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КЛИМАТИЧЕСКИЕ ИЗМЕНЕНИЯ И САРАНЧА: ЧЕГО ОЖИДАТЬ?

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CLIMATE CHANGES AND LOCUSTS: WHAT TO EXPECT?

В статье рассматривается воздействие глобального потепления на экологию саранчи. Область проведенного исследования – аутэкология итальянской, марокканской и азиатской саранчи, а также представителей отряда Прямокрылых – кузнечиков Melanoplus sanguinipes и Melanoplus bivittatus. Показано, что в условиях потепления климата вспышки численности саранчи могут стать более частыми и приводящими к большему ущербу для сельского хозяйства, чем в настоящее время. Это является серьезным вызовом для специалистов в области мониторинга и борьбы с нашествиями саранчи.

***Ключевые слова**: климат, изменения климата, глобальное потепление, насекомые, саранча, вспышки численности саранчи, мониторинг и борьба с нашествиями саранчи.*

The article describes the main features of the impact of global warming on insects, particularly grasshoppers Melanoplus sanguinipes and Melanoplus bivittatus, Italian, Moroccan and Asian locust. The field of research is the autoecology of some Orthoptera. It is shown, that the locust outbreaks may become more frequent and severe under warming climatic conditions. Climate warming, which causes shifts in locust distribution, phenology and voltinism, is a serious challenge for both, locust monitoring and management.

***Keywords**: climate, climate changes, global warming, insects, locusts, locust outbreaks, locust monitoring and management.*

Introduction

Climatic changes became manifest in the last several decades of the 20th century. These changes involved a significant increase of the variability of weather (extreme cold and sudden thaw in the fall, winter, and springs, more abnormally hot days in the summer), an increase in the frequency and intensity of extreme weather events (tornadoes, storms, hurricanes, floods, droughts), and an increase of uneven rainfall, melting of glaciers and permafrost, rising sea levels, etc. [2, 15, 16]. One of the most powerful manifestations of climate change is global warming. Over the past 100 years the average temperature of the atmosphere near the Earth's surface has increased by 0,74 ºC, and its growth rate gradually increased (Houghton et al., 2001). In the next 20 years, the temperature increase is expected to average 0,2 ºC a decade, and by the end of the 21st century, the Earth's temperature could rise 1,8 to 4,6 ºC [17]. Some areas "warm up" more than the others: for example, in Central Asia, average temperatures in the 2010s are 4 ºC higher than in the 20th century [32]. Experts attribute global warming to a sharp increase in carbon dioxide in the atmosphere due to human activity, which leads to "greenhouse effect" [1].

Why insects are so sensitive to climate warming?

Insects are poikilothermic (or ectothermic) animals, their body temperature is not constant, but varies depending on the ambient air temperature. Moreover, their life cycles are usually very short. Therefore, even small temperature changes in one direction or another can have a strong impact on insects' population dynamics (Stange et al., 2010). Temperature increase (if it occurs within the temperature optimum of a given species) is usually very beneficial for [39]. In addition to the direct impact the temperature increase may change the physiology of insect food plants and have, therefore, an indirect impact on phytophagous insects [6].

What are the main types of insect responses to climate warming?

An increase in temperature can trigger a variety of responses from insects [26]:

1) shifts in distribution areas. It usually occurs because insect host plants change their distribution due to climate change, and the insects follow. Temperate insects appear to express such reaction stronger than the tropical ones [25]. In the northern hemisphere the northern boundary of the distribution area of certain species expands to the north [33, 35, 36]. Alternatively, species may start to inhabit higher altitudes in the mountains [13];

2) changes in phenology and seasonal development of insects. For herbivores, it is directly related to changes in the phenology of host plants. Higher daily temperatures, if above species specific threshold temperatures, increase degree-day accumulations so the hatching of insects will occur earlier and their subsequent development will be faster in comparison with the multi-year averages [45];

3) an increase in the number of generations which is the result of changes in phenology and accelerated development. As a reaction to increased temperature, voltinism particularly increases in insects that produce several generations per year, such as aphids. A larger number of generations per season often increase insect species pest potential [27];

4) increased insect survival due to mild temperature conditions in the winter. Winter temperatures, that no longer reach lethally low levels for overwintering insect stages, increase their survival rate, which once again can lead to an increase in population size and pest potential. The increase in winter temperatures at the beginning of the 21st century contributed to a sharp reduction in mortality of overwintering larvae of bark beetles and led to a devastating mass outbreak which killed millions of hectares of conifer forest in the Rocky Mountain region of the United States [41]. Another illustration is the acclimatization of the mantid Hierodula tenuidentata tenuidentata Saussure in Kazakhstan. Its oothecas attached to tree branches survive warmer winters and as a result, the mantid populations have now established in Almaty [3] although previously they were known only from South Kazakhstan [28].

How locusts react to climate warming?

Based on different climatic simulation models, some locust and grasshopper species of the Northern hemisphere can expand their distribution areas to the north. [31] predicted that one of the most pestiferous North American acridid, Melanoplus sanguinipes

(Fabricius) (fig. 1) is likely to inhabit more northern Canada latitudes than before. Similarly, the distribution area of the Italian locust Calliptamus italicus (L.) (fig. 2) will shift to the north in Russia due to the climate warming [38].

Moroccan locust Dociostaurus maroccanus (Thunberg) (fig. 3) has already revealed such northern expansion of its distribution limit in Turkmenistan [19] and southern Kazakhstan [4]. Additionally, it produced another type of the shift in its distribution area. Historically, this species inhabits semi-deserts in foothills of the Mediterranean (sensu lato) region with spring ephemeral and ephemeroid vegetation consisting of Poa bulbosa, Alyssum desertorum, Carex pachystylis, Medicago falcata etc.[21]. Such vegetation develops in foothill ecotones at altitudes between 400 and 1.000 m.

However, in the recent years, climate warming caused a gradual shift of vegetation belts to higher altitudes [24]. As a result, in the 21st century, the Moroccan locust breeding habitats moved up, with their vertical distribution limit shifting approximately 300 m higher than before [22]. In Central Asia, it is not unusual now to find the Moroccan locust at altitudes of 1.600 and even 1.800 m above the sea level.

Recently, the Moroccan locust quite unexpectedly produced mass outbreak in Southern Russia (Stavropol), the region where infestations of this locusts were last recorded in the 1930s [44] and 1969 [29]. However, in 2012,

High densities of the Moroccan locust were found on over 400.000 ha in Stavropol, Dagestan and Kalmykia [40]. One of the reasons is that the 2012 spring was abnormally hot, and the locusts hatched one month earlier than usual and developed very fast. Such changes in acridid phenology caused by climate warming became more and more

Fig. 1. Grasshopper Melanoplus sanguinipes (Fabricius). Photo A. Latchininsky

Fig. 2. Italian locust Calliptamus italicus (L.). Photo A. Latchininsky

Fig. 3. Moroccan locust Dociostaurus maroccanus (Thunberg). Photo A. Latchininsky

frequent in the recent years. Indeed, grasshoppers and locusts hatch earlier and develop faster than before. This was shown for grasshopper assemblages from such differing geographic regions as Rocky Mountains of the USA [30], dry steppes of Inner Mongolia [43] and high plateaus of Tian-Shan mountains of Kyrgyzstan [42]. The faster development is explained by the fact that the sum of degree-days needed for grasshopper development is accumulated faster under warmer climatic conditions [36]. Interestingly, even the embryonic development of grasshoppers, which takes place in the soil, occurs faster with higher air temperatures. In Alaska, grasshoppers from the genus Melanoplus Stål used to spend two winters at an egg stage in the soil, which meant a two-year long life cycle [34]. However, a 3 ºC temperature increase in the recent decades accelerated the embryonic development and produced hatching already after the first winter resulting in a shift to univoltine life cycle in Melanoplus spp. [7].

Most acridids from Eurasia are also univoltine developing in a single generation per year, usually with overwintering diapausing eggs [23]. However, some species are known to have potential to develop more than one annual generation. For example, a Karakalpak population of the Asian Migratory locust Locusta migratoria migratoria L. (fig. 4) was shown to produce non-diapausing eggs which hatched two weeks after oviposition under laboratory conditions [20]. In the field, such cases of non-diapausing development of Locusta are very rare; one of them was documented for 1927 in Dagestan [8]. In the recent years, however, late-summer hatching of Locusta nymphs

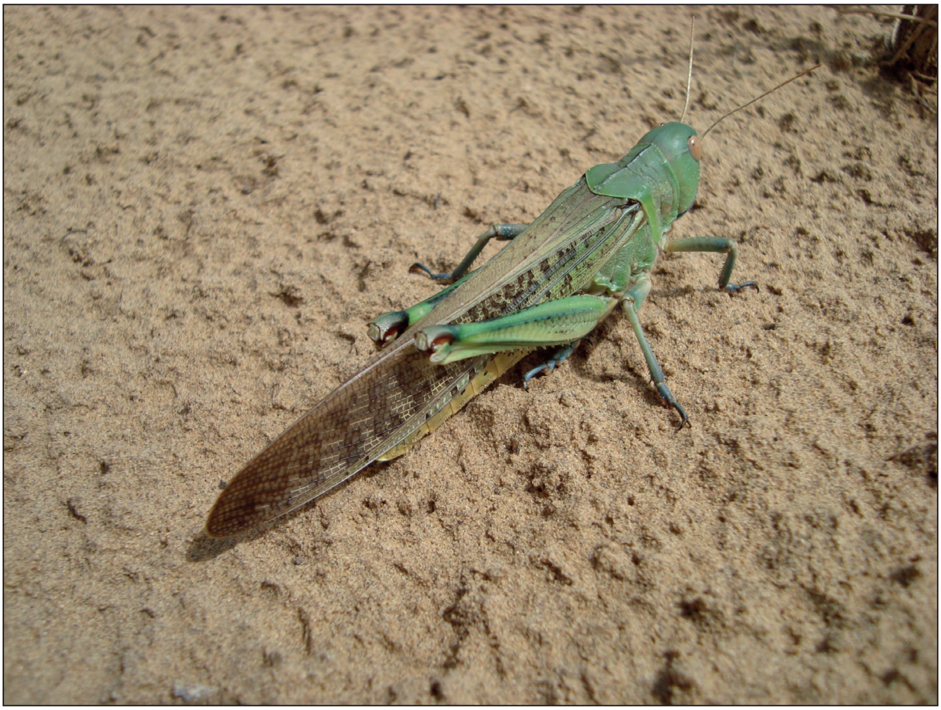

Fig. 4. Asian Migratory locust Locusta migratoria migratoria L. Photo A. Latchininsky

becomes more and more frequent. For example, in 2012, such event was documented simultaneously in two quite different breeding areas, one in Stavropol [40], the other in Karakalpakstan [10]. One explanation is that, because of the warming climate, the Asian Migratory locust phenology shifted to earlier dates allowing for a second generation to start in late summer. In North America, similar changes in voltinism are recorded for Melanoplus sanguinipes (Fabricius) in Arizona. Formerly a univoltine grasshopper, in the 21st century it produces two annual generations on a regular basis [18]. Another species of the same genus, Melanoplus bivittatus (Say) (fig. 5) was also recorded to lay eggs which developed without diapause under laboratory conditions revealing a potential to produce second generation per year [5].

Climate warming and locust control: what are the implications?

Evidently, new trends in locust and grasshopper phenology and life strategies caused by climate warming present serious problems for plant protection services. Monitoring and managing locust populations at high altitudes, like in the case of the Moroccan locust, is extremely difficult and time- and resource-consuming [12]. In such areas, insecticide treatments have to be applied using hand-held or back-pack sprayers, which are less efficient compared to aerial or ground treatments using vehicle or tractor sprayers. For example, in 2012 in Tajikistan, 7.700 ha were treated against D. maroccanus at altitudes between 1.000 and 1.750 m above sea level [9]. In the same year in Uzbekistan,

Fig. 5. Grasshopper Melanoplus bivittatus (Say). Photo A. Latchininsky

Fig. 6. Swarm of Asian Migratory locust Locusta migratoria migratoria L. Photo I. Lachininskaia

control of the Moroccan locust has been conducted on 25.000 ha in mountainous areas in Kashkadarya province with over 700 staff participating in these activities [10].

Regarding the Asian Migratory locust, its late-season hatching of the second generation occurs when the treatment campaign is over and there are no more resources (pesticides, fuel, scouts) to conduct anti-locust treatments. As a result, a large proportion of the population remains uncontrolled and can produce outbreaks and swarm flights (fig. 6) the next season [11].

To sum up, locust outbreaks may become more frequent and severe under warming climatic conditions [35]. Climate warming, which causes shifts in locust distribution, phenology and voltinism, is a serious challenge for both, locust monitoring and management.

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