

Available online at [GSC Online Press Directory](https://www.gsconlinepress.com/)

GSC Biological and Pharmaceutical Sciences

e-ISSN: 2581-3250, CODEN (USA): GBPSC2

Journal homepage: <https://www.gsconlinepress.com/journals/gscbps>

(REVIEW ARTICLE)



Evolutionary changes adopted by aphid species in order to survive in changing environment

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Publication history: Received on 18 December 2019; revised on 29 January 2020; accepted on 01 February 2020

Article DOI: <https://doi.org/10.30574/gscbps.2020.10.2.0245>

Abstract

Aphid belongs to the major category of plant's pests that can influence the plant by directly sucking the cell sap and also by spreading many plant diseases. As a counter response against intense control or management tactics applied by human being, which may include chemical treatment, use of resistant plant varieties, release of biological control agents, in-order to suppress the aphid population and ultimately to avoid the damages caused by aphid, aphid has evolved evolution in their behavior. In this review, we highlight some remarkable evolutionary responses to anthropogenic pressures in agro-ecosystems and discuss the mechanisms underlying the ecological and evolutionary success of aphids. We outline the symbiotic relationship between aphid and many other biological agents that ensure the survival of aphid.

Keywords: Aphid; Evolution; Management; Biological control; Behaviour; Chemical control

1. Introduction

Aphids (Insecta: Hemiptera: Aphididae) are from ancient group of insect pests that suck the cell sap and also having parasitic mode of damage for many of crops. Their origin is estimated 220-210 million years back in the history [1]. They mainly belong to temperate regions [2]. They are known for wide range of life cycle with little variation in color and form [3]. There are 5000 known species of aphid out of which about 100 species are referred as pests to agricultural crops [4]. When biotic as well as a-biotic factors are in favor, female aphid with wings give birth to wingless female aphid during mid to late October, after matting. This newly born wingless female aphid gave birth to new female wingless aphid after getting mature within 7 days. Wingless female aphid reproduces asexually and gave birth to 60-80 young-ones during the reproduction period that comprises of 20-30 days. Therefore, several generations of aphid occur at a time and rapid increase in aphid population can be seen [5]. They can reproduce at any temperature above freezing temperature but 55-77°F is the temperature where maximum reproduction takes place [6]. Females produced through parthenogenesis (reproduction process where egg is developed into embryo without involvement of sperm from male) are viviparous (development of young-one within the body of female). Parthenogenetically females are usually produced when day length is long. This benefits the aphid in rapid increase in population during growing seasons [7]. During long night duration (as during winter season) male aphid and sexual females are produced. And during this period of reproduction eggs are produced that are resistant to injury that could be caused by frost. Whether winged or wingless female is to produce is decided by several factors including available plants quality and also by the population of aphid already existing [8]. Winged females dispersed to the distant areas in-order to avoid reducing the crowding pressure. Winged females are more likely to move with air and is considered as the cause of population dispersal. Winged females are less fertile when compared with the wingless population [9].

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2. Variation in reproduction mood with global warming

Only sexual reproduction mood cannot ensure success of a specific organism in an ecosystem for long period of time. Therefore, every third specie of aphid have obligated lineage associated with obligate parthenogenesis [10]. Species existing in extremely cold winter regions are devoid of obligate parthenogenesis, hence they have female which is viviparous which cannot lay cold resistant eggs [11]. Obligate lineages can be seen dominate in specific crop aphids, wherever winter temperature allows their persistence [12]. This case has been studied in pea aphid *Acyrtosiphon pisum* where they are never reported to produce obligate parthenogenesis sexual females due to the presence of recessive allele, since males are produced during fall season and males during winter season [13]. OP males that have been produced during winter season can transfer this recessive allele to further produced generations producing highly prolific OP genotypes that can be adaptable to many of specific external conditions [14]. Thus, OP lineages have increased their geographical distribution, which enable them to compete with global warming. When aphid first flight data was analyzed there was one month advanced first flight time from 1974- 2014 data, in UK [15]. This change in behavior or response shown by aphid is due to the selection pressure imposed on aphid by global warming.

3. Defense against biological control agents

Along with the use of aphicides, aphid control strategies may also include control by biological agents which are in small number by population in natural ecosystem. Parasitoid wasps are most widely used control agents in aphid control programs. As application of control agents-imposed selection pressure on aphid population, as a counter response aphid has developed such traits which are resistant against these control agents [16]. Aphid lives in association with *Buchnera aphidicola*, which is a free-living gram-negative bacterium, it helps aphid in growth and reproduction process. There are many other species of bacteria which are transmitted by parent aphid to its progeny to live in symbiotic relation with it. These bacteria express facultative symbiotic relationship with aphid specie [17]. *Aphidius ervi* is a parasitic wasp that lay eggs within the body of aphid, but the presence of *Hamiltonella defensa* protects aphid specie by excreting toxin that toxify the eggs of parasitic wasp and ultimately protects aphid [18]. *Pandora neoaphidis* is a fungal insect pathogen which can cause disease to aphid but in case when *Regiella insecticola* it cannot cause disease [19]. Other than defensive symbiotic relationship in aphid species several types of responses can also be seen such as immune response and behavioural response [20].

4. Emergence of insecticide resistance

Since 1940s, aphid species are facing insecticides till now. This use of aphicides for aphid control has forced aphid to develop resistance against major class of chemicals in-order to survive. So far resistance in 14 species of aphid has been reported in literature [21]. *Myzus Persicae* is aphid specie in which variation in response against neonicotinoids is seen after several years of first exposure to neonicotinoids. *M. persicae* peach aphid was the first aphid specie in which chemical resistance was reported. Up to date about 6 various types of resistance mechanisms has confirmed in *M. persicae*. Out of six mechanisms two important mechanisms involves major modification in metabolic mechanism such as carboxylesterase is produced in large amount when aphid is under organophosphates and carbamate stress. Increased production of cytochrome P450 is carried out as resistance mechanism against neonicotinoids [22]. Other resistance management mechanisms may involve modification in target site. Resistant target site has been reported in case of neonicotinoids, Organochlorine and pyrethroid [23]. Genetic based resistance has also been evidenced in aphid.

5. Selection of new host plant

It is a general perception that aphid only rely on one or few species of host plants [24]. However, change in the available plant quality, plant population and defensive mechanism of plant to avoid pest attack, impose a serious selection pressure on pest [25]. These may include the introduction or importation of new plant species to a specific area or changes in defensive mechanism of already existing plant species. This leads towards evolutionary changes in aphid in-order to exist. *Myzus persicae* green peach aphid fulfil its nutritional needs from Peach plant but in case when primary host plant is not available it gets its need from *Nicotiana tabacum* tobacco plant; it is an evidence of evolutionary changes in aphid specie [26]. *N. tabacum* natively belongs to northern America while aphid origin is thought to be Europe and Asian continent, adaption of aphid to tobacco plant has occurred after 16th century probably this adaption is due to increased expression of P450 gene as a resistant gene. P450 gene is a resistance expressing gene against neonicotinoids [27]. In-order to avoid resistance expressed by plants against aphid, aphid invade new plant varieties. Nucleotide binding site of melon plant have vat-gene that repel aphid attack. When aphid attack melon plant to suck the cell sap, vat gene becomes activated and alternatively activating plant defence system. When study was conducted to confirm the effect of vat gene on aphid, vat gene and non- vat gene plants was exposed to aphid attack. Results showed

that few of aphid biotypes can survive or can feed in the presence of vat gene. Most of aphids avoid melon plant with vat gene [28].

6. Rapid adaptation of aphid in changing environment

Aphid is an interesting group of insects to study because they are affected by both biotic as well as abiotic factors surrounding them. These surrounding factors cause variation in traits. Varied traits can be used as predictor to predict the changes change in environment [29]. When aphid specie is facing selection pressure necessary changing in the genetic makeup is made to cope with the pressure. This change in gene can already exist or can be the result of required beneficial mutation. Genetic studies conducted related to aphid genes revealed that there is a lot of gene variation found in aphid and its ancestors even in populations produced by parthenogenesis [30]. Diversified genes can be the result of slow and episode wise recombination process or by gene mutation. Parents produce new allele of a gene and spread it to its offspring. This allele when undergo through parthenogenesis and transferred to new progeny in its new form. Gene mutation is rarely beneficial but in case of aphid large population is present which supports in a way that when a beneficial population occur it is passed on to its progeny strengthening the chances of aphid survival even in varying conditions [31]. Resistance against pesticides is a result of fast mutation while adaption to new environmental conditions is result of slow mutation [32].

7. Conclusion

Aphid is a serious pest of many crops including cotton. Many of evolutionary changes that enable aphid to cope with unfavourable conditions has been reported. In order to control the evolving aphid it is needed to use all the management tactics in sustainable manners. This study is to review the need of integrated pest management, as control tactics to suppress the population of aphid.

Compliance with ethical standards

Acknowledgments

There is no conflict of interest among authors.

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How to cite this article

Raza T, Rehman T, Yaseen H, Malik Muhammad WI and Razzaq S. (2020). Evolutionary changes adopted by aphid species in order to survive in changing environment. GSC Biological and Pharmaceutical Sciences, 10(2), 09-13.
