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Original article (Orijinal araştırma)

Development and survival of *Bemisia tabaci* reared on *Solanum nigrum* under field conditions

Doğa koşullarında *Solanum nigrum* üzerinde üretilen *Bemisia tabaci*'nin gelişmesi ve canlılık oranı

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Summary

Climate change is an important driver of changes in the abundance and distribution of insect pests. Whiteflies (Hemiptera: Aleyrodidae) are important plant pests and virus vectors in many agricultural systems worldwide. Among them, the sweet potato whitefly, *Bemisia tabaci* (Gennadius) is considered the most devastating pest of various crops worldwide. As a part of a multinational effort to develop a climatic model that will predict *B. tabaci* population outbreaks, the developmental time and survival rate of *B. tabaci* were evaluated under field conditions in Adana, Turkey in autumn 2013 and early summer in 2014. The temperature and humidity were measured hourly during the experiments. Results indicated that temperature has significant effects on immature life stages development and mortality of *B. tabaci*, and an inverse relationship between development time and temperature was observed. The total preadult developmental time of *B. tabaci* declined with increasing temperature, and was 24.6 and 21.8 days at average field temperatures of 21.4°C and 24.6°C in autumn and early summer, respectively. Higher total preadult mortality rate occurred in early summer 2014 due to considerably higher larval mortality. These results will be used for the development of new tools for combating the pest as a part of an IPM program.

Keywords: Black nightshade, development, survival, sweet potato whitefly

Özet

İklim değişikliği zararlı böceklerin yoğunluğu ve dağılımındaki değişmelerin önemli bir nedeni olarak görülmektedir. Beyazsinekler (Hemiptera: Aleyrodidae) dünyada pek çok tarımsal sistemin önemli bitki zararlısı ve virüs vektörleridir. *Bemisia tabaci* (Gennadius) tüm dünyada beyazsinek grubu içinde en önemli zararlı olarak kabul edilmektedir. Bu zararlının salgınlarını tahmin etmeye olanak sağlayacak bir klimatik model geliştirmek üzere uluslararası bir araştırmanın parçası olarak Adana ilinde doğa koşullarında 2013 yılı sonbaharı ve 2014 yılı yaz başında *B. tabaci*'nin gelişmesi ve canlılık oranı incelenmiştir. Çalışma süresince sıcaklık ve nem değerleri her saat kaydedilmiştir. Çalışma sonucunda sıcaklığın *B. tabaci*'nin gelişme süresi ve canlılık oranını önemli ölçüde etkilediği ve gelişme süresi ile sıcaklık arasında ters korelasyon olduğu saptanmıştır. *B. tabaci*'nin ergin öncesi gelişme süresi sıcaklıktaki artışla birlikte kısalmış olup, sonbahar ve yaz başında doğa koşullarındaki ortalama 21.4°C and 24.6°C sıcaklıkta sırasıyla 24.6 ve 21.8 gün olarak tespit edilmiştir. Zararlının ergin öncesi toplam ölüm oranı larva dönemindeki ölümlerin fazlalığından dolayı yaz başında daha yüksek bulunmuştur. Bu çalışma ile elde edilen sonuçlardan Entegre Zararlı yönetimi programlarında yeni yaklaşımların geliştirilmesinde yararlanılabilecektir.

Anahtar sözcükler: Köpek üzümü, gelişme, canlılık, tatlı patates beyazsineği

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Introduction

Climate change is one of the principal challenges confronting insects worldwide. Global warming and associated climatic changes are expected to affect the biological and ecological characteristics of insect species through direct effects on the physiology of organisms and through indirect effects on their habitat (Root et al., 2003). Climate warming of 1.1 to 6.4°C is expected to be beneficial for insects currently experiencing some level of cryo-stress in parts of their geographic distribution (Bale & Hayward, 2010). In temperate and Western Mediterranean areas, it is predicted that higher temperatures will have a positive impact on insect populations resulting from increased summer temperatures, as well as extended active season. However, insect species are already adapted to their optimum thermal range during the summer in climatic zones that are already warm, like the Eastern Mediterranean basin. Therefore, climate change is expected to have a strong effect on population growth rate of the insect species during cooler seasons while increased summer temperatures is predicted to contribute only slightly to the population expansion (Canto et al., 2009). Whiteflies (Hemiptera: Aleyrodidae) are important plant pests and virus vectors in many agricultural systems worldwide. Among them, the sweet potato whitefly, *Bemisia tabaci* (Gennadius) is considered the most devastating pest of vegetables, ornamentals, and agronomic crops throughout the tropical and subtropical regions of the world, because it can transmit over 200 species of plant viruses (Perring, 2001). Previous distributions of the *B. tabaci* species were limited to regions between the 30th latitudes; however the pest has invaded every continent in the world except Antarctica in the past two decades. Based on climate models, *B. tabaci* populations are expected to expand to the regions where increasing temperatures will eliminate frosts, allowing year round breeding (Bezemer et al., 1998). Due to the extreme polyphagy of the species, the effects of such changes will probably be profound and may lead to substantial ecosystem-wide changes (Trumble & Butler, 2009).

Temperature is an important factor for development and population growth of all insects (Bale et al., 2002; Auad & Moraes, 2003; Musana et al., 2013). Knowledge of how temperature influences the development and mortality of an insect species is important for understanding its potential population growth and geographical distribution. Such knowledge can help policy makers to understand the vulnerability of plant farming systems to major insect pests in the face of global warming. Furthermore, this may also help scientists to develop cost effective and environmental friendly Integrated Pest Management strategies (Musana et al., 2013) As a part of a multinational effort to develop a climatic model that will predict *B. tabaci* population outbreaks, this study was carried out to document developmental response (developmental rate and survivorship, which are important components of population growth) of *B. tabaci* (MEAM1 species, previously called biotype B) at temperature conditions between late-spring and early-summer (May-June) and between early and mid-autumn (September-October) in Adana located in Mediterranean region of Turkey.

Materials and Methods

Bemisia tabaci adults were collected from black nightshade (*Solanum nigrum* L.) in Adana and reared on the same plant in the laboratory to obtain sufficient number of individuals for experiment in controlled conditions. Experiments were also carried out on leaves of *S. nigrum* in the field using plexiglass clip-cells (55 x 70 mm) with their upper side covered by muslin in autumn (between September 20 and October 24 in 2013) and early-summer (between May 29 and June 23 in 2014). A couple (one male and one female) of *B. tabaci* was transferred to lower surface of each leaf covered by a plexiglass clip-cell. In total, 12 couples of the whitefly and 6 plants (two leaves per plant) were used to initiate experiments. After one day of oviposition, adults were removed from the cells. Hatching time and mortality of eggs laid by adults were determined by daily observations in both seasons. After the eggs were hatched, developmental time and the mortality of larval and pupal stages were also recorded by daily observations. The temperature and humidity near the clip cells were measured hourly during the experiments using a hobo device set on the plants.

Data on development time were analyzed by t-test ($P \leq 0.05$).

Results and Discussion

The temperature and humidity values collected hourly during the experiments revealed that the fluctuations in both climatic factors within and among days were higher in autumn (Figure 1). Developmental times of *B. tabaci* on *S. nigrum* in field conditions are shown in Table 1. The values obtained for incubation period of eggs in autumn and early summer were similar ($p > 0.05$) since average field temperatures during this period for both seasons were almost the same; 23.8°C in autumn and 23.9°C in early summer. Developmental time of larval stage decreased with increasing temperature, and was 12.9 days at average 20.9°C in autumn and 9.2 days at average 24.1°C in early summer ($p < 0.05$). There was no effect of increasing average field temperature (21.6°C in autumn and 26.2°C in early summer) on pupal developmental time which might be due to the high temperature fluctuations within and among days ($p > 0.05$) (Figure 1, Table 1). It is also possible that extremely higher relative humidity during pupal period in early summer 2014 interfered with pupal development (Figure 1, Table 1). Increase in average field temperature resulted in a significant decrease of total preadult developmental time, as the value obtained for developmental time in early summer 2014 was smaller than that obtained in autumn 2013 ($p < 0.05$) (Table 1). Similar to our results, inverse relationship between total preadult developmental time of *B. tabaci* and increasing temperatures was observed in laboratory conditions (Muniz & Nombela, 2001).

Mortality rates of *B. tabaci* on *S. nigrum* in field conditions are shown in Table 2. Even though average field temperatures during egg incubation period in both seasons were highly similar, the egg mortality in autumn 2013 was higher than that in early summer 2014. It may be attributed to the higher fluctuations in temperature and humidity within and among days in autumn 2013. Increase in average temperature during larval period resulted in higher mortality rate at the larval stage, whereas the mortality rate at the pupal stage decreased with an increasing temperature. A considerably higher larval mortality yielded also a higher total preadult mortality rate in early summer 2014 when compared to autumn 2013.

Results from this study indicate that like most ectothermic organisms, the sweet potato whitefly was sensitive to changes in temperature affecting its developmental time and survival. The developmental time of total preadult of the whitefly declines with increasing temperature. This inverse relationship between development time and temperature has been also observed in other insect species (Uygun & Atlihan, 2000; Auad & Moraes, 2003; Emana, 2007; Atlihan & Chi, 2008; Musana et al., 2013). On the other hand, this study was carried out in two different seasons, and seasonal changes may affect the nutritive composition of plants, including secondary plant metabolites which might affect developmental times and mortality rate.

As long as species optima for development are not exceeded, there might be positive direct responses of insects to increasing temperature conditions, such as accelerated development rates. Polyvoltine species, which are economically important insects like *B. tabaci*, will benefit from accelerated development rates allowing for an earlier completion of life cycles and the establishment of additional generations within a season (Lange et al., 2006; Jönsson et al., 2009).

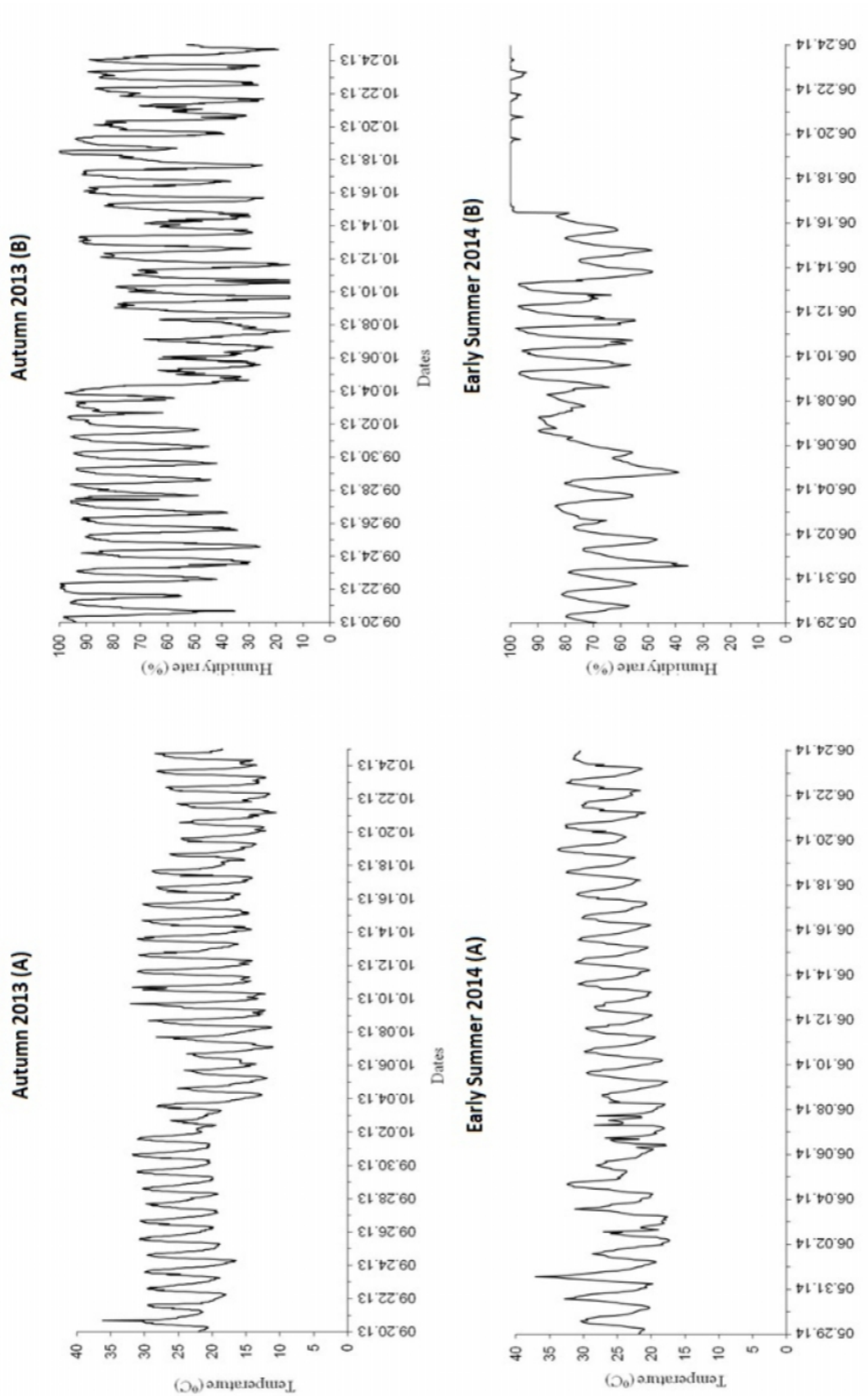

Figure 1. Temperature (A) and humidity (B) measured hourly during the experiments in Adana in autumn 2013 and early summer 2014.

Table 1. Developmental time (Mean ± SE) of *Bemisia tabaci* reared on *Solanum nigrum* in the field in autumn 2013 and spring 2014. Average field temperatures (AFT) and average field relative humidity (AFRH) were used for developmental time of each stage and total preadult

Season	n*	AFT (^{0}C)	AFRH (%)	Egg (day)	AFT (^{0}C)	AFRH (%)	Larva (day)	AFT (^{0}C)	AFRH (%)	Pupa (day)	AFT (^{0}C)	AFRH (%)	Total Preadult (day)
Autumn 2013	264	23.8	72.7	7.7 ± 0.35	20.9	60.4	12.9 ± 0.61	21.6	62.3	4.2 ± 0.17	21.4	63.8	24.6 ± 0.60
Spring 2014	254	23.9	67.9	8.6 ± 0.14	24.1	77.6	9.2 ± 0.15	26.2	99.4	4.0 ± 0.19	24.6	80.1	21.8 ± 0.13

* Number of individuals that survived to adulthood. t-test (P≤0.05) was used for statistical analysis.

Table 2. Preadult mortality of *Bemisia tabaci* reared on *Solanum nigrum* in field in autumn 2013 and early summer 2014. Average field temperatures (AFT) and average field relative humidity (AFRH) were used for developmental time of each stage and total preadult

Season	n	AFT (^{0}C)	AFRH (%)	Egg (%)	AFT (^{0}C)	AFRH (%)	Larva (%)	AFT (^{0}C)	AFRH (%)	Pupa (%)	AFT (^{0}C)	AFRH (%)	Preadult mortality (%)
Autumn 2013	365	23.8	72.7	17.3	20.9	60.4	8.9	21.6	62.3	4.0	21.4	63.8	27.7
Early summer 2014	387	23.9	67.9	9.0	24.1	77.6	26.1	26.2	99.4	2.3	24.6	80.1	33.5

Experiments in this study were carried out at temperature conditions which may be accepted optimum or near the optimum for development and survival of *B. tabaci*. Optimal temperature conditions for development, survival and fecundity of most insects occur above 20°C and under 30°C (Uygun & Atlihan, 2000; Morgan et al., 2001; Atlihan & Özgökçe, 2002; Diaz & Fereres, 2005). Further field experiments should be carried out in order to understand how extreme temperatures affect development, survival and fecundity of *B. tabaci*. Experiments with virtually identical setups like the ones described here were conducted in several countries around the Mediterranean. The combined data produced by this concerted effort are expected to provide the necessary parameters for developing a reliable population dynamics model capable of integrating climatic data that will permit the prediction of *B. tabaci* population outbreaks under current and future climatic conditions.

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References

Atlihan, R. & M.S. Özgökçe, 2002. Development, Fecundity and Prey Consumption of *Exochomus nigromaculatus* Feeding on *Hyalopterus pruni.* Phytoparasitica, 30(5): 443-450.

Atlihan, R. & H. Chi, 2008. Temperature-dependent development and demography of *Scymnus subvillosus* (Coleoptera: Coccinellidae) reared on *Hyalopterus pruni* (Homoptera: Aphididae). Journal of Economic Entomology, 101: 325-333.

Auad, A.M. & J.C.D. Moraes, 2003. Biological aspects and life table of *Uroleucon ambrosiae* (Thomas, 1878) as a function of temperature. Scientia Agricola, 60: 657-662.

Bale, J.S., G.J. Masters, I.D. Hodkinson, C. Awmack, T.M. Bezemer, V.K. Brown, J. Butterfield, A. Buse, J.C. Coulson, J. Farrar, J.E.G. Good, R. Harrington, S. Hartley, T.H. Jones, R.L. Lindroth, M.C. Press, I. Symrnioudis, A.D. Watt, & J.B. Whittaker, 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Global Change Biology, 8: 1-16.

Bale, J.S. & S.A.L. Hayward, 2010. Insects overwintering in a changing climate. Journal of Experimental Biology, 213: 980-994.

Bezemer, T.M. & T.H. Jones, 1998. Long-term effects of elevated CO_2 and temperature on populations of the peach potato aphid *Myzus persicae* and its parasitoid *Aphidius matricariae*. Oecologia, 116: 128-135.

Canto, T., M.A. Aranda & A. Fereres, 2009. Climate change effects on physiology and population processes of hosts and vectors that influence the spread of hemipteran-borne plant viruses. Global Change Biology, 15: 1884-1894.

Diaz, B.M. & A. Fereres, 2005. Life table and population parameters of *Nasonovia ribisnigri* (Homoptera: Aphididae) at different constant temperatures. Environmental Entomology, 34: 527-534.

Emana, G.D., 2007. Comparative studies of the influence of relative humidity and temperature on the longevity and fecundity of the parasitoid, *Cotesia flavipes*. Journal of Insect Science, 7(19): 1-7.

Jönsson, A.M., G. Appelberg, S. Harding, & L. Bärring, 2009. Spatio-temporal impact of climate change on the activity and voltinism of the spruce bark beetle, *Ips typographus*. Global Change Biology, 15: 486-499.

Lange, H., B. Okland, & P. Krokene, 2006. Thresholds in the life cycle of the spruce bark beetle under climate change. International Journal of Complex Systems 1648: 1-10.

Morgan, D., K.F.A. Walters, & J.N. Aegerter, 2001. Effect of temperature and cultivar on pea aphid, *Acyrthosiphon pisum* (Hemiptera: Aphididae) life history. Bulletin of Entomological Research, 91: 47-52.

Muniz, M. & G. Nombela, 2001. Differential variation in development of the B- and Q-biotypes of *Bemisia tabaci* on sweet pepper *Capsicum annuum* L. at constant temperatures. Environmental Entomology, 30: 720-727.

Musana, P., J.S. Okonya, S. Kyamanywa & J. Kroschel, 2013. Effect of temperature on the development, reproduction and mortality of the sweetpotato weevil *Cylas brunneus* (Fabricius) (Coleoptera: Brentidae). Uganda Journal of Agricultural Sciences, 14: 77-84.

Perring, T.M., 2001. The *Bemisia tabaci* species complex. Crop Protection, 20: 725-737.

Root, T., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig & J.A. Pounds, 2003. Fingerprints of global warming on wild animals and plants. Nature, 421: 57-60.

Trumble, J. & C. Butler, 2009. Climate change will exacerbate California's insect pest problems. California Agriculture, 63: 73-78.

Uygun, N. & R. Atlihan, 2000. The effect of temperature on development and fecundity of *Scymnus levaillanti*. BioControl, 45: 453-462.