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Sıcaklık Değişkenliğinin Afitlerin Yaşam Döngüsüne Etkileri: Dört Örnek Tür

Gazi GÖRÜR[1]*, Gizem BAŞER[2], Hayal AKYILDIRIM BEĞEN[3], Özhan ŞENOL[4], Başak AKYÜREK[5]

[1,2,4]Niğde Ömer Halisdemir University, Science and Art Faculty, Department of Biotechnology, 51000, Niğde
[3]Artvin Coruh University, Health Services, Vocational School, 08000, Artvin
[5]Amasya University, Amasya Technical Sciences, Vocational School, 05000, Amasya

[1]https://orcid.org/ 0000-0001-5713-418X
[2]https://orcid.org/0000-0002-4588-786X
[3]https://orcid.org/ 0000-0003-2028-5827
[4]https://orcid.org/ 0000-0002-7747-0866
[5]https://orcid.org/0000-0001-7317-9193
*Sorumlu yazar: gazigorur@yahoo.com

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ÖZ

Küresel ısınma hayvan türlerinin çoğu dâhil bütün organizmaları, özellikle afitleri büyük oranda etkileme potansiyeline sahiptir. Dört afit türü, *Cinara cedri, Cinara tujafilina, Metopolophium dirhodum, Pterochloroides persicae*, soğuk ve kurak bölgelerde yaygın olarak varolanın aksine kış mevsiminde Niğde ve Artvin illerinde partenogenetik nesillerini devam ettirmiştir. Belirlenen türlerin Niğde ve Artvin koşullarında holosiklik yaşam döngüsü göstermeleri nedeniyle kış sezonunu yumurta halinde geçirmeleri gerektiği değerlendirilmiştir. Kış aylarının ortalama sıcaklık değerlerinde son iki yılda meydana gelen sıcaklık değişkenliklerin etkisiyle bu değişkenliklerin etkisinin göstergesi olarak daha fazla partenogenetik nesil vermelerine imkân vermiştir. Elde edilen bulgular sıcaklık artışının afitlerde daha fazla nesil vermeleri ve bu nedenle ciddi zararlı olacakları genel yaklaşımıyla uyumluluk göstermiştir.

Effects of Temperature Fluctuations on Aphids Life Cycle: Four Case Species

Research Article

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ABSTRACT

Global warming has great potential to influence all organisms including many animal species, in particular aphids. It has been shown that four aphid species, *Cinara cedri, Cinara tujafilina, Metopolophium dirhodum, Pterochloroides persicae,* maintained their parthenogenetic generations in Niğde and Artvin Provinces during the winter season in contrast to common life cycles related with cooler and dry conditions. It has been considered that determined aphid species should spend winter season as an overwintering egg as these species mainly show holocyclic life cycles in Niğde and Artvin. Fluctuations in winter average temperature in Niğde and Artvin during last two years enable them to produce more parthenogenetic generations as an indicator of the influences of the temperature fluctuations. These findings are in coincidence with the general approaches that increase in temperature most probably result in more generations in aphid species and in turn let these species to become a severe pest.

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1.Introduction

Climate changes including fluctuations and increase in temperature have been one of the most important ecological effects in recent years for all living organisms. The ten warmest years existed on earth for January–December in the 1880–2021 meteorological record are 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020 and 2021 respectively. The average global land and ocean surface temperature for January–December 2021 was 0.84°C above the 20th century average of 13.9°C. Moreover, there is also increase in each month average temperature year to year (URL 2). A similar scenario exists also in Turkey. Predicted temperature increases in Turkey for 2100 compared with 1960-1990, based on a large number of climate models are about 2.5-3°C in the north, 3-3.5°C over central and south-western regions, and 3.5-4.0°C in the east. Turkey's annual mean temperature in January 2021 was 5.4°C. This value is 2.7°C above from 1981- 2010 normal (2.7°C). This value made January 2021 the second warmest January since 1971 (URL 3). Global climate change especially an increase in average temperature has a significant impact on the geographical distribution, population dynamics, and phenology of many organisms, particularly for insects. The life history of insects such as growth, development, survival, feeding, reproduction and migration closely related with environmental temperatures as they are poikilothermic. Thus, how to overcome the effects of global warming becomes a fundamental issue for both individual success and maintenance of insect population. Previous studies have shown that climate warming can increase the growth and development of insects, leading to earlier appearance and longer life cycle with producing more generations in different insects such as butterflies, bees, dragonflies and damselflies, flies, beetles and also aphids. Aphids with a small body size, being a highly invasive species due to phenotypic plasticity, showing efficient insecticide resistance, unique reproduction style and short development time, developing defenses against natural enemies and plant chemistry, having a strong symbiotic relations with obligate and facultative bacteria, being an obligatory (even parasitic) phytophagous insects with close relationships with host plants range are susceptible to the change in environmental conditions, especially to temperature changes (Sepulveda et al., 2021). These characteristics let aphid species being a model group to study the effects of global warming on animals, particularly insects. The life cycle of the green peach aphid *Myzus persicae* is directly affected from environmental temperature. While the reproductive mode of *M. persicae* is generally cyclically parthenogenetic in colder conditions, they have cyclical parthenogenesis, as well as obligate parthenogenesis in warmer regions. Several studies have reported that climate change, especially temperature change, has a significant influence on the occurrence and growth of aphids. Aphids are considered as sentinels of climate change, as there are early detected and much larger numbers of individuals flying around resulting in more aphids flying in spring and early summer, when host plants are particularly susceptible to damage. It has been shown that every 1°C rise in mean temperature for January and February resulted in two weeks earlier flight for the peach potato aphid, *M. persicae* (URL 1).

Wu et al. (2020) showed that the first appearance dates and the first migration period of the three aphids (*M. persicae, Aphis gossypii* and *Sitobion avenae*) become earlier, while the disappearance and the last migration dates were slightly delayed. The Rothamsted Insect Survey (RIS) found that the first migratory date of 55 aphid species in the UK was earlier and the average migratory season of most species was significantly extended, although different species showed varied response patterns due to warming temperature (Bell et al., 2015). Furthermore, the first emerge of the nymphs of juniper aphid, *Cinara juniperi,* in the temperate areas of Poland is earlier as local spring temperature increased (Durak et al., 2016). Moreover, during the warmer early winter of 2013–2014, female adult aphids of *Stomaphis* spp. successfully lived for four months longer than usual (Depa et al., 2015). This study aimed to find out whether there were any impacts of the recognized increase in winter temperature to followed aphid species.

2. Material and Methods

Four aphid species (*C. cedri, C. tujafilina, M. dirhodum, P. persicae*) followed about two years (from March 2020 to December 2021), especially during the fall and winter season, and then samples were collected from Niğde and Artvin Provinces. All sampled population recorded and preserved according to standard methods followed by aphidologist (Blackman and Eastop, 2022). Collected samples defined according to identification key offered by Blackman and Eastop (2022). Biology, host plant usage and taxonomical statues derived for each defined species (Blackman and Eastop, 2022; Favret, 2022; URL 5) and colony appearances of each species on host plants photographed. Meteorological data related to global warming and sampling area were obtained (Table 1). Voucher specimen of the defined species are deposited at the Biotechnology Department of the Niğde Ömer Halisdemir University.

Table 1: Average temperature of both Artvin and Niğde Province (URL 4)

	Average Temperature (°C)			
	Artvin Province		Niğde Province	
	January	February	January	February
Long term (About 80 years)	2.6	3.8	-0.3	1.1
2020	3.0	4.9	0.4	2.1
2021	3.6	5.7	3.1	2.9

3. Results

The obtained information for four species during field observations and detections, *M. dirhodum, C. cedri, C. tujafilina, P. persicae,* combined and compared with the general information provided in literatures. Results for each species are given in alphabetical order.

3.1. *Cinara (Cinara) cedri* Mimeur, 1936, Cedar bark aphid

C. cedri shows monoecious holocylic life cycle, they feed on the bark, branches and trunks of the various *Cedrus* spp. (*atlantica, brevifolia, deodora, libani*) and distributed in Europe, the Mediterranean region, North Africa, south-west and Central Asia, also been introduced to North America and Argentina (Blackman and Eastop, 2022; URL 5). It has been shown that they might cause severe damages related with colonization intensity (Oğuzoğlu and Avcı, 2019). Generally, they produce oviparae and males in October-November to produce egg to ensure to survive under the harsh conditions, and then following the overwintering egg individuals hatch around middle March-April on the same host plant (Blackman and Eastop, 2022; URL 5). Recent studies clearly indicated how temperature changes dramatically influence the life history traits of the *C. cedri* (Ji et al., 2021). The detected *C. cedri* population in Niğde Province clearly demonstrated how increased average temperature extended the parthenogenetic reproduction period of the population on the *Cedrus* sp. As Niğde is one of the cold regions in Turkey, it was expected to detect overwintering egg around October, but there was still parthenogenetic population heavily colonized on the branch of the *Cedrus* sp. even in January (Figure 1) indicating more than 10 generations at least in this period.

Figure 1. *Cinara cedri* population on *Cedrus* sp. in Niğde on 10th January

3.2. *Cinara (Cupressobium) tujafilina* (Del Guercio, 1909), Cypress pine aphid, Thuja aphid

C. tujafilina is an almost entirely monoecious anholocyclic species feeding mainly on the undersides of branches near the trunk - or, in midsummer, on roots of many genera of Cupressaceae including *Chamaecyparis, Cupressus, Juniperus* and *Platycladus orientalis,* mostly on the twigs of the *P. orientalis* (Syn: *Thuja orientalis*) and it is almost cosmopolitan (Blackman and Eastop, 2022; URL 5). It has been shown that they rarely produce sexual forms and eggs especially in cooler and higher altitude regions and in laboratories as shown in Iran, Poland and Kyrgyzstan. Mainly produces three to five overwintering generations on the roots of *P. orientalis* in winter. Related with environmental temperature changes also *C. tujafilina* changes feeding sites, aphids migrate from leaves to the main trunk at 13 °C, and move to root at 0°C (Blackman and Eastop, 2022; URL 5). Actually findings parthenogenetically produced population on *P. orientalis* at the 16^{th}/19^{th} February is not big surprise even mean temperature is not suitable for minimum development, but they supposed to be on the bark/trunk/root instead of being on the twigs-branches of the *P. orientalis* related with mean temperature in both Artvin and Niğde (Figure 2). Detecting population on the twigs of the host plant in the middle of the February most probably indicating that environmental conditions did not force them to move on the host plant root.

Figure 2. *Cinara tujafilina* colonies detected on *Platycladus orientalis;* **a)**16^{th} February in Artvin, **b)**19^{th} February in Niğde

3.3. *Metopolophium(Metopolophium) dirhodum* (Walker,1849), The rose grain aphid, rose-grass aphid

M. dirhodum shows heteroecious holocyclic life cycles. They mainly feed on wild and cultivated *Rosa* spp. in spring, and produce sexual forms and lay eggs on these host plants related with environmental conditions basically in the middle of the fall season. They migrate to various species of Poaceae and Cyperaceae at the beginning of June. Large colonies on cereals might cause economic damage either directly feeding phloem sap or transmitting maize mosaic virus and barley yellow dwarf virus. It has been shown that some overwintering on grasses occurs in some parts of Europe, New Zealand and Brazil, meaning that they easily change their life cycle related with environmental conditions. In heteroecious holocyclic life cycle, overwintering eggs laid on rose during October-November hatch in March to give fundatrices in April, the return migration of gynoparae to rose occurs in October-November, and their offspring develop to oviparae_(Blackman and Eastop, 2022; URL 5). In contrast to this general pattern, it has been shown that studied *M. dirhodum* population maintained their normal parthenogenetic reproduction phase on *Rosa* sp. by February during the year of 2020 to 2021 in both Artvin and Niğde Province (Figure 3). They extended their parthenogenetic survival more than two months indicating at least six more generations.

Figure 3. *Metopolophium dirhodum* species detected on *Rosa* sp., **a**)13th February in Niğde, b) 16th February in Artvin

3.4. *Pterochloroides persicae* (Cholodkovsky, 1898), Black peach aphid, Brown peach aphid, Peach trunk aphid, Giant black bark aphid

P. persicae form dense colonies preferably in the shaded part of the *Prunus* spp., and produce huge amount of honeydew and thus are usually attended by ants. This species probably originated from East-Central Asia, has extended distribution through westwards and southwards into Europe and the Middle East where it has become an important pest of peach and almond trees (Blackman and Eastop, 2022; URL 5). Most populations of the *P. persicae* are monoecious anholocyclic in warmer regions on *Prunus* spp. In a cooler and dry region, it is monoecious holocyclic on *Prunus* spp. (*armeniaca*, *persica*, *spinosa*), sexual forms were recorded in a higher altitude of the Iran and also detected in Poland (Blackman and Eastop, 2022; URL 5). Individuals start to hatch from the egg in Middle of the March in a cooler condition where they produce overwintering eggs. Interestingly, population determined just hatched from eggs on the host plant, both *Prunus dulcis* and *P. persica* was on 13th February which was about a month earlier than expectation (Figure 4). Recently, it has been shown that increase in both the number of generation and extending distribution let *P. persicae* to become a severe pest for *Prunus* spp.(URL 5), it is possible to determine a similar tendency in Turkey as they hatch earlier and produce more generations even in a cooler and dry area like Niğde Province.


Figure 4. Hatched *Pterochloroides persicae* individuals from overwintering egg on *Prunus dulcis* in Niğde on 13th February.

4. Discussion

Global warming generally favors the better development of aphid populations due to the very short generation time and their great reproductive capacity. An increase of only 1 °C in the winter mean temperature advances the timing of spring migration in aphids by two weeks and has shown that an increase in temperature of only 2.8 °C would allow the number of generations produced per year to increase from 18 to 23 (Harrington, 1994; Harrington et al., 1995; Yamamura and Kritani, 1998) and also larger population size. The warmed temperature may endorse the growth of aphid populations and substantial increase by shortening the development time and increasing in fecundity (Hulle et al., 2010). Mounica et al. (2020) pointed out that maize aphid, *Rhopalosiphum padi*, reduced development time and significantly increased the number of the generations under accelerated temperature. Four studied aphid species, *C. cedri, C. tujafilina, M. dirhodum, P. persicae,* showed similar pattern in Niğde and Artvin Province even there were species specific differences also recognized. While *M. dirhodum*, *C. tujafilina* and *C. cedri* showed about 6 to 10 more generations related with temperature changes, *P. persicae* showed about a month earlier hatch from the egg meaning at least 3 more generations at least in this certain condition. Durak and Sobkowiak (2013) clearly indicated how increased temperature influenced life history traits of the *C. tujafilina* and also other aphid species adding more generations. In addition to the increased temperature impacts on the number of the generations produced, the minimum temperature for aphid development is generally about 4 °C, but this also changes within and between species (Hulle et al.,2010). When the mean temperature of the Niğde and Artvin Provinces were taken into consideration, there are also species specific interactions detected while 3 of the species continued to reproduce parthenogenetically, *P. persicae* produced overwintering egg and hatched early from the egg. Despite the numerous studies carried out to clarify global warming effects on the aphid populations, it is not possible to launch a general decision on whether all aphid populations will be affected (Newman, 2003; Pritchard et al., 2007). The long term data on aphids can be used to achieve more accurate decision about the increased temperature effects on each aphid species especially for agricultural aspects, that is one of the most vulnerable area to the predicted climate change with an adverse impact on crop loses, and aphid management. Whether the increase in the number of the generations under this definitive situation both in Niğde and Artvin Provinces are continuous, there should be longer term studies should be conducted and population should be followed carefully. World aphid fauna consists of about 5300 defined aphid species (Favret, 2022) and about 615 species listed for Turkey aphid fauna (Görür et al., 2022). It has been considered that global warming effects on aphid species are species specific and more study might be carried on especially agriculturally important aphid species. As Turkey is one of the countries that is going to be affected adversely from global warming, more coordinated and detailed study is planned to follow increased temperature influences on aphid species that may increase their capacity of damaging especially agriculturally important host plants. To reach a more accurate and plausible pattern about how global warming affects aphid species, what is going to be result, the overall influences of the global warming on aphid-host plant-natural enemy interactions should be studied in a local and global scale.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

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