Food and Agriculture
Organization of the
United Nations

Practical guidelines on three locust pests in Caucasus and Central Asia

Biology, ecology and behaviour

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Alexandre Latchininsky

Food and Agriculture Organization of the United Nations

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Front cover: moroccan locust, italian locust, and Asian migratory locust adults.
Back cover moroccan locust adults.

CONTENTS

ABBREVIATIONS

CCA	Caucasus and Central Asia
E/F	locust phase index, the proportion of the length of tegmen E to the length of hind femur F
fam.	family
FAO	Food and Agriculture Organization of the United Nations
G	Gregarious Phase
ha	hectare
ind.	individual
km	kilometre
m	metre
m^2	square metre
mm	millimetre
N	northern latitude
s	second
S	Solitary Phase
T	Transiens Phase

INTRODUCTION

The pratical guidelines provide detailed information on the biology, ecology and behaviour of three species of locust pests in Caucasus and Central Asia (CCA) – the italian locust *Calliptamus italicus* (L., 1758), the moroccan locust *Dociostaurus maroccanus* (Thunberg, 1815) and the Asian migratory locust – *Locusta migratoria migratoria* (L., 1758). They were prepared in the framework of the interregional and multi-funded "Programme to improve national and regional locust management in CCA" implemented under the auspices of the Food and Agriculture Organization of the United Nations (FAO) since 2011 in ten countries: Afghanistan, Azerbaijan, Armenia, Georgia, Kazakhstan, Kyrgyzstan, Russian Federation, Tajikistan, Turkmenistan, and Uzbekistan.

Together with other volumes on various topics related to locust management, these practical guidelines provide very comprehensive yet accessible information not only for locust control and plant protection specialists in the CCA countries, but also for researchers, students, and the widest range of readers.

The practical guidelines are divided into several parts. The first three are devoted to general issues of biology, ecology, phase variability, life cycle and behaviour of locust pests. They deal separately with each of the three gregarious locust species in CCA – the Italian Locust, the moroccan locust, and the Asian migratory locust. The Guidelines end with an annotated list of the most important publications on these harmful locusts. In addition, three cards containing concise information on each of the listed three species and suitable for use in the field are also included.

GENERAL INFORMATION

LOCUSTS – WHAT ARE THEY?

Locusts are insects belonging to the order of Orthoptera, a suborder of short-horned (Caelifera), superfamily of acridids Acridoidea. In our fauna this superfamily includes three families: Acrididae, Pamphagidae and Pyrgomorphidae. These are the insects of average or large sizes (Figure 1) having two pairs of wings, the front one represents leathery narrow tegmina, and the hind one is the actual wings which are folded fanwise at rest and spread at flight (Figure 2). Hind legs of locusts are modified for jumping; antennae are shorter than body; ovipositor of females is short (Figure 1).

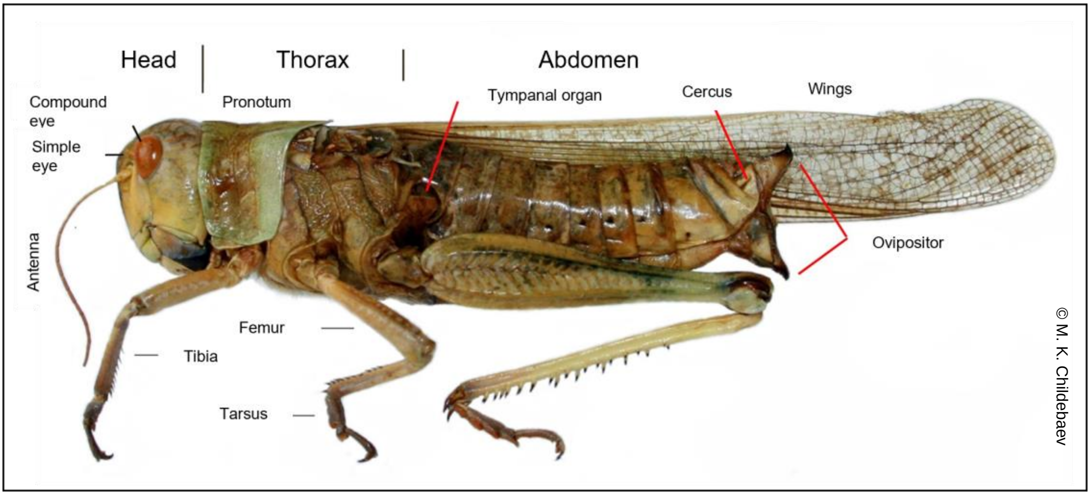


Figure 1. Adult female of Asian migratory locust *Locusta migratoria migratoria* (L., 1758), side view

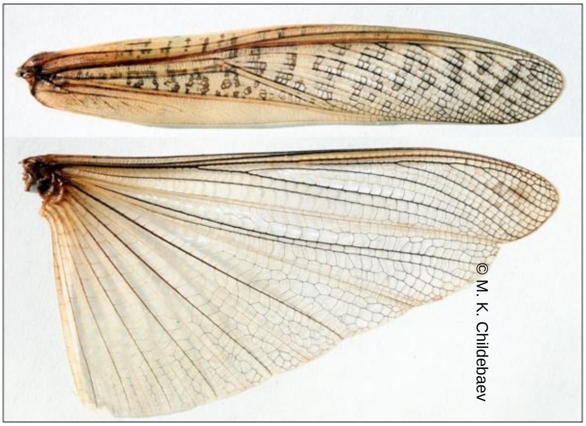


Figure 2. Right tegmen and wing of Asian migratory locust

The last two traits distinguish acridids from the representatives of long-horned suborder (Ensifera) – katydids (fam. *Tettigoniidae*) and crickets (family -fam.-. *Gryllidae*) – which have antennae longer than body, and usually long, sword-like (curved) or straight ovipositor (Figure 3). Besides, acridids have their hearing organ (tympanal organ) on the first abdominal segment (Figure 1) while long-horned orthopterans have it on front tibia.

Depending on life habits, acridids are divided into **locusts** and **grasshoppers**. Locusts differ from grasshoppers by the phenomenon **of phase change** in their biology, which was discovered by the great Russian/British entomologist Boris Petrovich Uvarov (1886–1970). He is considered the father of modern science about locusts – acridology, and the founder and first director of the famous London Anti-Locust Research Center.

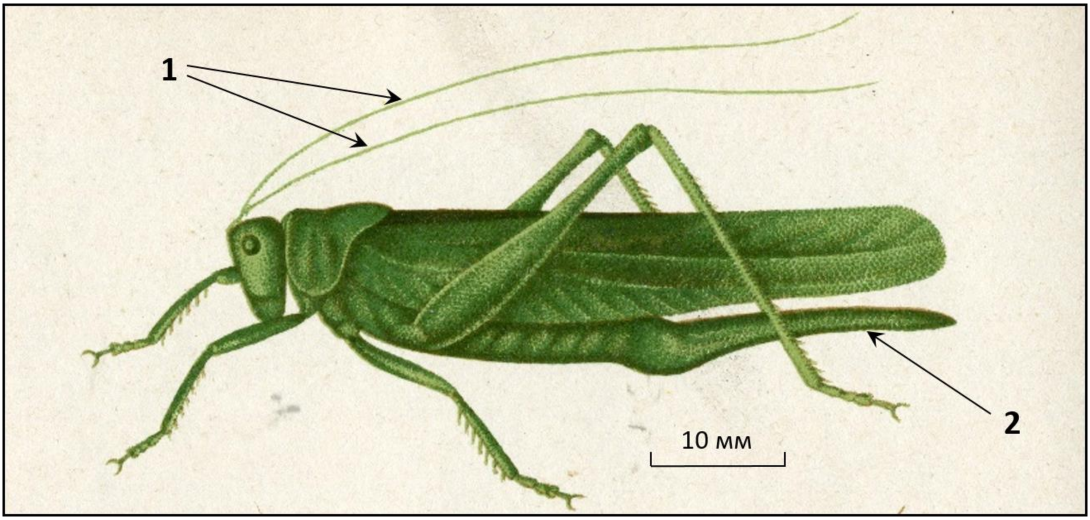


Figure 3. Great green bush-cricket, or katydid *Tettigonia viridissima* (L., 1758), female, side view
(from Rossikov and Rybakov, 1897, modified)
1 – Antennae (longer than body); 2 – Ovipositor (long, sword-like curved)

2. LOCUST PHASES

What is the phenomenon of phase change? Depending on population density, locusts can be presented by solitary or gregarious forms, which B. P. Uvarov called “phases”. At low density the locusts behave as single-living and scattered individuals, avoid each other except for the mating period, and have protective (camouflage) coloration helping them to escape from predators. However, under favorable ecological conditions, their density increases, and the habits and behaviour change dramatically. They form dense groups named hopper bands, and their coloration becomes vivid and contrasting, combining black, red, yellow, or orange tones. After fledging the swarms of adult locusts can contain billions of individuals, being the largest groups of terrestrial animals on the planet. Behavioural changes are followed by changes in morphology, particularly in the shape of pronotum and the proportion of some body parts: wings become longer, and hind legs – shorter. However, these morphological modifications become obvious later, usually in the next generation. There are also profound changes in physiology and genetics, but their description lies beyond the limits of these practical guidelines. It is to be noted that not all phase changes described above could happen in every locust species. In CCA, they are most evident in Asian migratory locust *Locusta migratoria migratoria* L., 1758. Some species have phase changes in behaviour only, while morphological and colour modifications can be quite negligible or totally absent. More details will be described in the chapters devoted to each species of locusts.

How does the transformation occur from single-living individuals into multi-thousand or multi-million bands and swarms capable of long migrations? It varies between the species but usually everything begins with the favorable ecological and weather conditions which contribute to female concentration in suitable biotopes during egg-laying. When a female locust lays eggs it excretes into the soil a special secretion from accessory glands, and the volatile compounds of the secretion attract other females in the vicinity. This leads to the crowding of egg-laying females within relatively small area resulting in high density of egg-pods, which can reach hundreds and even thousands per square metre (m^2). Depending on the species, an egg-pod laid by CCA locusts typically contains from twenty to over a hundred eggs, therefore the density of the next generation's hoppers at hatching can dramatically exceed the parental density and reach tens of thousands per m^2. Newly hatched hoppers tend to crowd and stimulate each other by touching with antennae and legs. This tactile stimulation triggers the generation of special “gregarization hormones”, particularly serotonin. Visual stimuli and olfaction also help hoppers to keep cohesive bands and not scatter. Over time, small hopper groups merge into huge bands marching in one direction. Swarming behaviour is enhanced by recurrent tactile, visual, and olfactory stimulation, and the hopper coloration becomes more and more contrasting. This is how solitary hoppers gradually transform into gregarious locusts.

Solitary and gregarious phases of locusts are the two extremes in a continuous series of a number of transitional forms. Transformation from solitary to gregarious phase takes several (usually four or more) generations, and the process is reversible. Reverse transformation from gregarious to solitary phases is usually shorter encompassing only two or three generations. Transition from one phase to another is known as phase transformation or phase change. Since the CCA locust species have only one generation per year (exceptions will be described later) the transformation from solitary to gregarious phase takes at least several years. Put another way, a locust outbreak, that is, a rapid transition from low to high density, does not occur momentarily and spontaneously, but is preceded by a few years of intensive population growth. Therefore, locust control Specialists should closely monitor pest population dynamics and learn to recognize signs of increasing gregarization from one season to the next. This can be done, for example, by comparing morphometric characters of adult locusts between the current and preceding years. This allows for a more accurate locust outbreak forecasting and implementing preventive management of locust populations.

Phase transformation that is, transition from the solitary to gregarious phase is the key process in the outbreak formation of locusts. It is very important to understand which factors trigger the process; these factors will be discussed in detail in the specific sections of these practical guidelines.

Though the largest grasshopper family Acrididae comprises over 12 000 species, the vast majority of those are non-gregarious ones, with only about a dozen of species capable to swarm. Evolutionally, swarming behaviour (gregariousness) is a relatively young phenomenon which has developed independently in several Acrididae subfamilies. Swarming capacity is believed to improve locust survival and help withstand the pressure from natural enemies, while long-distance migrations contribute to the species expansion into the new geographical regions.

3. LIFE CYCLE

3.1 Embryonic development

Acridids are insects with incomplete metamorphosis, therefore, their life cycle consists of three stages: egg, nymph, and adult (Figure 4). Egg-pods are laid into the soil in summer or autumn. Embryonic development starts immediately after egg-laying but ceases very soon to resume in spring. This long interruption in development is known as embryonic diapause. It is an adaptation necessary for the CCA locust species to survive long winters. Diapause is broken by at least four weeks of low soil temperatures (0°C to 4°C or lower). The embryos resume development when the weather becomes consistently warm in spring. During this period, the temperature has less influence on the embryonic development than the soil moisture from melting snow or spring rains.

After the completion of embryonic development, hatching occurs; first scattered, then *en masse*. To predict the timing of hatching, it is necessary to consider long-term average climate data (temperature and humidity) of particular year. It should be noted that the timing of egg-laying has no influence on the timing of hopper hatching.

How long can the eggs remain in the soil without losing viability? In other words, is it possible that the eggs "accumulate" in the soil during several years and then hatch simultaneously? Experiments showed that locust eggs stay viable for about 18 to 24 months. This means that if due to some reasons the eggs fail to hatch within a year after laying, there is a certain chance for hatching in two years, but it becomes less likely in three or more years because the eggs will succumb.

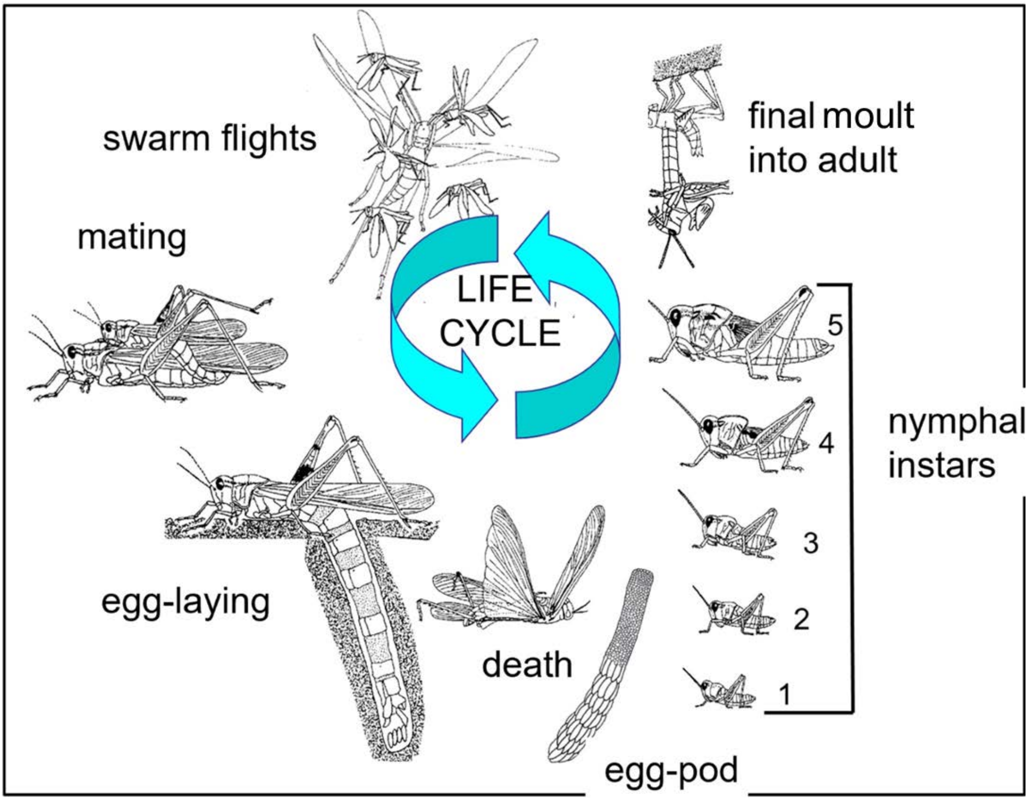


Figure 4. Life cycle of locusts
(from Latchininsky et al., 2002, modified)

3.2 Nymphs

Nymphs or hoppers hatch out in spring and begin active feeding and collective movement in groups called hopper bands. The hoppers leave an egg-pod through an opening under the egg-pod lid (Figure 5). The nymphal stage typically includes five instars, in between which the hoppers moult and become larger in size. In addition, the number of antennal segments increases, and wing pads develop. The duration of the nymphal stage depends on the species, weather conditions, and temperature in the first place.

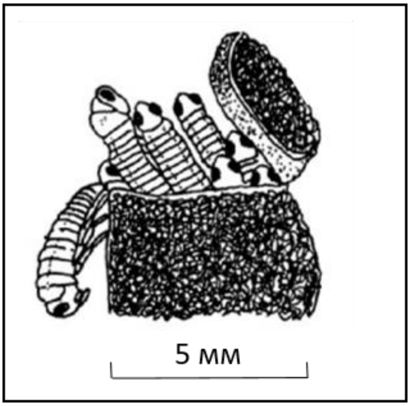


Figure 5. Hatchlings come out of an egg-pod
(after Künckel d'Herculais, 1893–1905 from Uvarov, 1927, modified)

For practical purposes, it is important to learn to correctly determine the hopper instars. This skill is necessary for making a timely decision on locust control treatments, which are most effective when the population is dominated by second and third hopper instars. Later instars (not to mention the adults) are more resistant to pesticides, requiring higher dose rates to be applied compared to earlier instars. Moreover, hopper band expands in area with each consecutive instar; therefore, it is easier and more effective to control early instars than later ones. To identify the instar, it is necessary to examine shape and position of the wing pads with a magnifying glass or under a dissecting microscope (Figure 6). First instar hoppers have no wind pads. Second instar nymphs have barely visible wing pads marked by slightly retracted downwards rear lower corners of the mesonotum and metanotum. Third instars have quite visible wing pads with numerous longitudinal veins. Fourth instars have larger wing pads, which become almost as long as the protonum. The wind pads change their position: they are no longer on the sides of the thorax but move to its top. Finally, the fifth instars have well-developed wing pads generally equal to the protonum in length.

Besides the wing pads, the number of the antennal segments (from 13 in the first instar to 25–35 in the fifth instar) and development and shape of external genitalia can be used to identify the instars. The hoppers grow with each instar: total body length increases by three to five times during the hopper stage, while body weight roughly doubles with each moulting.

It has been shown that about 90 percent of natural mortality in acridids occurs during the first instar. It is the period, approximately one week after hatching, when the hoppers are the most susceptible to adverse ambient conditions and natural enemies. Subsequently hopper survival rate increases with each instar.

The area occupied by a hopper band increases with each consecutive instar. For example, the band of 2nd instar nymphs is about twice as large as the 1st instar band, and by the 5th instar, the band increases in area 40 to 300 times compared to the 1st instar. This factor has a practical importance: the earlier anti-locust treatments are conducted, the smaller is the area to be treated, which translates into the economy of time, funds, pesticides, etc.

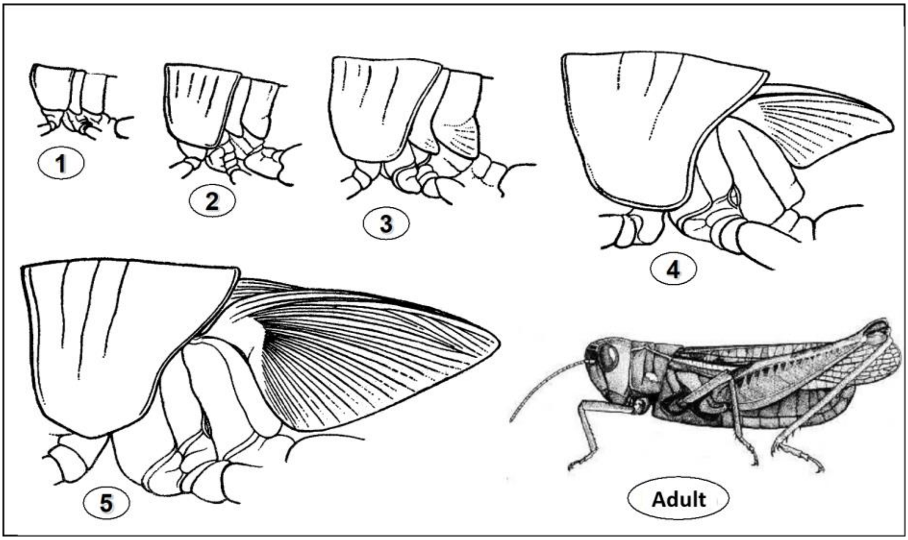


Figure 6. Instar determination in hoppers and adult locusts based on development of wing pads (wings)
[from Bey-Bienko & Mishchenko, 1951; adult of *Arcyptera microptera* (Fischer von Waldheim, 1833) – from Latchininsky et al., 2002]
Instars 1st to 3rd have wing pads pointing downwards; instars 4th and 5th have their wing pads on top.

3.2.1 Nymphal behaviour

Daily behaviour of gregarious hoppers includes three main periods: rest, feeding, and movement. Duration and sequence of these activities depend primarily on the temperature. For example, when the temperature drops below 10°C the hoppers fall into cold stupor, while the temperature above 48°C causes heat depression. Interestingly, the hoppers are capable of withstanding much lower temperatures, even below freezing. At -5°C they freeze entirely and become fragile but can endure such freezing for half an hour. When the temperature rises above 0°C again, the hoppers thaw without any visible signs of damage. Therefore, short periods of light frost present no danger to the hoppers. However, negative temperatures may result in mass mortality if they last for a few hours.

Hoppers usually spend nights on plants. When the temperature begins to rise after the sunrise, the hoppers gather on well-lit parts of the plants or soil, forming the so-called "sun bands" (Figure 7). This usually lasts from 6 to 8 a.m. Then the groups disperse, and the hoppers begin feeding. Feeding can take place all day long and even at night, but usually there are two periods of peaks in feeding activity, in the morning and in the evening. The morning peak lasts about two hours from approximately 8 a.m. when air temperature is between 18°C and 20°C. The evening peak lasts about an hour or one hour and a half from approximately 5 to 6.30 p.m. at air temperature of 20–22°C.

Figure 7. "Sun bands" of the 1st instar nymphs of the moroccan locust

Hoppers start moving upon completion of morning feeding. Collective band movement (also called "marching") takes place between 10 a.m. and 4 to 5 p.m. In the hottest hours, between noon and 2 p.m., the marching rate decreases, and the hoppers tend to hide in the shade where available. Distance covered by marching bands depends on hopper instar, air temperature, vegetation, and relief. This distance has a major practical importance when applying locust control treatments with slow-acting insecticides, such as biopesticides or insect growth regulators (IGR). It will be discussed in more detail in the practical guidelines volume on control.

So, why do the hoppers start marching? So far there is no unanimous opinion on this matter. To explain that marching is triggered exclusively by search for food would not be correct, because it is not uncommon for a locust hopper band to move across a heavily vegetated area without feeding at all. Some recent publications state that hoppers suffer from the shortage of protein and salt, which they try to compensate by attacking their conspecifics, that is, by cannibalism. So, the hoppers in the front rows of a band try to escape predation from behind, hence the overall movement of the entire band occurs. However, we believe that cannibalism as the driving force of nymphal marching is overestimated because this claim is not supported by numerous field observations.

3.2.2 Moulting

Acridids grow in size during their nymphal period, which usually includes five stages (instars). Between the instars, the acridids moult (Figure 8). As such, our locusts undergo five moults. The hoppers become generally less active about a day before the moulting. A few hours before moulting the hoppers stop feeding just to resume it two or three hours after the moulting. To moult, a hopper climbs up a plant and hangs head down. In a few minutes the old exoskeleton ruptures along the protonum and the next instar nymph falls to the ground. The entire moulting takes approximately half an hour. The exuviae remains attached to the plant for some time, while the newly moulted nymph climbs back on a plant or hides in the shade. The new exoskeleton is soft and light in colour and it takes one to two hours for it to become hard and dark. Moulting usually occurs in the daytime, between 10 a.m. and 5 p.m.

Figure 8. A moult (from 5th instar to adult) in the moroccan locust

3.3 Adults

Fifth instar hoppers moult for the last time to become adult locusts with fully developed wings (Figure 8). The newly fledged adults are immature; they start feeding actively and begin flying in a few days. At first, they take short flights, just for a few meters, but gradually the distance increases. Depending on the species, sexual maturation takes from a few days to several weeks, during which time the locusts migrate in swarms causing damage to native vegetation and agricultural crops. Then the locusts begin active mating. For practical purposes it is important to learn how to determine locust's sex. To do so it is necessary to examine the tip of the locust's abdomen: male locust has the abdomen ending with so-called subgenital plate with two short protrusions – cerci, while female locust has an ovipositor which consists of four short hook-shaped valves (Figure 9). Females lay eggs several days or weeks after mating. Such properties of the ground, as particle size, compactness and humidity are the key factors in choosing a site for egg-laying. Before laying eggs, the female tests the soil repeatedly by probing it with an ovipositor which bears numerous chemo-, mechano- and hygroreceptors. Egg-pods are deposited in the upper layers of the soil and the female's abdomen can extend several times due to elastic intersegmentary membranes (Figure 4, egg-laying). If the soil is unsuitable the female takes her abdomen out and moves to a different site. The place where females tried to lay eggs are marked with multiple holes in the soil. Such careful probing is quite justified because acridids spend (at an embryonic stage) about nine months out of twelve in the soil. Usually, the process of oviposition takes about 30 to 40 minutes. Although egg-laying may occur over a period of several weeks or even months, the hoppers hatch out almost simultaneously in spring.

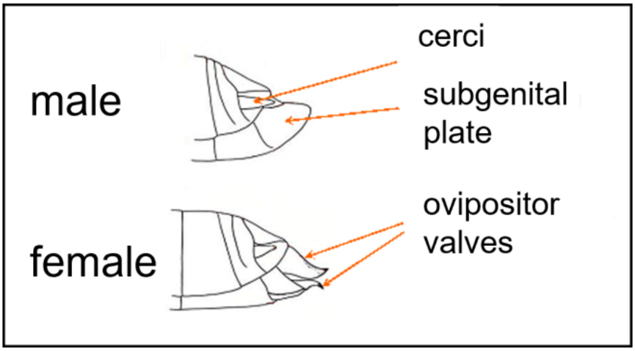


Figure 9. Difference between sexes in the structure of the tip of the abdomen in locusts

3.4 Egg-pods

Instead of laying one egg at a time like katydids or crickets, female locusts lay eggs in batches. The eggs are glued together with a froth from the female's accessory glands which hardens into a specific structure called egg-pod. The egg-pods are a unique adaptation specific to the Acrididae family. It helps the embryos to survive under extreme environmental conditions. The eggs are protected with hard walls consisting of the soil particles and vegetation debris cemented with the froth. The walls allow the locust embryos to survive high and low ambient temperatures, excessive or deficient soil moisture. Female locusts lay their pods in the upper layers of the soil where the temperatures may vary from +40 °C in summer to -40°C in winter and the eggs may be flooded with water for several months (as in the case of the Asian migratory locust); nevertheless, the hoppers hatch out in due time. Most of CCA acridids overwinter as eggs thus making the embryonic stage the longest (lasting for up to nine or ten months) period in the locusts' annual cycle. However, the functions of the egg-pods are not limited to creating a protection barrier for the eggs. Acridid embryos are live organisms, they breathe and develop (see Section 3.1), and the egg-pods ensure gas and water exchange through their semi-permeable walls.

Depending on the species the egg-pods differ in shape, size and the number of eggs which varies from four to 150 in the species of our fauna. Typically, female locusts lay two to four(occasionally up to six) egg-pods, one to two weeks apart. The number of egg-pods laid by a female depends on the availability of food and weather conditions: if the weather during oviposition is mild and warm, females continue to lay eggs, but when the first frosts hit, females start to die off. The first pods usually contain more eggs than the last ones.

3.5 Population Dynamics and Harmfulness

Acridids are one of the major ecological groups in grassland ecosystems. Their densities may reach thousands of individuals per m^2 with dry weight totaling several tons per hectare. High abundance, voracity and polyphagy make the acridids important economic pests. Calculations show that acridids consume about 30 percent of the above-ground foliage, and in the outbreak years they can destroy vegetation in their breeding habitats. Acridids attack almost every crop as well as hay fields and pastures. At the same time, acridids are an integral part of a grassland ecosystem, contributing to nutrient cycling. At low densities acridids stimulate plant growth, while their feces are a perfect fertilizer.

Locust multiannual dynamics are characterized by dramatic population fluctuations, with the periods of low abundance (recessions or depressions) changing to the periods of high abundance (outbreaks). Population dynamics are governed by three main groups of factors: abiotic (weather conditions), biotic (natural enemies), and anthropogenic (locust control operations). Other anthropogenic factors such as water regulation in the lowlands or excessive grazing in a steppe may also contribute to providing favorable conditions for locust outbreaks.

Regarding weather factors, hot and dry years are usually best for the rapid growth of locust populations. The locusts develop faster and are less prone to diseases in hot and dry weather. As a result, the increased survival rate and fecundity lead to population growth. Therefore, global warming creates favorable conditions for increased economic importance of locusts. Global warming makes it possible for locusts to expand their habitats both latitudinally and altitudinally, their developmental rate accelerates which means that certain species become capable of completing two generations in a year, instead of a usual single one.

Locusts have many different natural enemies attacking all stages of the locust's life cycle – eggs, nymphs, and adults. Natural enemies are very effective in controlling the locust populations when the locust abundance is relatively low. However, during outbreaks, that is, when locust population peaks, natural enemies are practically incapable of controlling their hosts' numbers. But they become noticeable again during the phase of recession and may precipitate the outbreak collapse.

In terms of the anthropogenic factors, large-scale locust control operations certainly contribute to a certain reduction of locust populations, but usually they are unable to suppress an outbreak completely. Moreover, in some cases anthropogenic activities create favorable conditions for locust outbreaks. Low farming standards, severe overgrazing, abandoned crop fields contribute to the increased abundance and harmfulness of locusts. That is why it is extremely important for the locust control services to focus not only on suppression of locust outbreaks but rather, on their prevention. Preventive strategy is the most efficient, cost-effective, and environmentally friendly way to reduce impact from locust pests. To implement such strategy, it is necessary to have an in-depth knowledge of the factors potentially leading to locust outbreaks and measures to be taken. This volume of the practical guidelinesprovides the basic information on biology, ecology and behaviour of locusts; this knowledge should be the foundation for any strategy and tactics of locust control.

The following chapters of these practical guidelines contain information on three gregarious locust species from the CCA region, namely:

the italian locust *Calliptamus italicus* (L., 1758),
the moroccan locust *Dociostaurus maroccanus* (Thunberg, 1815),
the Asian migratory locust *Locusta migratoria migrartoria* (L., 1758).

These three species belong to the family Acrididae.

It is necessary to note that besides these three species, CCA can experience invasions of the desert locust *Schistocerca gregaria* (Forskål, 1775) from family Acrididae, subfamily Cyrtacanthacridinae. Immigration swarm flights of this species occurred in 1929 in Central Asia and in 1930 in Caucasus. The most recent invasion took place in Turkmenistan in 1962. Also, the desert locust can frequently invade southern Afghanistan from Iran. Usually immigrating swarms consist of pink-coloured immature adults (Figure 10A), which turn yellow after sexual maturation (Figure 10B). Desert locust eggs develop without embryonic diapause and nymphs hatch two to three weeks after oviposition. Nymphs of the gregarious phase have vivid and contrasting coloration (Figure 10C). Since this species does not have permanent breeding areas in CCA, it is not considered in detail in the present practical guidelines.

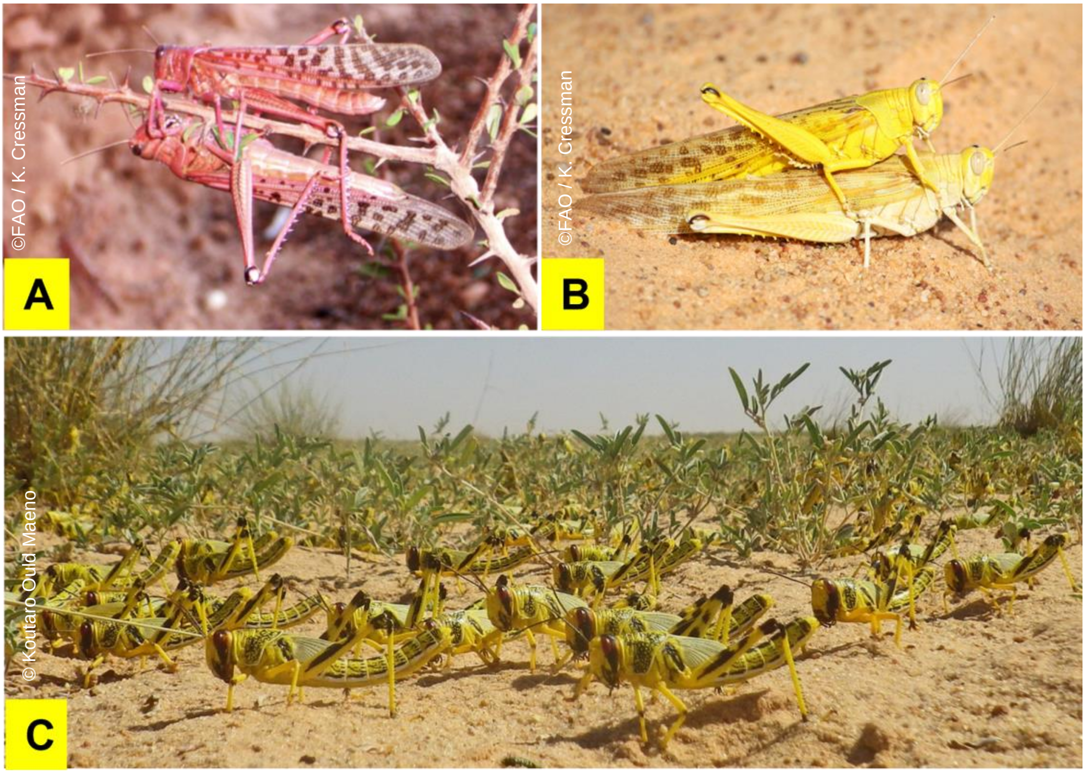


Figure 10. Desert locust *Schistocerca gregaria* (Forskål, 1775)
A – immature adults; B – mature adults; C – hopper band of 5th instar nymphs of gregarious phase

4. ITALIAN LOCUST

Figure 11. Adult Italian locust *Calliptamus italicus* (L., 1758)

The italian locust (Figure 11) belongs to the subfamily Calliptaminae (Calopteninae). Locusts of this subfamily can be identified by a well-developed conical tubercule on the protonum between coxas of the front legs if viewed from below (Figure 12).

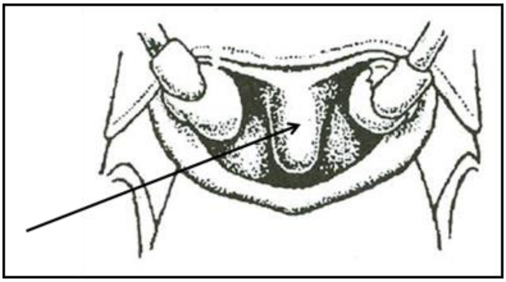


Figure 12. Pronotum tubercule (marked with arrow)
(from Bey-Bienko & Mishchenko, 1951)

4.1 Distribution area

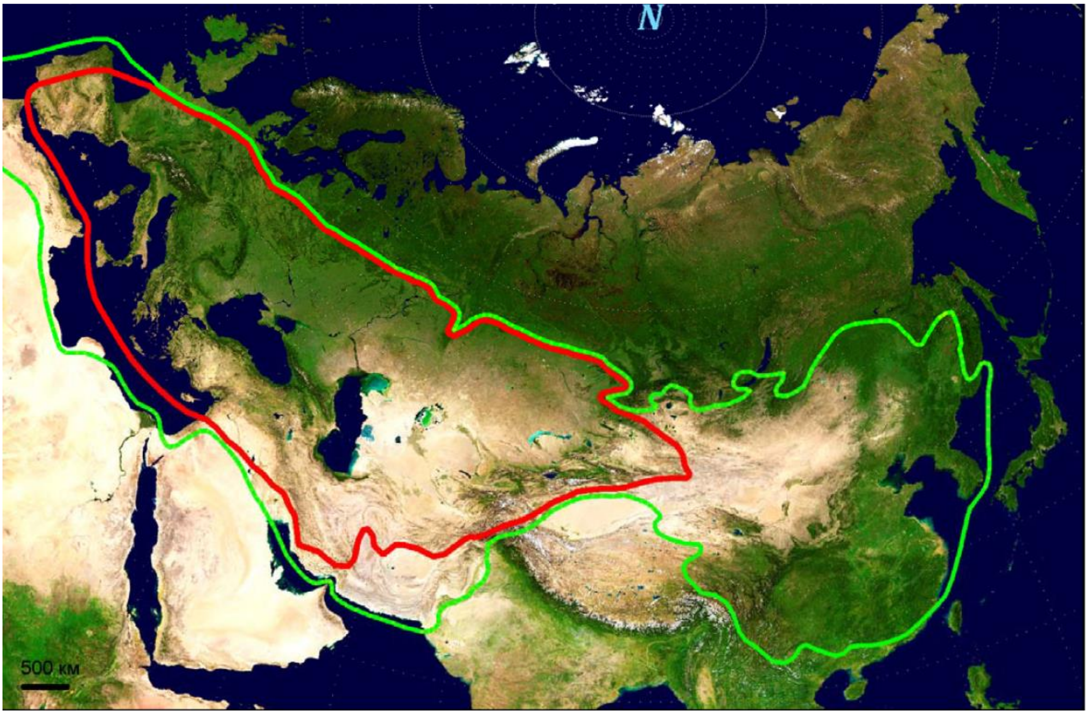


Figure 13. Distribution area of the italian locust (red line) and entire genus *Calliptamus* (green line) (excluding Atlantic islands)
(from Sergeev et al., 2017)

The distribution area of the italian locust (Figure 13) generally covers the Mediterranean region and Western Asia. The northern boundary of the species' distribution area extends to the central Europe where sparse populations occur (southern half of Germany, almost entire Poland, south of the Non-Black Soil Zone and almost the entire forest steppe in the European Russian Federation up to Tatarstan), and the forest steppe zone of the Western Siberia. In the south, the species is widely distributed along the northern shore of the Mediterranean Sea and Southwest Asia. It is also common in Iran and Afghanistan but does not extend to their southern borders.

Dry steppes and semideserts covered with mosaic vegetation, predominantly with different sage species (*Artemisia* spp.) are the preferred habitats. In the southern part of its area (e.g. Uzbekistan, Tajikistan, and Turkmenistan) the italian locust mostly inhabits river valleys and oases, hence the common name “Oasis Locust” sometimes appearing in old publications. This species is found in the Tien Shan, Pamir-Alay and Kopet Dagh mountains. In Caucases, the italian locust has economic importance in Eastern Georgia, Armenia and in some parts of Azerbaijan.

The most frequent outbreak zone of the italian locust is situated in Kazakhstan and adjacent areas of the Russian Federation, that is, the Volga region and south of the Western Siberia. In all these areas the species prefers fallow lands and overgrazed pastures with sages (*Artemisia* spp.) (Figure 14).

Figure 14. Fallow land covered with sages (*Artemisia* spp.) – the preferred habitat of the italian locust

4.2 Morphology

4.2.1 Adult

Medium-sized, stubby locust (Figure 11, 15–17). The species is characterized by a pronounced sexual dimorphism: males are typically much smaller than females (Table 1; Figure 17). Protonum bears no X-shaped markings, with well-developed lateral carinas (Figure 16).

Figure 15. Adult italian locusts on a watermelon

Table 1. Morphological characters of adult italian locusts

Sex/character	Body length, milimeter (mm)	Tegmen length, mm	Hind femur length, mm
Males	14.5–28.7	7.7–22.2	6.1–15.0
Females	21.9–41.6	11.0–32.0	8.3–24.6

Figure 16. Lateral carinae (showed with arrows) on the pronotum of the italian locust

The species has well-developed tegmina. The hind femur is short and thick. Coloration is quite variable: from blackish-brown to grayish-brown or sometimes even whitish. Often, there are light longitudinal bands (especially, along lateral carinae of the protonum) and spots. The wings are pink at the bases. Hind femur is red or pink on the inner side, with two disrupted blackish bands. Hind tibias are red or pink in colour. Male cerci widen towards the apical end; the upper top blade is significantly longer than the lower top blade; the lower blade bears a distinct sharp spine (Figure 18A).

Figure 17. Copulating italian locusts
Male (on top) is significantly smaller than female

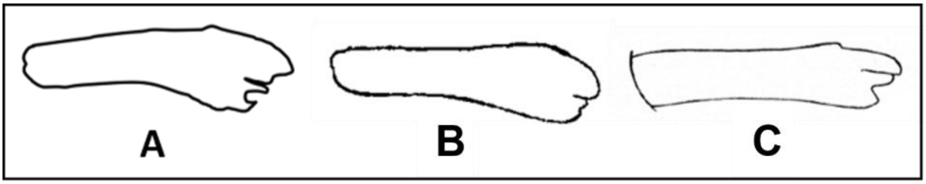


Figure 18. Cerci of males from genus *Calliptamus* Audinet-Serville
(from Bey-Bienko & Mishchenko, 1951 and Latchininsky et al., 2002)
A – italian locust *Calliptamus italicus*; B – *Calliptamus turanicus*; C – *Calliptamus barbarus*

4.2.1.1 Differences between solitary and gregarious phases

There are no distinctive coloration differences between the two phases of the italian locust, the species being unique in that respect among most other locusts. In general, the gregarious italian locusts are slightly larger in size, with longer tegmina and wings than the solitary locusts have. As explained before (Section 2), phases differ primarily in their behaviour.

Conventionally, the ratio between the tegmen length (E) and the hind femur length (F) is used to identify locust phase. In solitary phase the E/F ratio of italian locust does not exceed 1.40 in females and 1.42 in males while typical gregarious locusts of the species have the ratio >1.61 (females) and >1.63 (males). Figure 19 shows how to take measurements of the tegmen and femur. It is better to do this with a caliper.

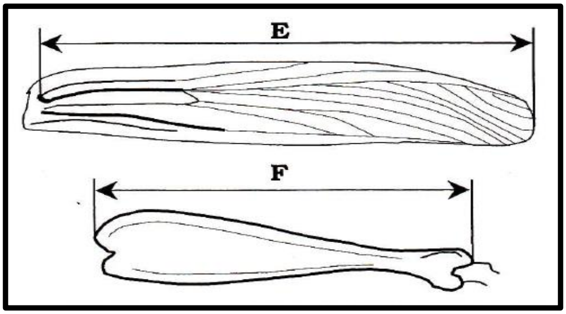


Figure 19. Morphometrical measurements used to identify locust phases

(from Latchininsky et al., 2002)
E – tegmen length; F – hind femur length

4.2.1.2 Related species

There are several species in the genus *Calliptamus* which look very much like the italian locust and are hard to distinguish (especially in the case of hoppers or adult females). The Turanian Locust *Calliptamus turanicus* Serg. (Tarbinsky, 1930) differs from the italian locust by larger size and uniform coloration of the inner side of hind femur with no dark spots or bands. *Calliptamus barbarus* (Costa, 1836) differs from the italian locust mostly by orange coloration of the upper side of the hind tibia while the italian locust has them pinkish or red. In addition, species of the genus *Calliptamus* differ from each other in the shape of male cerci (Figure 18 A-C). It should be noted that *C. barbarus* rarely gathers into large bands and its behaviour is mostly that of a non-gregarious species. The Turanian Locust most probably falls in between the typical gregarious and solitary species due to its ability to sometimes gather in bands and swarms and move collectively.

4.2.2 Nymphs (Figure 20)

The species has five instars. Development of the wing pads is the easiest way to identify the instars (Figure 6). Table 2 shows other characters distinctive of different instars.

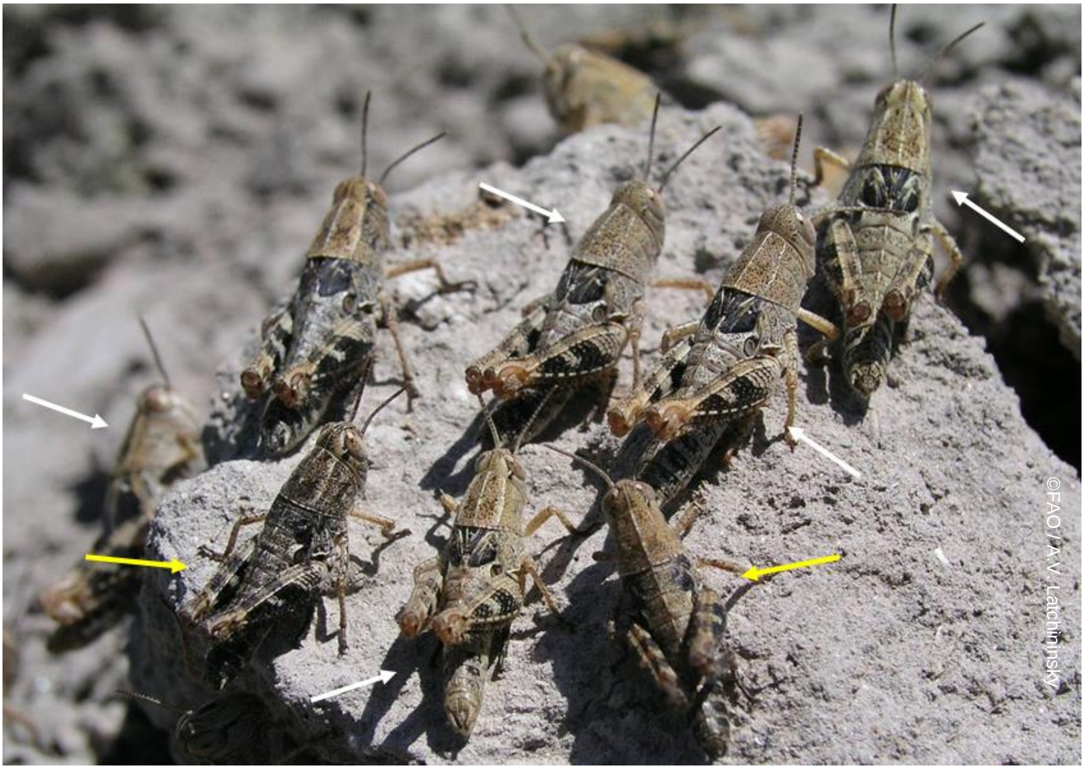


Figure 20. Nymphs of 3rd and 4th instars of the italian locust

Yellow arrows: 3rd instar; white arrows: 4th instar. Note the position of the wing pads: 3rd instar nymphs have them on the sides of the pronotum and pointing down while 4th instar nymphs have them on the back and pointing up.

4.2.3 Egg-pod

The species' egg-pod (Figure 21) has a shape of a cylinder, curved and relatively slim (3.5–4.0 mm in the upper portion and 4.0–6.0 mm in the lower portion). It is 22.0–42.0 mm long and consists of two parts. The upper part is 10–21 mm long formed by a straight column of translucent whitish foam. The lower portion of the pod, containing eggs, is separated from the upper foam column with a "waist" the egg-containing portion is 10–22 mm long with hard and relatively thin walls of semi-froth solid mass cemented with soil particles. The eggs (20–60, typically 30–45) are stacked very densely in four layers at a 45 - 80° angle to the walls and cemented with opaque and cloudy grayish yellow secretion.

Table 2. Morphological characteristics of different instars of the italian locust

Instar	Body length, mm	Hind femur length, mm	Number of antennal segments
1st	5.0–6.0	2.5–3.0	13
2nd	6.0–7.0	3.8–5.5	16–17
3rd	11.0–16.0	5.0–8.0	18–22
4th	10.0–22.0	7.0–12.0	21–23
5th	12.0–28.0	9.0–15.0	23–24

Female lays several egg-pods (typically from four to six) during its life cycle. Thus, one female can possibly lay up to 150 eggs. The egg-pods laid later in the season are smaller in size and contain fewer eggs packed only in two or three layers compared to the early season egg-pods. During outbreaks, females lay egg-pods very densely: up to 400–800 per m^2 on average, with a maximum of up to 10 000 egg-pods per m^2.

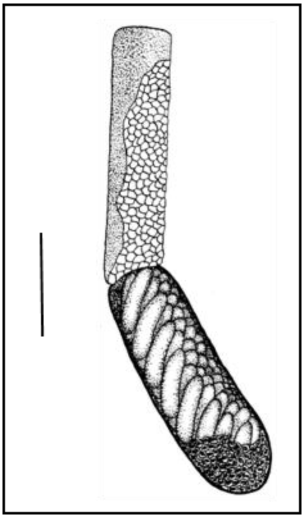


Figure 21. Italian locust egg-pod
(from Latchininsky et al., 2002)
Vertical line on the left corresponds to 10 mm

4.3 Biology and ecology

The italian locust is a very ecologically plastic species inhabiting a variety of biotopes: weedy waste lands, road-sides, edges of crop fields, fallows and other abandoned lands. Frequently the habitats emerge as a result of anthropogenic factor, such as overgrazing.

Food preferences: italian locust is a polyphagous species which can feed on plants from a variety of families, with slight preference towards forbs. The heaviest damage occurs in the following crops: sunflower, legumes, buckwheat, potato, cucurbits, cotton, flax, onions, vegetables, and different grain crops, including wheat and corn. In the cereals the locusts eat out grains or clip ears and whisks. The locust can also feed on medicinal and ether-bearing plants, damage fruit trees and shrubs and strip young forest plantations. The locust feeds on many wild plant species. Sage *Artemisia* spp., wild grasses and legumes are among the preferred ones.

Phenology: hoppers of the italian locust hatch out relatively late, usually by the end of May to beginning of June. Unlike the moroccan locust, the hatching is extended over a long period of time and may take up several (in some cases, up to six or seven) weeks within one site. As a result, the bands of the species are frequently comprised of all nymphal instars from first to fifth and may include even adults. This creates certain problems for choosing the appropriate timing for anti-locust treatments: if implemented too early, there is a possibility of the second wave of hatching; if performed too late, a significant part of the population may already fledge. Thus, it is not an easy task to determine the best timing for anti-locust operations.

After hatching, italian locust hoppers often concentrate on weeds at the perimeter of cultivated lands, roadsides, etc. (Figure 22) and from there, they infest crop fields. Therefore, timely control of weeds is very important for preventing the hoppers to form dense bands.

Hoppers of the gregarious phase form bands and begin collective movement as early as the second instar. The longest reported distance covered by a band of later instars in a single day is 400 m and the band may travel several kilometers during the duration of the nymphal stage. A band of the italian locust may take the shape of a circle, an oval or a ribbon, with size varying from a few square metres to 10 kilometer (km) long and up to 100 meter (m) wide.

Development of the italian locust hoppers takes longer than in Moroccan or migratory locusts. Even in a warm year it takes 40—45 days from hatching to fledging in the gregarious phase and 55–70 days in the solitary phase. Sexual maturation takes another 6–15 days after fledging. Then the locusts begin mating actively and in another 10–15 days females start laying eggs. Thus egg-laying usually begins 16–30 days after the final moult, occurring in the second half of July, and may last till the end of September. Massive dying out of the italian locust populations typically occurs in late September to early October.

The italian locust females can lay eggs into different soils preferring open, well-warmed sites (Figure 23). The egg-pods are often laid in recent fallow lands covered with *Artemisia* spp. plants and grasses. The species generally prefers sandy and sandy clay soils but there are reports of egg laying into thick grass sod and even cracks in the asphalt road pavement. During outbreaks the average density of egg-pods may reach 400–800 per m^2, with a maximum of up to 10 000 per m^2, which is the absolute record egg-pod density among all locust species.

Figure 22. Concentration of italian locust early-instar nymphs on weeds

Gregarious adults can swarm and fly 20–30 (in some cases, 40–60) km a day; the total distance covered by adult locusts during their life cycle may reach 200–300 km. For *transiens* phase of the locust only short-distance flights of small swarmlets are reported, about 1–3 km per day. A swarm takes off in the wind but flies mostly downwind at 50–200 m altitude at a speed of 10 m/s. The reasons behind the swarm movements of the italian locust are still not quite clear.

Mass outbreaks of the italian locust may be catastrophic, affecting millions of hectares, especially in Kazakhstan and adjacent regions of the Russian Federation. Several hot dry years in a row occurring in the main outbreak source areas facilitate the growth of the italian locust populations. Excessive precipitation, especially in late spring and early summer, has negative impact on the populations of the species. Conditions during winter are of less importance: the egg-pod of the italian locust has strong walls protecting embryos from the harshest conditions. Only prolonged periods of extremely cold and snowless weather may exceptionally result in mortality of some eggs in the egg-pods.

Figure 23. Italian locust female oviposits in soil cracks

In certain cases, especially when the species abundance declines, **natural enemies** may have considerable impact on the locust populations. Among the natural enemies, as in the case of the moroccan locust, the most dangerous for the eggs are blister beetles (family Meloidae) and bee flies (family Bombyliidae), while hoppers and adults are primarily attacked by tachinid flies (family Tachinidae), robber flies (family Asilidae) (see Figure 32) and flesh flies (family Sarcophagidae). Eurasian rooks (*Corvus frugilegus*) often feed on the locust. Flocks of rooks sometimes may serve an indicator of egg-beds of the italian locust and other acridids.

Wet years sometimes bring epizootic outbreaks of entomophthorosis caused by a pathogenic fungus *Entomophaga grylli*, which makes the locusts climb up the plants and die in a particular posture (Figure 24). There are some viral diseases affecting the italian locust too. Viruses and fungi of the genera *Beauveria* and *Metarhizium* are considered the most promising agents for the biological control of locusts.

Figure 24. North American grasshopper (*Melanoplus bivittatus*), killed by *Entomophaga grylli* fungus

5. MOROCCAN LOCUST

Figure 25. Adult moroccan locust *Dociostaurus maroccanus* (Thunberg, 1815)

The moroccan locust (Figure 25) belongs to subfamily Gomphocerinae. The species was described from the Atlas Mountains in Morocco, hence the species' name.

5.1 Distribution Area

The distribution area of the moroccan locust stretches for 10 000 km from the islands in the Atlantic Ocean (Canary Islands, Madeira) in the west to South-Eastern Kazakhstan in the East (Figure 26). The southern boundary is in Northern Africa along the 28th parallel northern latitude (N), while the northern one reaches 46° N in the Northern Caucasus and 49° N in the Subcarpathia. Thus, it stretches from north to south for approximately 2 000 km. The area is extensively fragmented: outbreak foci are separated by mountain ranges and vast water bodies preventing population exchanges.

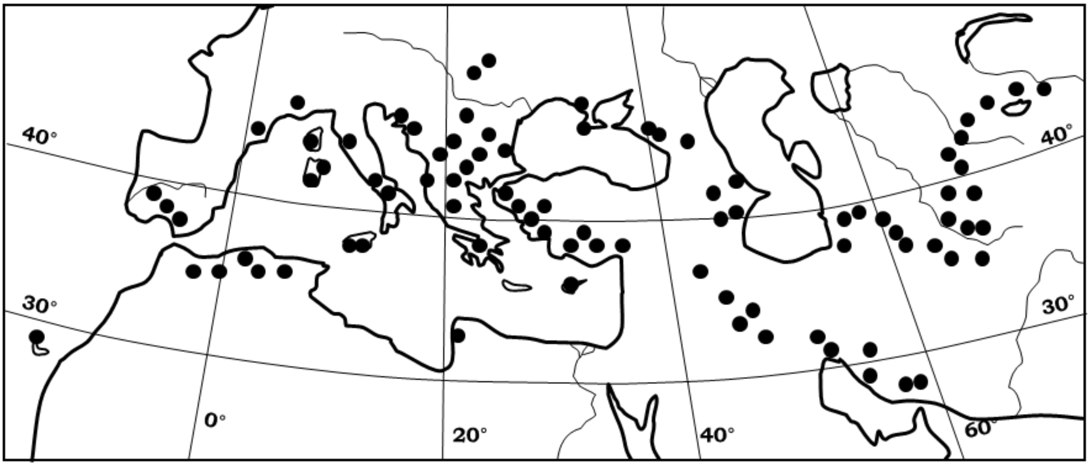


Figure 26. Distribution area of the moroccan locust *Dociostaurus maroccanus* (Thunberg, 1815)
(from Latchininsky et al., 2002, modified)

The main breeding areas in the CCA region are located in Azerbaijan, Georgia, Northern Afghanistan, Southern Kazakhstan (Zhambyl and Turkestan regions), Kyrgyzstan (Osh and Jalal-Abad regions in the south, Batken region in the west), Tajikistan (valleys of the Kafirnigan, Vakhsh, and Kyzyl-Su Rivers in the south), the Russian Federation (the Northern Caucasus), Turkmenistan (foothills of the Koohitang and Kopet Dagh Mountains) and Uzbekistan (the largest breeding areas within the CCA region: Quashqadaryo and Surxondaryo regions in the south, Samarkand region in the central part, Tashkent and Jizzak regions in the north). Many breeding areas are situated along the borders between neighbouring countries. As a result, bands of hoppers and especially swarms of adult moroccan locusts frequently cross the state borders making it difficult to carry out monitoring and control operations, which require international coordination and close cooperation of the locust management services.

5.2 Morphology

5.2.1 Adult

Adult moroccan locusts are of medium size with slender body (Figure 25 and 27, Table 3). The tegmina go beyond the apex of the hind femur; they often bear grayish or brownish spots. Wings are transparent. The body is grayish-yellow ("straw-coloured") with dark spots. Hind tibia are typically red, or, less frequently, yellow, pinkish, or whitish. There is an X-shaped yellowish or whitish mark on the protonum, composed of two narrow, almost uniformly wide bands (Figure 30a). Adult male weighs about 0.6 g, female – about 1.2 g on average.

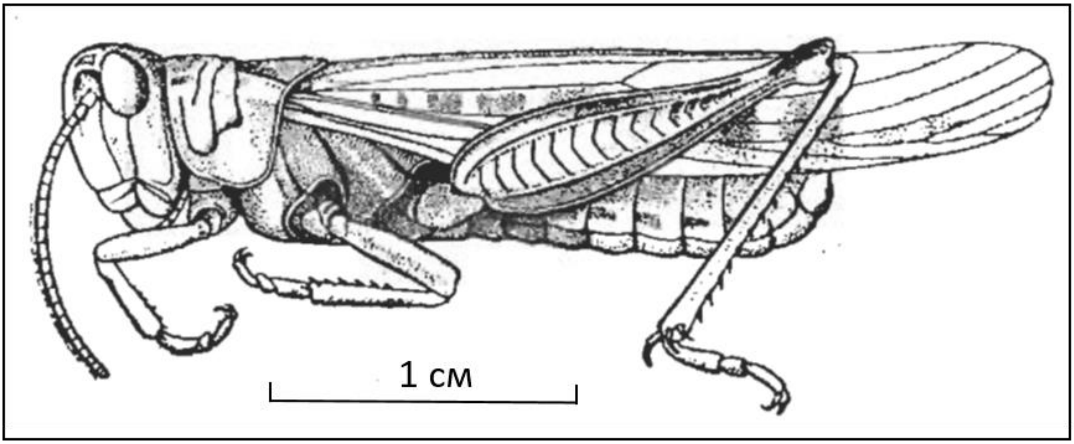


Figure 27. Adult male of the moroccan locust (side view)
(from Bey-Bienko, 1931)

Table 3. Morphological characteristics of moroccan locust adults

Sex / Character	Body length, mm	Tegmen length, mm	Hind femur length, mm
Male	16.5–28.5	17.5–27.0	13.2–17.4
Female	20.5–38.0	23.0–36.0	15.5–21.6

5.2.1.1 Difference between solitary and gregarious phases

Adult solitary locusts have numerous dark spots on their tegmina while gregarious individuals have transparent tegmina. In addition, solitary locusts have three dark markings on the upper face of the hind femur, which are absent in gregarious individuals (Figure 28). Overall coloration of the solitary phase is more vivid, while gregarious locusts are more washed-out, "straw-coloured", without contrasting dark spots (Figure 29). Solitary locusts are generally smaller than gregarious ones. E/F ratio (ratio of tegmen length to hind femur length) in solitary phase is lower than in gregarious phase (Table 4).

Table 4. Specific characters of phases of moroccan locust adults

Phase / Character	Male body length, mm	Female body length, mm	E/F Ratio
Solitary Phase	16.5–22.5	20.5–28.5	1,30–1,57 (average 1.46)
Gregarious Phase	22.0–28.5	25.0–38.0	1,58–1,83 (average 1.70)

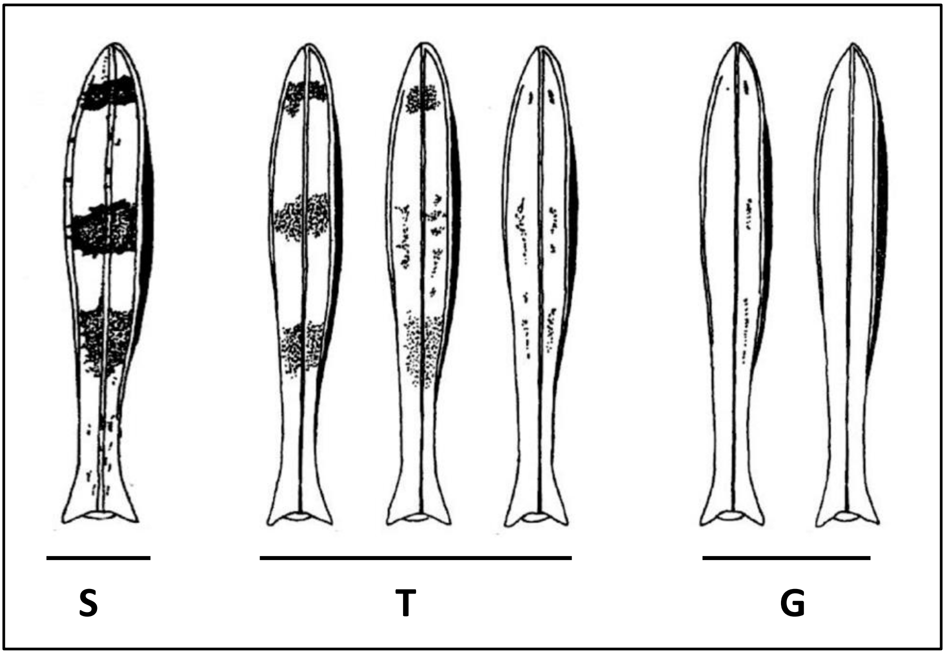


Figure 28. Development of dark spots on the hind femurs of the moroccan locust depending on the phase
(from Pasquier in Skaf, 1972, modified)
S – Solitary Phase; T – *Transiens* Phase; G – Gregarious Phase

5.2.1.2 Related Species

moroccan locust may coexist with other species of the genus *Dociostaurus*, in particular, with *Dociostaurus kraussi* (Ingenitzky, 1897). Compared to the moroccan locust, *D. kraussi* has a stalkier body, thicker hind femurs, and shorter wings (which are always considerably shorter than the abdomen in females and barely reaching it in males). In addition, both hoppers and adults *D. kraussi* have the X-shaped mark on the protonum with wider pale bands in the rear part of it than the moroccan locusts (Figure 30B).

The species are different in phenology as well: at the same sites *D. kraussi* hoppers hatch out approximately one week earlier than the moroccan locust. Therefore, emergence of the first instar hoppers of *D. kraussi* is a good indication of upcoming hatching of the moroccan locust hoppers. Finally, *D. kraussi* is a non-gregarious grasshopper species which does not form dense bands of hoppers or swarms of adults, characteristic for the moroccan locust.

Figure 29. Differences in coloration between the adult moroccan locusts of the solitary (S) and gregarious (G) phases

Solitary phase is more vividly coloured while gregarious phase is more washed-out

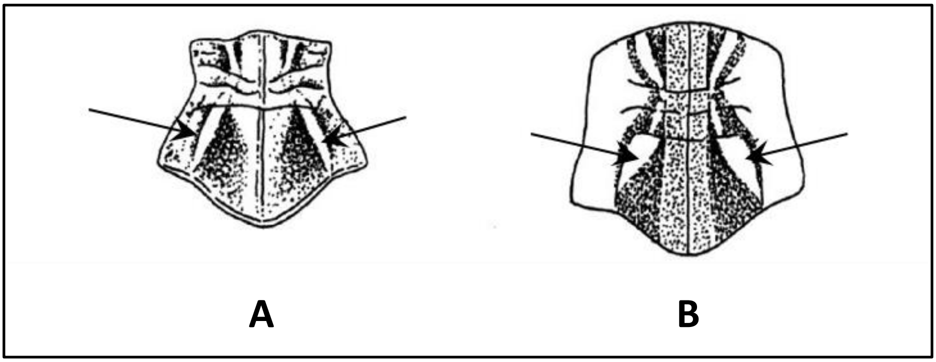


Figure 30. X-shaped mark on the protonum of *Dociostaurus maroccanus* (A) and *Dociostaurus kraussi* (B)
(from Uvarov, 1927b, modified)
Rear parts of the pale bands of the X-shaped mark (marked with arrows) are wider in *Dociostaurus kraussi* than in the moroccan locust

5.2.2 Nymphs

The species has five nymphal instars. The instars can be identified by the development of the wing pads (Figure 5). In addition, instars differ in size, mass, and number of antennal segments (Table 5).

Table 5. Morphological characteristics and mass of the nymphal instars of moroccan locust

Instar	Body length, mm	Hind femur length, mm	Number of antennal segments	Average mass, mg
1st	5.0–8.0	3.0–4.0	13	10
2nd	6.0–11.0	3.8–5.0	15–17	23
3rd	8.0–14.0	5.5–7.0	20	65
4th	13.0–22.0	7.5–10.0	21–22	128
5th	17.0–28.0	10.5–14.5	23–24	293

5.2.3 Egg-pod

The moroccan locust's egg-pod (Figure 31) has a shape of slightly curved or straight cylinder, slightly wider in the lower part, with total length of 16–35 mm. It has very hard clayey walls 0.3–1.0 mm thick. The opening is sealed with a thick (1 mm) soil lid. The eggs in the amount of 18–42 (30–36 on average) are stacked in the lower portion of the pod in three or four rows, at an angle to the walls. The eggs are topped with a column of fine foam secretion.

A B

Figure 31. Egg-pods of the moroccan locust
(A – from Latchininsky et al., 2002)
Vertical line on the left corresponds to 10 mm

5.3 Biology and ecology

The moroccan locust inhabits foothill semideserts covered with ephemeral vegetation. Predominant plant species is bulbous grass *Poa bulbosa* (Figure 32), with inclusions of desert sedge, alfalfa, cranesbill, quitch grass, and wheatgrass. Preferred soils are slightly saline loess loams. Typical altitude is 800 to 1 200 m above sea level, but recently there is tendency to expand to higher elevations (1 500 m and more). Egg-laying is done in virgin unplowed areas with very dense soil. The species prefers sites with vegetation cover alternating with bare soil, a type of mosaic biotope (Figure 33).

Food preferences: the moroccan locust is a polyphagous species capable to feed on any crops, from cereals and legumes to vegetables, cotton, cucurbits, fruit trees, vines, and even conifers. During mass outbreaks the hoppers first strip off all natural vegetation in the foothills where they hatch and then descend to valleys to feed on crops. The hopper bands start moving collectively from the second instar and are reported to travel up to 17 km (typically less) during their entire nymphal period. The bands formed by the moroccan locust stretch into strips a few kilometers long and tens of meters wide (Figure 35).

Figure 32. Vegetation cover dominated by *Poa bulbosa* at the hatching sites of the moroccan locust

Phenology: the moroccan locust is an early-spring species, which hatches from late February (southern parts of the distribution area) till late April (northern parts) (Figure 36). Hatching occurs concertedly and is completed in three to five days at one site. Maximum reported density of newly hatched hoppers is 21 000 individuals per m^2. Each instar lasts five to seven days. Sexual maturation of adults takes two to five days.

Egg-laying takes place in May to June; typically, a female lays not more than two egg-pods with a weekly interval between layings. There may be up to several hundreds of egg-pods laid on a square metre, with maximum density up to 8 000 pods per m^2. During egg-laying a female is frequently attacked by several males trying to copulate with her (Figure 39). Soon after the last egg-pod is laid, the locusts begin to die off, finishing their life cycle by the end of June or early July. Thus, the post-embryonic development of the Moroccan locust lasts for about three months (one month as hoppers and two months as adults), while the embryonic development in the soil takes up the remaining nine months of the year.

The moroccan locust requires particular soil conditions for oviposition. Females lay eggs only into very compact, unplowed loamy soil (Figure 34). In this aspect the moroccan locust is different from the italian locust, which is less exigent to the substrate for oviposition.

Figure 33. Moroccan locust habitat with mosaic ephemeral vegetation cover (Kyrgyzstan)

Adult locusts begin flying 10–15 days after fledging. The flights take place during a month at the altitude of 100 m at 8–10 m/second (s), when the temperature is above 28 °C. Typically during the entire life adults migrate to about 25–30 km (in rare cases up to 100 km). The species has rather sparse swarms, with maximum density on the ground of up to 300 locusts per m^2. The swarms regularly migrate from the egg-laying habitats (foothills) to the feeding habitats (croplands) inflicting extreme damage to cotton, cucurbits, and grain crops. Sometimes the egg-laying and feeding habitats are separated by state borders, which makes it difficult to carry out locust control operations and may even lead to tensions between the neighbouring countries.

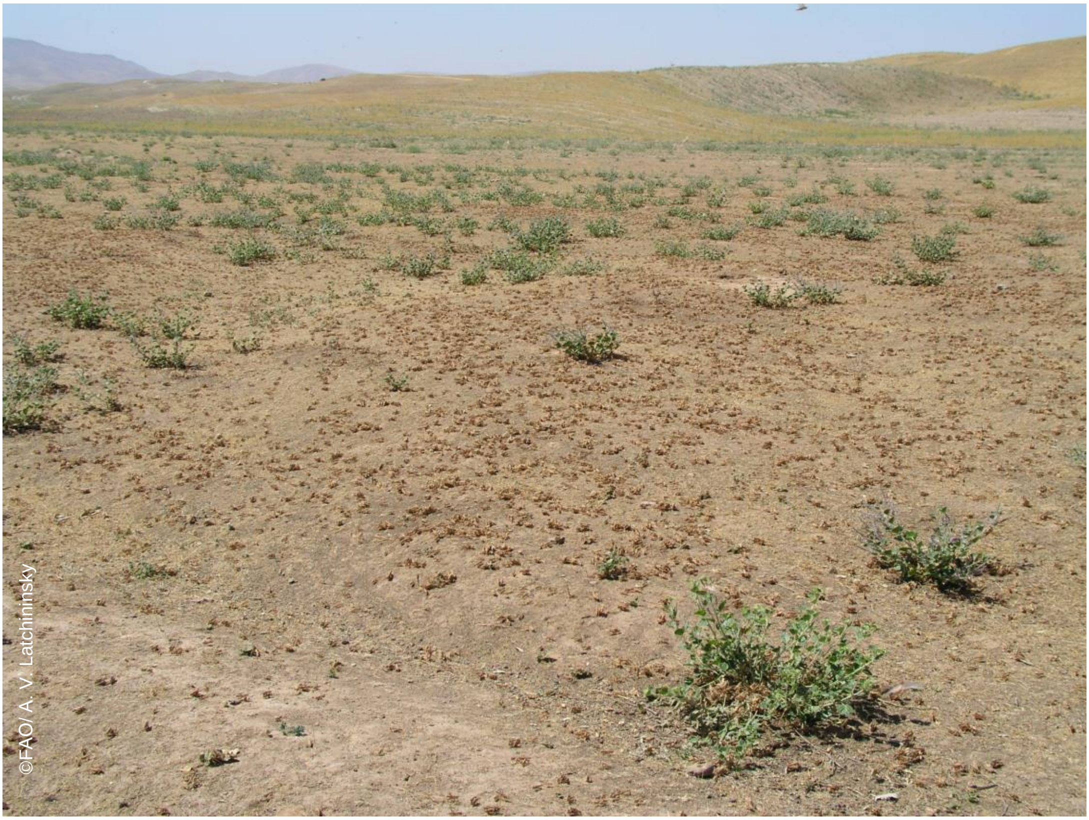


Figure 34. Typical egg-laying site of the moroccan locust in Southern Uzbekistan

The beginning of mass outbreaks is usually triggered by drought, which forces hoppers to concentrate in depressions and other sites with remaining green vegetation. Such crowding in limited areas contributes to the formation and maintenance of the gregarious phase. Optimal weather conditions are about 100 mm of precipitation from March to May. Excessive humidity provides the conditions for the fungal growth in the egg-pods, while insufficient humidity may lead to egg mortality in the egg-pods from desiccation.

In certain cases, **natural enemies** (arthropods and vertebrates) can have a significant impact on the population decrease of the moroccan locust; however, this does not typically occur during the peak of the outbreak but only when the populations decline. Among the enemies, the most dangerous for the eggs are the blister beetles (family Meloidae) and bee flies (family Bombyliidae) (Figure 37A, B), while hoppers and adults are preyed by tachinid flies (family Tachinidae), robber flies (family Asilidae) (Figure 38A) and arachnids solifugids (family Soliphugidae) (Figure 38B). Larvae of bee flies can be seen among the egg-pods on Figure 31B.

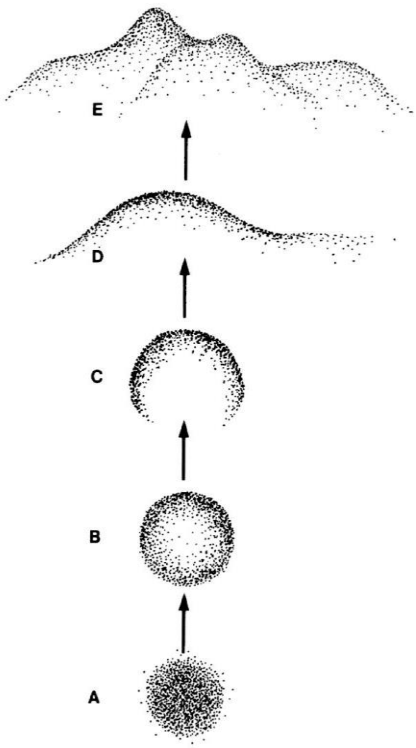


Figure 35. Formation of the ribbon-shaped hopper band of the moroccan locust
(from Siyazov, 1913)
A – E – stages of unfolding of the band from a ball (A) into a ribbon (E)

Flocks of rosy starlings (*Sturnus roseus*) sometimes attack bands of the moroccan locust and scatter them but typically the starlings switch to feeding on the locusts only during the outbreaks, therefore, their regulatory function is considered to be a minor one. The most promising agents for the biological control of the locusts are pathogenic microorganisms, particularly the fungi from genera *Beauveria* and *Metarhizium*, which are discussed in more detail in the volume of the practical guidelines devoted to locust control. It should be noted that in general, weather conditions have more influence on population dynamics of the moroccan locust than natural enemies, which are heavily dependent on the weather as well.

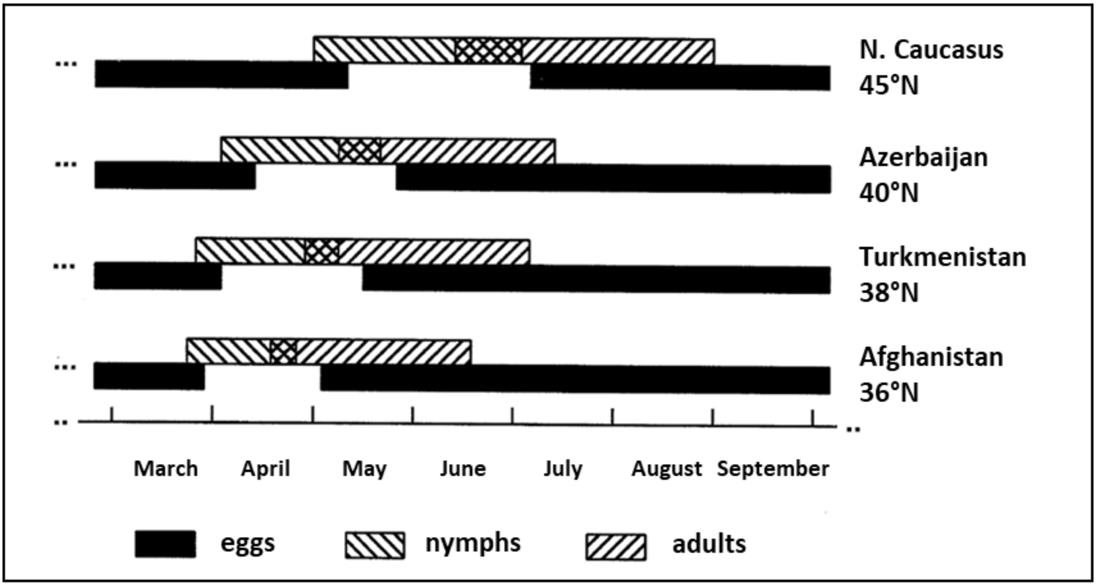


Figure 36. Phenology of the moroccan locust as a function of latitude
(from Latchininsky & Launois-Luong, 1992, modified)
Hatching occurs earlier and the life cycle stages are shorter towards the south

A **B**

Figure 37. Natural enemies of the moroccan locust eggs

A – Bee fly (Family Bombyliidae); B – Blister beetle (Family Meloidae)

A **B**

Figure 38. Natural enemies of the moroccan locust nymphs and adults

A – Robber fly (Family Asilidae); B – Arachnid solifugid (Family Soliphugidae)

Figure 39. Female moroccan locust during egg-laying and males that try to copulate with her.

6. ASIAN MIGRATORY LOCUST

Figure 40. Adult male of the Asian migratory locust *Locusta migratoria migratoria* (L., 1758)

Asian migratory locust (Figure 40) belongs to the subfamily Oedipodinae (or Locustinae).

6.1 Distribution area

Migratory locust *Locusta migratoria* has the largest distribution area among all locusts on Earth (Figure 41). It was considered that this species had nine subspecies or geographical races. One of these subspecies is the nominative subspecies *Locusta migratoria migratoria* (for convenience hereinafter referred to as "Asian Locust") inhabiting Kazakhstan, Central Asia and the south of the Russian Federation. There are several permanent breeding areas of Asian Locust in this territory concentrated along the banks of the rivers, lakes, and seas, in the stands *of Phragmites australis* forming large areas – reeds (Figure 42). The most active are the Balkhash-Alakol, Amudarya, Caspian, Dagestan, and Lower Volga breeding areas.

According to recent genetic studies, the Migratory Locust has only two subspecies, the northern one *Locusta migratoria migratoria* and the southern one *Locusta migratoria migratorioides*. The overall migratory locust distribution range and an approximate border between the ranges of its two subspecies are shown in Figure 41.

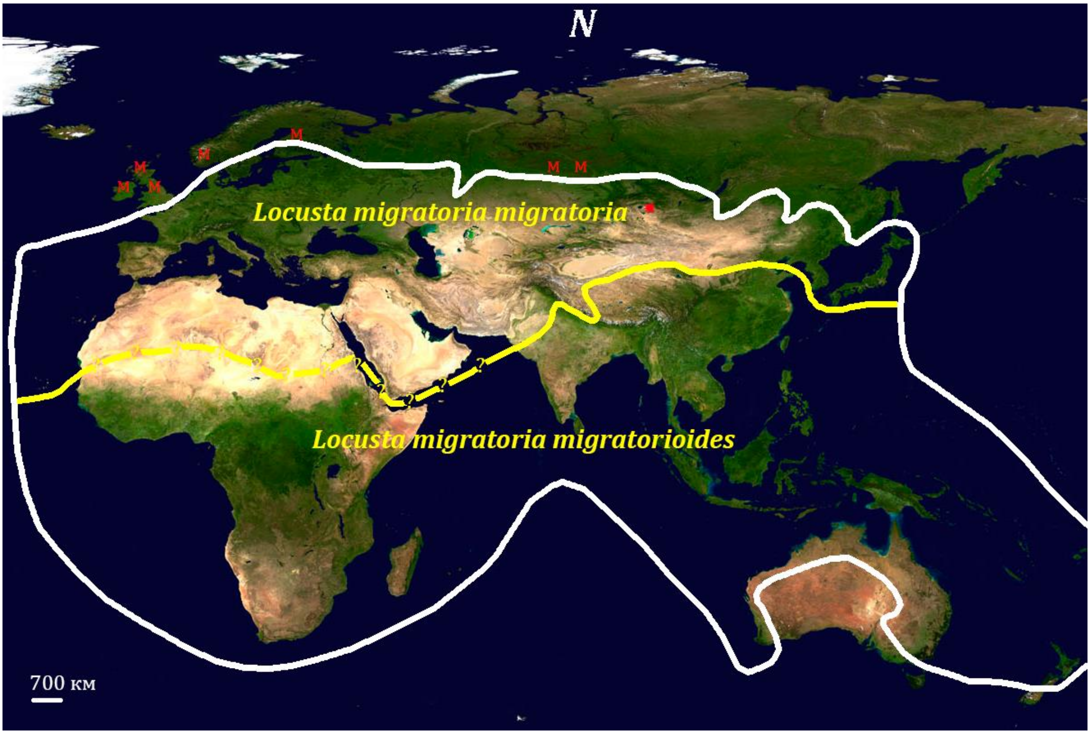


Figure 41. Distribution range of the migratory locust *Locusta migratoria* (L., 1758) and its two subspecies (from Sergeev, 2017)

Distribution range is shown without Tonga Islands. M – Main directions of swarm flights beyond the northern boundary; ? – portions of the border between the ranges of the two subspecies, which need to be confirmed.

Figure 42. Vegetation with predominance of the common reed *Phragmites australis* – favourite habitat of migratory locust

6.2 Morphology

6.2.1 Adults

Large insect (Table 6). Mandibles are blue. The protonum bears no X-shaped mark, with median carina. Wings are transparent (Figure 3). The under thorax is covered with short dense hairs, forming a pilosity. The coloration is green, yellowish-green, brown, or grey.

Table 6. Morphological characteristics of Asian Locust adults

Sex/character	Body length, mm	Tegmen length, mm	Hind femur length, mm
Male	35–50	43.5–56.0	22.0–26.0
Female	45–55	49.0–61.0	20.0–32.0

There are no species closely related to Asian Locust in our fauna. The Mid-Russian migratory locust *L. m. rossica* Uvarov et Zolotarevsky, 1929, which differs from the Asian Locust by smaller size, is widespread in forest-steppes and in the south of forest zone of the Russian Federation. The Mid-Russian migratory locust is smaller than the Asian Locust and does not form dense hopper bands or swarms.

6.2.1.1 Differences in solitary and gregarious phases

Phases of Asian Locust are well distinguished by the shape of protonum: it is saddle-shaped in gregarious phase and concave in solitary phase, both in adults (Figure 43) and hoppers (Figure 44). The adult E/F index (the ratio of tegmen length to hind femur length) in gregarious phase adults is >2,00 (to 2,23) and in solitary phase adults it is <1,96. In general, individuals of solitary phase are slightly larger than gregarious ones (in contrast to the moroccan locust whose solitary individuals are smaller than gregarious ones). It is to be noted that B. P. Uvarov postulated his revolutionary theory of phase variability in locusts studying the migratory locust.

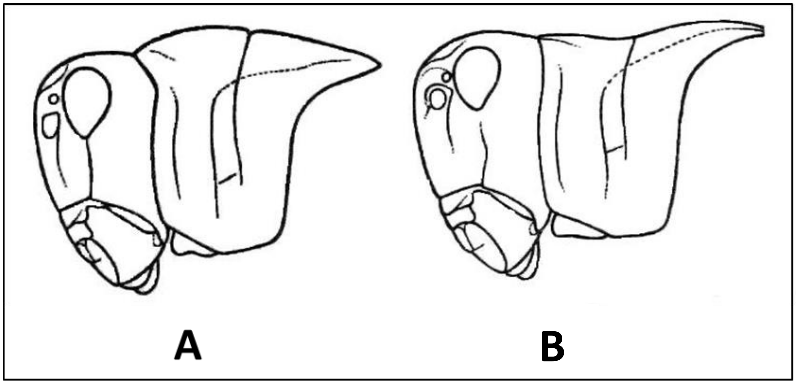


Figure 43. Head and pronotum of adult of the solitary (A) and gregarious (B) phases of Asian Locust
(from Bey-Bienko and Mishchenko, 1951)

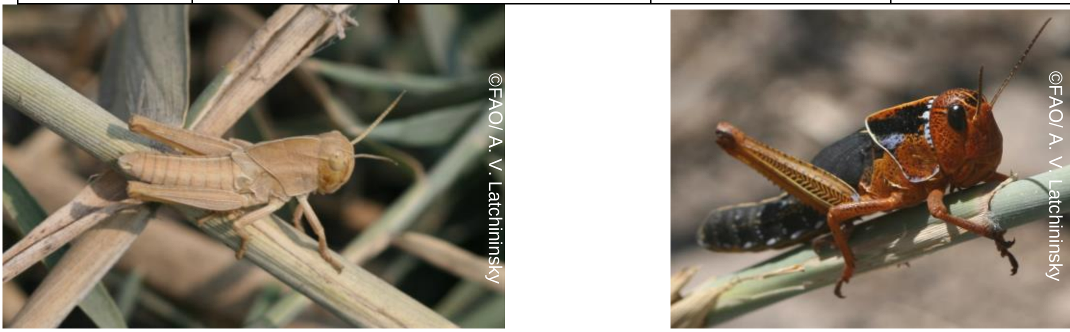
6.2.2 Nymphs

There are five hopper instars. Some distinguishing characters are presented in Table 7. The colour of hoppers of the solitary phase is gray, black, brown, green, or pale-yellow (Figure 44A). The colour of early-instar gregarious hoppers is dark gray or black; the colour of late-instar gregarious ones becomes lighter, with predominance of orange tones and velvety-black spots on protonum (Figure 44B).

Table 7. Morphological traits and mass of Asian Locust hoppers

Hopper instar	Body length, mm	Hind femur length, mm	Number of antennal segments	Average mass, g
1st	7.0–10.0	4.0	13–14	0.025
2nd	10.0–14.0	5.0–6.0	18	0.05
3rd	16.0–21.0	8.0–9.0	20–21	0.12
4th	24.0–26.0	11.0–13.0	22–23	0.32

5th	25.0–40.0	15.0–18.0	24–25	1.35



A B

Figure 44. 4th instar nymph of solitary phase (A) and 5th instar nymph of gregarious phase (B) of Asian Locust

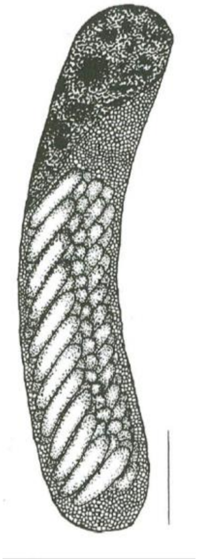
6.2.3 Egg-pod

Large, cylindrical, 50–85 mm long, 7–10 mm in diameter. The height of secretion column above eggs is 15–25 mm. There are 40–120 eggs (60–80 on average), arranged in four longitudinal rows at a 40–45° angle to walls (Figure 46). The egg-pod is fragile, it disintegrates when taken out of the soil.

6.3. Biology and ecology

Despite the extensive distribution area, all habitats of the Asian Locust are very similar to each other. These are mainly reed stands in the lower reaches of rivers or around lakes, which are a complex wetland system of canals, large and small reservoirs, islands, and rivulets (Figure 42, 45). Vegetation is represented by reeds as well as other semi-aquatic grasses, sedges and pollocks. Soils are light, sandy, and sandy-loamy, less often clayey, sometimes slightly saline.

Figure 45. Reed stands in the delta of the River Amudarya in the Aral Sea zone, Karakalpakstan, in the breeding area of the Asian Locust



A

B

Figure 46. Egg-pod (A) and eggs (B) of Asian Locust
(A: from Latchininsky et al., 2002)
Vertical line corresponds to 10 mm

Phenology: in most breeding areas hatching occurs in the middle or end of May. The hatching is concerted and is completed in four or five days within one egg-bed. Hopper development lasts for 35–40 days. Fledging begins in late June. Approximately ten days after fledging, the locusts start making short flights, first for short distances, then more and more long. Adult locusts mature within two to four weeks and begin mating; two to three weeks later the females start laying eggs. Each female lays two or three, and if the weather is warm in the autumn, up to five egg-pods into light, sandy soil. There are reports of parthenogenesis in the Asian Locust, that is, the eggs developed without being fertilized by male.

Typically, the Asian Locust, like other gregarious locusts in CCA, has only one generation per year. However, there are records of late (in late summer) hopper hatching in Dagestan and Aral Sea region, which illustrate the possibility of the second generation within one year.

Feeding preferences: the Asian Locust prefers feeding on grasses, such as common reed (Figure 47), wheatgrass, wood reed and other monocots (sedges and juncaceous). Accordingly, grain crops including rice suffer highest damage by the Asian Locust. However, when a swarm leaves the breeding area or in the absence of favorite grassy forage, the Asian Locust may feed on a wide range of plants, damaging all major crops. With a lack of food, cannibalism can also be developed.

The gregarious phase of the Asian Locust is characterized by formation of large hopper bands (Figure 48), with maximum density reaching 80 000 hoppers per m^2 for the 1st instar and 7 000 hoppers per m^2 for the 5th instar. The hopper bands march actively, covering up to 3 km a day (5th instar) and may move away from their hatching areas for a distance of up to 30 km during the nymphal period. The hopper bands can easily overcome small water bodies that they encounter on the way. Swarms of Asian Locust (Figure 50) can cover long distances (about 100 km per day), moving at a speed of 8–12 m/s. There are known cases when the swarms took off from the Amudarya breeding area near the Aral Sea, flew across the Caspian Sea and reached Azerbaijan and Dagestan, covering the distance of more than 1 000 km.

Figure 47. Typical damage of common reed by Asian Locust

5th instar nymph is shown

The population dynamics of the Asian Locust are determined by the hydrological regimen in the breeding area: alternating seasonal floods and drying of reed stands cause a reduction or expansion of the forage base and areas suitable for egg-laying. As a result of high floodings, extensive areas of reed stands are covered with water. When the water begins to recede, previously flooded areas become overgrown with reeds, which creates favourable conditions for Asian Locust to breed. Therefore, mass outbreaks usually begin when high floods are followed by dry periods.

Among **natural enemies** of Asian Locust, blister beetles (family *Meloidae*) are important, damaging eggs in egg-pods (Figure 37B). The red-headed blister beetle *Epicauta erythrocephala* (Figure 49) is considered one of the most important regulators of the abundance of this locust. Tachinid flies (family *Tachinidae*) attack both hoppers and adults; sometimes several dozens of tachinid fly larvae develop in a single Asian Locust. Quite numerous also are the representatives of the family *Sarcophagidae,* especially the ones from the genus *Blaesoxipha*, attacking hoppers and adults.

Similarly, to the Moroccan and Italian locusts, natural enemies are usually able only to precipitate the end of the Asian Locust outbreak and their regulatory role in the recession phase of population dynamics is much more effective than in the upsurge (outbreak) phase.

Figure 48. Young-instar hopper band of Asian Locust

Figure 49. Blister beetle *Epicauta erythrocephala* (Pallas, 1776) – egg parasite and important regulator of the Asian Locust population dynamics

Figure 50. Swarm of Asian Locust (Astrakhan region, southern Russian Federation)

7. BIBLIOGRAPHY

Russian-language bibliography on italian locust *Calliptamus italicus* (L., 1758), moroccan locust *Dociostaurus maroccanus* (Thunberg, 1815) and Asian Locust *Locusta migratoria migratoria* (L., 1758) as well as a less detailed one on the desert locust *Schistocerca gregaria* (Forskål, 1775) in Caucasus and Central Asia can be accessed from the FAO Locust Watch in CCA website: http://www.fao.org/ag/locusts-CCA/common/ecg/1028/ru/BIBLIO_RUS.pdf.

Below the reader will find a list of publications in languages other than the Russian, mostly related to the locust species in CCA, as well as some publications of general interest on locust bio-ecology.

Albrecht F.O., 1967. *Polymorphisme phasaire et biologie des acridiens migrateurs*. Paris, Editions Masson.

Ayali A., 2019. The puzzle of locust density-dependent phase polyphenism. *Current Opinion in Insect Science,* 35: 41–47.

Baron S.R., 1972. *The Desert Locust.* London, Eyre Methuen.

Bazazi S., Buhl J., Hale J.J., Anstey M.L., Sword G.A., Simpson S.J. & Couzin I.D., 2008. Collective motion and cannibalism in locust migratory bands. *Current Biology,* 18(10): 735–739.

Bodenheimer F.S., Shulov A., 1951. Egg-development and diapause in the Moroccan Locust (*Dociostaurus maroccanus* Thunb.). *Bulletin of the Research Council of Israel*, 1: 59–75.

Buhl J., Sumpter D.J.T., Couzin I.C., et al., 2006. From disorder to order in marching locusts. *Science* 312, 1402–1406.

Cheke R.A., Young S., Wang X., Tratalos J.A., Tang S. and Cressman K., 2021. Evidence for a Causal Relationship between the Solar Cycle and Locust Abundance. *Agronomy,* 11(1): 69.

Çiplak B., 2021. Locust and Grasshopper Outbreaks in the Near East: Review under Global Warming Context. *Agronomy*, 11(1): 111.

COPR (Centre for Overseas Pest Research), 1982. *The locust and grasshopper agricultural manual*. London: 1–690.

Cullen D.A., Cease A.J., Latchininsky A.V., Ayali A., Berryr K., Buhl J., De Keyser R., Foquet B., Hadrich J.C., Matheson T., Ott S.R., Poot-Pech M., Robinson B.E., Smith J.M., Song H., Sword G.A., Vanden Broeck J., Verdonck R., Verlinden H., Rogers S.M., 2017. From Molecules to Management: Mechanisms and Consequences of Locust Phase Polyphenism. In: Heleen Verlinden, editor, *Advances in Insect Physiology, Vol. 53*, Oxford: Academic Press, 2017, pp. 167–285.

Ellis P.E., 1951. The marching behavior of hoppers of the African Migratory Locust (*Locusta migratoria migratorioides* R. et F.) in the laboratory. *Anti-Locust Bulletin,* 7: 1–48.

FAO (Food and Agricultural Organization of the United Nations), 2001. *Desert Locust Guidelines*, 2nd edition. Vol. I-VI: 1–286 + 173 pp. appendices. Rome.

Greathead D.J., 1963. A review of the insect enemies of Acridoidea (Orthoptera). *Transactions of the Royal Entomological Society of London,* 114: 437–517.

Hansen M.J., Buhl J., Bazazi S., Simpson S.J. & Sword G.A., 2011. Cannibalism in the lifeboat – collective movement in Australian plague locusts. *Behavioral Ecology and Sociobiology,* 65(9), 1715–1720.

Jazykov (Zakhvatkin) A.A., **1931**. Parasites and hyperparasites of the egg-pods of injurious locusts (Acridodidea) of Turkestan. *Bulletin of Entomological Research*, 22(3): 385–391.

Key K.H.I., 1950. A critique on the phase theory of locusts. *The Quarterly Review of Biology*, 25(4): 363–407.

Kokanova E.O., 2017. Natural foci of the Moroccan Locust *Dociostaurus maroccanus* (Thunberg, 1815) (Orthoptera, Acrididae) in Turkmenistan and their current state. Entomological Review, 97(5); 584–593.

Latchininsky A.V., 1998. Moroccan locust *Dociostaurus maroccanus* (Thunberg, 1815): a faunistic rarity or an important economic pest? – *Journal of Insect Conservation* 2: 167-178.

Latchininsky A.V., 2013. Locusts and remote sensing: A review. *Journal of Applied Remote Sensing* 7 (1), 1–32.

Latchininsky A.V., 2019. *Locusts.* Pp. 115–126 in: Jae Chun Choe (Ed.) Elsevier Encyclopedia of Animal Behavior, Second Edition. Vol. 3, Academic Press.

Latchininsky A.V., Launois-Luong M.H., 1992. *Le Criquet marocain*, Dociostaurus maroccanus (*Thunberg, 1815*), *dans la partie orientale de son aire de distribution. Etude monographique relative à l'ex-URSS et aux pays proches*. XIX + 270 pp. International Center of Agronomic Research for Development CIRAD-GERDAT-PRIFAS: Montpellier, France / All-Russian Research Institute for Plant Protection VIZR: St Petersburg, Russian Federation.

Latchininsky A.V., Launois-Luong M.H., 1997. *Le Criquet pelèrin*, Schistocerca gregaria (Forscål*, 1775*), *dans la partie nord-orientale de son aire d'invasion.* XVIII + 192 pp. International Center of Agronomic Research for Development CIRAD-PRIFAS: Montpellier, France / All-Russian Research Institute for Plant Protection VIZR: St Petersburg, Russian Federation.

Lecoq M., Zhang L., 2020. *Encyclopedia of Pest Orthoptera of the World.* China Agricultural University Press.

Lockwood J.A., Latchininsky A.V. & Sergeev M.G. (Eds.), 2000. *Grasshoppers and Grassland Health. Managing Grasshopper Outbreaks without Risking Environmental Disaster*. Kluwer Academic Publishers (NATO Science Series), Dordrecht / Boston / London – X + 221 pp.

Pener M.P., Simpson S.J., 2009. Locust phase polyphenism: An update. *Advances in Insect Physiology* 36, 1–272.

Santiago-Álvarez C., Quesada-Moraga E. & Hernández-Crespo P., 2003. Diapause termination and post-diapause development in the Mediterranean locust *Dociostaurus maroccanus* (Orth., Acrididae) under field conditions. *Journal of Applied Entomology*, 127(6): 369–373.

Sergeev M.G., 1997. *Ecogeographical distribution of Orthoptera*. Pp. 129–144 in: Gangwere S.K., Muralirangan M.C. & Muralirangan M. (eds.). *The bionomics of Grasshoppers, Katydids and Their Kin*. CAB International, Farringdon, Oxon – NY.

Simpson S.J., Sword G.A., 2008. Locusts. *Current Biology* 18, R364–R366.

Skaf R., 1972. Le Criquet marocain au Proche-Orient el sa grégarisation sous l'influence de l'homme. *Bulletin de la Société d'Écologie,* 3(3): 247–325.

Song H., 2011. Density-dependent phase polyphenism in nonmodel locusts: A minireview. *Psyche* 2011, 1–16.

Steedman A., 1988. Locust Handbook, 2nd ed. Overseas Development Natural Resource Institute: London.

Uvarov B.P., 1932. Ecological studies on the Moroccan locust in Western Anatolia. *Bulletin of Entomological Research,* 23: 273–287.

Uvarov B.P., 1933. Ecology of the Moroccan Locust in Iraq and Syria and the prevention of its out-breaks. *Bulletin of Entomological Research,* 24: 407–418**.**

Uvarov B.P., 1966. *Grasshoppers and Locusts. A Handbook of General Acridology, Volume I: Anatomy, Physiology, Development, Phase Polymorphism, Introduction to Taxonomy*. Anti-Locust Research Centre, University Press: Cambridge.

Uvarov B.P., 1977. *Grasshoppers and Locusts. A Handbook of General Acridology, Volume II: Behaviour, Ecology, Biogeography, Population Dynamics*. Centre for Overseas Pest Research, University Press: London.

Zhang L., Lecoq M., Latchininsky A.V., Hunter D., 2019. Locust and grasshopper management. *Annual Review of Entomology* 64: 15–34.

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9 789251 385593

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