds. Both aphid species are using Prunus as a primary host and Poaceae species as summer hosts in central and northern parts of Iran. There are many factors such as insect-host plant relationships and various stressors that cause phenotypic plasticity in insects [9].

Stress can produce continuous, discrete, and fixed variation in morphology and cause a systematic problem for their identification. The main point for radiation of aphid separation by choosing another host is by sexual morphs that usually appear on trees. The host-related species are called peach and plum aphids. Sycamore aphid *Drepanosiphum plaanoides* survival depends on the trait in reproducing at the onset of warm conditions in the spring. Early spring heat increases the mortality of their second generation. Therefore, the first generation increases their reproduction of nymphs, but in the second generation, a longer living adult in winged parthenogenesis form has less reproduction [10]. Therefore, biotypes of fundatrix from first or second generation aphids are likely to produce species adapted to the time of warm weather onset in the spring. Speciation and parthenogenesis of aphids by changing summer hosts throughout the year without sexual reproduction in mild winter temperatures is common in *Myzys persicae*, *Aphis gossypii,* and *A. craccivora*. They are likely to have less variation compared to holocyclic species [11].

Following are suggestions by the perplexity site and other sources to show a possible route of aphid biotypes to change into new species.

Holocyclic aphids choose a new winter host for fundatrix appearance in spring. An example is *Hyalopterus pruni* and *H. amigdali.*

Aphid symbiotic relationships play a crucial role in Acyrthosiphon pisum adaptation to use Vicia villosa as a new host [12].

Myzus cerasi, or black cherry aphid, overwinters on cherry and their summer hosts with low survival is Gallium umaparine. Transitioning to a new host plant resulted in low survival rates due to the need for significant transcription changes, particularly in genes related to detoxification and metabolic processes [13].

Clones of *Myzus persicae* were collected from *Prunus persicae* and secondary hosts; *Nicotiana taba*cum, *Brassica oleracea, Beta vulgaris,* and *Capsicum annuum* from various regions of Greece. In the northern regions, they were holocyclic, producing sexuals, but in the south, they lived parthenogenetically predominantly. All clones were reared in the laboratory on potato and their color or morphological differences were measured. It is concluded that 89% of 1723 specimens studied could be classified into two groups [14].

The preference of aphids feeding on cultivated sweet lupine compared to wild bitter plants. Many aphid species such as *Acyrthosiphon pisum* (Ap), *Aphis craccivora* (Ac), *Aphis fabae* (Af), *Macrosiphum albifrons* (Ma), *M. euphorbiae* (Me), *Myzus persicae* (Mp), and M. ornatus (Mo) feed on lupines. It was found that only lupines with reduced alkaloids were preferred by these aphids for feeding on lupines. The difference in acceptance of aphids to feed on sweet or wild bitter lupines was related to their alkaloid contents. It was interesting to find that previously resistant cultivars to aphid infestation needed only five generations of *Macrosiphum albifrons* to become adapted for feeding on resistant cultivars with increased alkaloid contents [15].

• Speciation in Aphids

Aphids have evolved diverse strategies for host plant association and have developed the ability to change their host plants in evolutionary time. New species described as a result of genetic variability, phenotypic plasticity, and their symbiotic relationships often means that they rapidly evolved various routes of escaping plant secondary metabolites. There is evidence that metabolic and other stressors can induce evolution by DNA epigenetic modifications and genomic variation in agricultural insect pest (AIP) aphids. Adaptive reaction to stress by DNA methylation in CpG, and histone modification is the first step for producing resistance to stress. Mutagenesis and variation in genome structure are factors for inducing new characters into increasing genotypes [16]. Stress can only increase individual resistance to stressors by differential performances. Insects have individual responses to stress by metabolic signaling pathways. Adapted individuals to stress can resist or decrease the harmful stress effects of sub-lethal doses of insecticides or resist starvation and heat stress. Epigenetic changes can pass the resistance to the next generations by genetic DNA modifications after a few generations of bisulfite sequencing (WGB-seq). Gene regulation by DNA methylation in an experiment design can obtain multi-omic data on AIP to assess the mechanism of adaptive evolution in morphology and physiological variations. The morphological distinction between Aphis L. species in Iran was only possible by comparing identified species in the British Museum [17].

II-GRASSHOPPERS

Orthoptera radiated 300 mya and Acrididae originated in the Paleocene era of the Cenozoic period about 59.3 mya. There are more than 25,700 known Orthoptera species that contain crickets, katydids, locusts, and grasshoppers. Acrididae is divided into Ensifera with long antennae and Caelifera with shorter antennae. The phylogeny of Orthoptera after mitogenomic gene sequences divided the order into the following five superorders

- Tridactyloides
- Tetrigoidea
- Eumastacoidea
- Pneumoroidea
- Acridoidea

Acridoidea is divided into eight subfamilies

- Cyrtacanthacridina
- Calliptaminae
- Catantopinae
- Oxyinae
- Melanopinae
- Acridina
- Oedipodinae
- Gomphocerinae

Bei-Bienko and Mishchenko published keys to the fauna of the USSR and adjacent countries in two parts translated to English in 1963 [18]. A list of aphid species in Iran and Afghanistan was published by [19]. Extinction of many aphids is reported when Shumakov's list of Iranian Orthoptera in 1963 is compared with Garai's list in 2010 [20]. The identification of Gomphocerinae, especially Chorthippus spp., needs careful comparison of female attraction to male song and requires careful acoustic studies. The attached article shows the putative efforts of Hodjat (Appendix 2) to separate Chorthippus species by morphological keys.

• The ER Role in Spreading Depression (SD) of Locust

At high temperature or anoxia stress temporarily shuts down the neural-muscular system of the locust that by stressing depression-like (SD) events become motionless for short periods of time. The detailed function of SD is similar to mammalian pathogenesis of stress by affecting the cortical tissue in the cerebral cortex. The endoplasmic reticulum (ER) potassium channels are vital in maintaining K+ homeostasis in locusts. Studies have identified ATP-sensitive cationic channels in the ER that are involved in the regulation of intercellular or intracellular ion concentration of K+. These channels influence the overall ionic balance of locust cells. SD in locusts is the phenomenon that has a relation to stress response with ER interaction. A wave of cellular depolarization followed by a period of suppressed neural activity in locusts under environmental stress can serve an adaptive function by conserving energy and terminating neural network operation during stressful conditions. The detailed function of SD stress in locusts and ER affecting cell physiology in response to stress is described in reviews by various authors [21].

Schistocerca gregaria (Forskal) under low density is green and in cryptic form. At high densities, they produce conspicuous yellow and black markings with morphological, physiological, and behavioral changes. Insect hormones are involved in activating anti-oxidative enzymes. Adipokinetic hormones (AKHs) regulate insect metabolism and provide flight energy in Locusta migratoria (L.). Three peptide structures: two octapeptides and one decapeptide are involved in the onset of flight. They regulate flight energy by metabolic neurohormones that are released from the corpora cardiacum (CC) . Free radicals are quickly converted to water and oxygen to prevent damage to cells. They can have a beneficial effect in destroying or damaging cells or detoxifying pois. For example, free radicals are produced in Anopheles albimana Petrocchi for killing its parasite, Plasmodium [22].

Stridulation and Chorthippus Species Complex. Refer to appendix 1.

2. Discussion

It is clear that the morphology and physiology of insect species in different ecological conditions will change, and if they succeed in surpassing environmental stressors, they are adapted to their niche by some changes in their morphology and physiology[23]. The subject of adaptation, plasticity, and variation in insects is basically discussed for defining species. The author is faced with many problems in identifying Iranian species of Aphis and *Chorthippus*. Molecular phylogeny of insect identification by barcoding, genomics, and other -omics suggest ways for accurate insect identification[24]. Studying evolution is underway by scientists to explain achievements of Aphis and Chorthippus possible routes of speciation. Attached articles explain examples of difficulties in identifying aphids and *Chorthippus* species by morphological keys.

References

1. Jousselin E and Elias M. (2019). Testing host-plant driven speciation in phytophagous Insects: a phylogenetic perspective. Hal-02400722.
2. Von Dohlen, C. D., & Moran, N. A. (1995). Molecular phylogeny of the Homoptera: a paraphyletic taxon. *Journal of molecular evolution, 41,* 211-223.
3. Loxdale H, and Balog A. (2018). Aphid specialism as an example of ecological-evolutionary divergence. *PUB-Med-28836372.*
4. Hodjat SH, Editor, G. Lampel. (1993). A list of aphids and their host plants in Iran. *University of Shahid Chmran, Publication 195*.148 pages.
5. Lombaert E, Carletto J, Piotte C, Fauvergue X, Lecoq H, and two others. (2009). Response of the melon aphid, Aphis gossypii, to host-plant resistance: Evidence for high adaptive potential despite low genetic variability. *Entomologia Experimental et Applicata 133*: 46-56. 2009.
6. Hillis, D. M., & Dixon, M. T. (1991). Ribosomal DNA: molecular evolution and phylogenetic inference. *The Quarterly review of biology, 66*(4), 411-453.
7. Khanal N, Vitek C and Kaiat R. (2023). The known and unknown aphid biotypes, and Their role in mediating host plant defenses. *Diversity,15*,186. MDPI.
8. Basky, Z., & Szalay-Marszo, L. (1987). Study of isolation mechanisms in the Hyalopterus pruni and Hyalopterus amygdali complex. *Population structure, genetics and taxonomy of aphids and thysanoptera: proceedings of [the] International Smyposia, held at Smolenice, Czechoslovakia, Sept. 9-14, 1985/edited by J. Holman [et al.].*
9. Hodjat SH, & Saboori A. (2021). Variatioin, Plasticity and possible Epigenetic influences in species belonging to the tribe Gomphocerini (Orthoptera; Gomphocerinae): A review. *Journal of Crop Protection. 10*(1): 1-18.
10. Wellings PW. (1985). Reproduction tactics in the sycamore aphids. In the population structure, genetic and taxonomy of aphids and Thtsanoptera. Proceeding of Symposia: Czechoslovakia, 1985. *SPB Academic Publishung, The Hague*. Pp: 19-28.
11. Hodjat SH. (1985). Population structure genetics and Taxonomy of aphids and thysanoptera. Proceeding of International Symposia at Smolenice. *Czechoslovakia. Aphis species of Iran.* PP; 370-376.
12. Lu H, Zhu J, Yu J, Chen X, KangL, and Cui F. (2020). A symbiotic virus facilitates Adaptation to host plants by suppressing Jasmonic acid responses. PUB-MED, 19-0016-R.
13. Thorpe P, Escudero-Martinez CM, Akker S, E-v, and Bos JIB (2020). Transcriptional changes in the aphid species *Myzus cerasi* under Different host and environmental conditions. *Insect Molecular Biology 2020*.
14. Margaritopulus JT, Tsitsipis JA, Zintzaras E, and Blackman RE (2000) .Host correlated morphological variation of Myzus persicae (Hemiptera;Aphididae) populations in Greece. *Bulletin Entomological Research, 2000*; 20 (3):233-244.
15. Thieme T, Truberg B, and Dixon AFG. (2014). Phenotypic plasticity in the response of aphids to host plant quality. *European Journal of Entomological Sciences. 4*(2), pp, 92-96.
16. Gunn, J. C., Christensen, B. M., Bueno, E. M., Cohen, Z. P., Kissonergis, A. S., & Chen, Y. H. (2024). Agricultural insect pests as models for studying stress-induced evolutionary processes. *Insect Molecular Biology, 33*(5), 432-443.
17. Hodjat SH. (1985). Population structure genetics and Taxonomy of aphids and thysanoptera. Proceeding of International Symposia at Smolenice. Czechoslovakia. *Aphis species of Iran*. PP; 370-376.
18. Bei-Bienko, G. Y., & Mishchenko, L. L. (1963). Locusts and Grasshoppers of the USSR and Adjacent Countries. *Jerusalem: Israel Program for scientific translations*.
19. Shumakov, E. M. (1963), Acridoidea of Afghanistan and Iran. *Academie des Science de L, URSS. 284 pp*.
20. Hodjat SH. (2019). A view on the historic and contemporary acridid fauna (Orthoptera: Caelifera:Acrididae) of Iran-A call for conservation efforts. *Journal of Crop Protection 2019, 8*(2): 135-142.
21. Rodgers CI, Armstrong GAB and Robertson RM. (2010). Coma in response to Environmental stressin the locust: A model for cortical spreading depression. *Journal of Insect Physiology, Elsevier Ltd*.
22. Crowther, C., Bonser, S. P., & Schwanz, L. E. (2024). Plasticity and the adaptive evolution of switchlike reaction norms under environmental change. *Evolution Letters, 8*(1), 64-75.
23. Garai, G. A. (2010). Contribution to the knowledge of the Iranian Orthopteroid insects. *Esperiana, 15*, 393-417.
24. Hodjat SH. (2024). Cellular stress and its impact on Insect Morphogenesis as crop pests. Chapter 14 of a book submitted to Prof. Jalal Afshar Zoological Museum, Faculty of Agriculture, University of Tehran, Karaj, Iran. Hal-04664230
25. Moran NA. (1999). Molecular data support a rapid radiation of aphid in the Cretaceous and multiple origins of host alteration. *Biological Journal O Linnean Society, 2000*. 71; 689-717.