JOURNAL OF AGRICULTURE AND APPLIED BIOLOGY
2021, Vol. 2, No. 1, 61 – 69
http://dx.doi.org/10.11594/jaab.02.01.08

Review Article

Desert locust (*Schistocerca gregaria* Forskal) and its management: A review

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Article history:
Submitted 07 March 2021
Accepted 03 May 2021
Published 05 June 2021

Keywords:
Aggregation
Desert Locust
Phenylacetonitrile
Pheromones

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Abstract

The desert locust [*Schistocerca gregaria* (Forskal)] (Orthoptera: Acrididae) is one of the world's most dangerous and destructive migratory pests. It is a highly voracious and polyphagous insect. Its swarms can travel hundreds of kilometers per day and infest areas covering millions of square kilometers, resulting in substantial crop losses. We synthesize published research data and reports on the life cycle, behavior, phases, and damage of the desert locust, as well as its possible management practices, in this study. There are difficulties involved in estimating locust populations because locust swarms are highly mobile. Cultural control, baiting, dusting with insecticide, and spraying liquid insecticides (chemical or biological) using ultra-low volume (ULV) application are all options for controlling locust swarms. Improved knowledge on pest biology, as well as more efficient monitoring and control strategies, are essential components of an effective management strategy.

Introduction

Desert locust (*Schistocerca gregaria* Forskal) is the world's most deadly and destructive migratory pest (Cressman et al., 2016; Lazar et al., 2016; FAO, 2020a; Joshi et al., 2020). It is ravenous eaters; an adult desert locust weighs about 2 grams (a fraction of an ounce) can consume roughly its weight daily (Baskar, 2020; Latchininsky et al., 2016; Bayer, 2021). The locusts steal food from people's mouths and livestock that they depend on for survival (FAO, 2021). The pest epidemic, according to the FAO, poses a "unprecedented danger" to food security and livelihoods in areas already vulnerable to climate change (Mission, 2020; Banik et al., 2020; Eagling, 2020). Swarms of desert locusts are a major economic problem in more than 65 countries, covering more than 20% of the world's total land area (EurekAlert, 2020). It causes substantial agricultural damage (Maeno et al., 2020; Latchininsky et al., 2011; D'Alessandro et al.,

How to cite:
Katel, S., Mandal, H. R., Neupane, P., Timsina, S., Pokhrel, P., Katuwal, A., Subedi, S., Shrestha, J., & Shah, K. K. (2021). Desert locust (*Schistocerca gregaria* Forskal) and its management: A review. *Journal of Agriculture and Applied Biology, 2* (1), 61 – 69. doi: 10.11594/jaab.02.01.08

2015). Desert locust is a direct threat to the food security (Kumar, 2020). It has an effect on food security because it destroys crops, reducing the amount of food available to human populations. They also eat grasses and other wild plants, which has an effect on livestock and wildlife (Escorihuela et al., 2018).

It is estimated that one-tenth of the world's population livelihoods are affected by desert locusts (FAO, 2016). Grasshoppers and locusts are structurally different, despite their similar appearance. Both have distinct personalities. The front wings of grasshoppers are thin and tough, while the outer wings are broad and flexible. For long-distance flight, the locusts' wings grow longer and stronger. Locusts have a smaller body size than grasshoppers. Locusts are also capable of living the solitary or gregarious phase, while grasshoppers can only be solitary. Female locusts are more extensive than their male counterparts in their solitary states, although their sizes decrease in the swarming phase. In comparison to grasshoppers, locusts can fly over long distances and they also have smaller bodies than a grasshopper. They are voracious, as a single adult locust will eat enough vegetation to equal its weight (roughly 2 grams) in a single day (Latchininsky et al., 2016; Dandabathula et al., 2020).

Locust swarms are extremely mobile, capable of flying across continents and destroying entire livelihoods in less than six hours, with adult swarms covering around 150 kilometers a day. Desert locusts wreak havoc on food security by destroying crops, reducing food availability to humans. They also eat grasses and other wild plants, which affecting livestock and wildlife (Escorihuela et al., 2018). Desert locusts are difficult to control, but with proactive monitoring, early action, and targeted application of appropriate control measures as required (Samejo et al., 2021). Improved knowledge of pest biology and ecology, as well as more efficient monitoring and control methods, are now essential components of an effective preventive management strategy (Zhang et al., 2019). Locust control programs still rely on chemical pesticides. Improved pest biology and ecology knowledge and more efficient monitoring and control methods are essential components of an effective preventive management strategy (Zhang et al., 2019). This review highlights the life cycle, behavior, phases of the desert locust and crop losses, and its management.

Life cycle of desert locust

Desert locusts have six stages, the first five of which are non-flying. They begin flying, mating, and laying eggs once they reach adulthood, and the cycle continues (Masinde, 2020). With an average lifespan of 3-5 months, desert locusts go through three stages: egg, nymph, and adult. Female lays eggs in the bare sandy soil having moisture about 5-10 cm below the surface with the valves of the abdomen. The female will check the moisture content of the soil by placing or inserting the tip of the abdomen. The eggs are present in batches called egg pod, which are arranged similar to the miniature hand of banana and are similar to rice grains which are 3-4 cm long and its top is about 5-10 cm below the surface which can store less or equal to 80 eggs in the gregarious phase and 90-160 eggs in a solitary stage. The eggs hatch into wingless larvae or nymph called hoppers and, after few hours of hatching, the eggs turn black in color. Skin is shed 5-6 times by the hopper. When adults are winged, weight increases although they are sexually immature; after some time, they become mature and can copulate and lay eggs. Generally, a female can produce 16-20 variable locusts in a single generation. The development of an egg is directly proportional to soil temperature at pod depth (Symmons & Cressman, 2001) and moisture absorbed during embryonic development (Homberg, 2015). The life span of the desert locust is about 3-5 months, in which the development of hopper takes place 30-40 days, and adults mature from 2-4 months depending on environmental conditions, i.e., temperature. Similarly, an adult can feed up to 2-5 g every day according to its body weight.

The locusts move to green vegetation when the vegetation starts to dry out and come into physical contact with each other and begin to behave as a single cohesive mass (Cressman, 2016).

Phases of locust

Locusts go through phase polymorphism, which means they may go from being solitary to being gregarious, which means they congregate in large groups (Duncan, 2020). Solitarious locusts are cryptically colored nymphs that tend to live alone and are relatively inactive. Gregarious locusts have bright colors, form bands (as larvae) or swarms (as adults) and are usually very mobile. Individuals are solitarious while locusts are found in low densities. If the locusts grow, they form dense groups and become more dangerous (Symmons & Cressman, 2001). According to scientists, the brain chemical serotonin has been discovered to transform a solitary phase into a gregarious phase. Contact is the catalyst for the transformation of solitary locusts. Physical contact becomes inevitable when the locust population grows, and locusts begin to emit serotonin (Blue, 2018; Balasubramanian, 2020).

Due to an increase in the chemical serotonin in their nervous system, desert locusts may become gregarious and swarm (Armstrong, 2020). When the rains are particularly heavy, the population will rapidly grow, resulting in massive swarms. Desert locusts then scatter in swarms in searching for food and ideal breeding conditions (Showler, 2019).

Due to a lack of food, desert locusts are forced to congregate. The swarming of solitary locusts causes a shift as this occurs. The insects go through a process known as gregarious behavior. The gregarious traits are due to a small (3 kDa), a hydrophilic labile "gregarizing" factor that is created during egg deposition and predisposes neonate nymphs to gregarious behavior (McCaffery & Simpson, 1998). Pests can spread across continents, and locusts can migrate hundreds of miles in a single night. In a relaxed environment, the Desert Locust *Schistocerca gregaria*, for example, can infect 60 countries (Popov et al. 1991); locusts congregate and become more polyphagous (Le Gall et al., 2019). A temporary stage is a transition from a single stage to a group stage and vice versa, and the locust is a temporary stage. When grasshoppers reproduce, they form a group, and when they die, they become decayed (Symmons & Cressman, 2001). The phases have distinct morphology (e.g., brain size, body size, and color), physiology (neuroendocrinological status), and behaviour (tendency to move with their crowd and reaction timing to moving objects) (Cabej, 2019). The phases of the locust are shown in Figure 1.

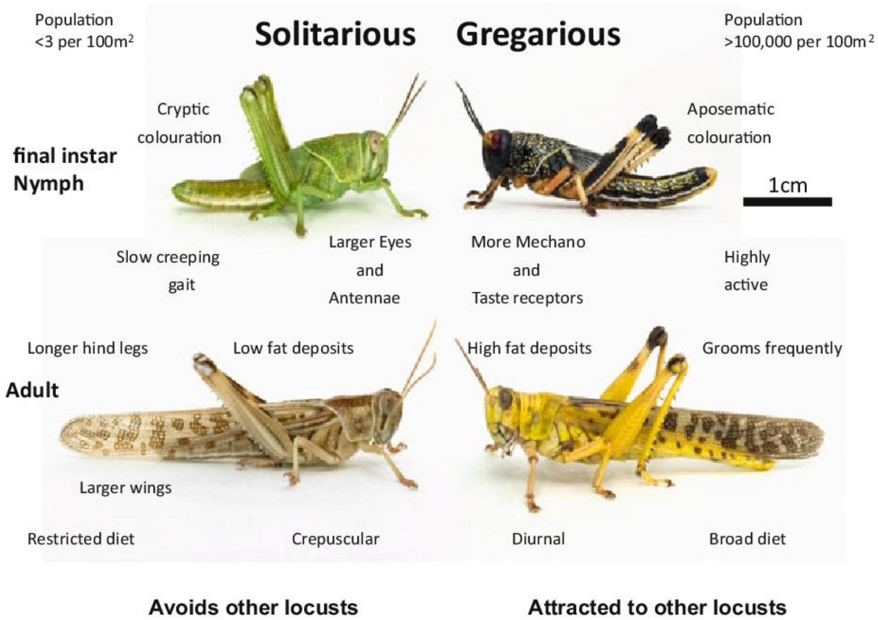

Figure 1. Difference between solitarious and gregarious phases of desert locusts (Schistocerca gregaria Forskal) in their larval instar and adult stages. (*Rogers, 2014*)

Behavior of locust

The desert locust is migratory in habitat depending upon the population densities, rainfall occurrence between spring, summer, winter, and breeding area (Homberg, 2015). Hopper spends little time on the ground moving over the bare ground alternating resting moving up and down in the large dense low plants vegetations and east and west where there are tall plants in open spaces (Symmons & Cressman, 2001).

Adults: For the adult wings to harden sufficiently, it takes about ten days after fledging. Rainfall provides a favorable maturation condition where male matures faster than female (Symmons & Cressman, 2001).

Solitary adults: Mainly, the solitary adults fly during the night at the temperature of 20-22 ^{0}C after forming groups they became concentrated when the vegetation dries up (Symmons & Cressman, 2001). They mainly rest on the ground and fly when they are disturbed. During dusk, they are more active and move short distances up to 20-30 minutes after sunset and cover 60-250 km in a single night (Homberg, 2015). The wind with high velocity mainly disperses their population, and when the wind is hotter, the more the distance travel by the locust. According to FAO (2016), "A swarm of 1 km^2 eats the same amount of food in one day as 35,000 people". After 30 minutes of social contact, the grouping behavior of desert locusts increases (Ellis, 1963), becomes more gregarious when crowded together (Gillett, 1988). Similarly, when the swarm of locust can cover a distance of 100 km in the prevailing direction per day, bands can move up to 5-130 km day^{-1} (Steedman, 1998) but individual flight speed is 3-6 m s^{-1} usually if the wind speed is low i.e., <2 m s^{-1} flight tracks are observed visually while at high-speed wind i.e., 2-4 m s^{-1} tracks are downwind (Homberg, 2015). The size of the swarm of the locust is given in Table 1.

Desert locusts are polyphagous insects which feed on various parts of plants such as leaves, shoots, flowers, fruit, seeds, stems, and even bark (Shrestha et al., 2021). The damage and loss to crops are severe when desert locusts occur in a plague (gregarious phase). At this condition, the management of locusts should be carried out to prevent losses.

Table 1. Size of swarm and locust

Sizes	Swarm	Band
Very small	Less than 1 km^2	1-25 m^2
Small	1-10 km^2	25-2500 m^2
Medium	10-100 km^2	2500 m^2-10 ha
Large	100-500 km^2	10-50 ha
Very Large	>500 km^2	>50 ha

(Source: FAO, 2020a; FAO, 2020b)

Management of desert locust

From the beginning of civilization, the locust has been most devastating threats to agriculture, and different control campaign has been carried out costing millions of dollars. However, no satisfactory outcome has been observed, although the use of various chemical insecticides causes severe problems in the environment. FAO runs the desert locust information service (DLIS); it collects information by video (http://www.fao.org/ag/locusts) and social media (FAO, 2016). National, regional and international components are coordinated by FAO that helps to achieve global meta-population management (FAO, 2020a; FAO, 2020b). To prevent lengthy and expensive operations, it is important to detect desert locust populations early on, before they enter the plague level (Ibrahim, 2008). The cost for control of desert locust plagues can be very high. Population monitoring and forecasting are two aspects of locust management (Elston, 2013). However, since most breeding sites are remote and inaccessible, and adult locusts are highly mobile insects that occupy vast swaths of land, predicting locust populations is difficult

(Elston, 2013). Cultural control (digging, burning), baiting (spreading locust food impregnated with insecticides), dusting with insecticide, and spraying liquid insecticides (chemical or biological) using ultra-low volume (ULV) application are all methods for controlling locust swarms (Elston, 2013).

Cultural practices

Cultural methods of pest control consist of regular farm operations in such a way that either destroy the pests or prevent them from causing economic loss. As we know that, locusts contain high protein sources. So, it can be used as feed for people, livestock, duck, and fish. Two grams of locust contains an energy source of 0.5 gram protein and an energy value of 2 Kcal (Van, 1992). Hand-picking of locusts for food and feed purposes can minimize the population of desert locusts. Killing or trampling bands, plowing or burning egg-infested fields, trapping hoppers in pits (Sharma, 2014), and making loud noises with acoustic and electronic equipment are among the other cultural practices (Ibrahim et al., 2013). To prevent them from sinking into the ground, the locals use fire, clouds of smoke, and loud noises.

Mechanical method

Traditional mechanical control methods are effective when there is low locust infestation and labor is cheap. Making noise increases the randomness of a swarm which helps to decrease its population and helps to break it apart (FAO, 2020a; FAO, 2020b). During the day, desert locusts are healthy, but they congregate on trees and open land without dense vegetation at night. They are dormant until the sun shines so that a mosquito net can catch the desert locusts. Baiting and dusting are the most powerful methods for handling hoppers (Wiktelius et al., 2003). The destruction of bands and swarms may be used to control locust plagues. Mechanical controls methods that are mechanical methods are promising alternatives to control the pest.

Botanical method

Botanicals are mostly plant-based products. Plant oils come in two forms: edible oils and essential oils, which are protective against locusts. They are broad-spectrum pesticides that are less toxic, less costly, and more easily available while still being safe for the environment and non-target organisms. On the crop vegetation, the botanical pesticide can have only mild adverse effects. Pests' resistance to them is slow to develop and uncommon (Raghavendra et al., 2016). Pyrethrum, rotenone, neem, and essential oils are among the most commonly used botanical items for managing desert locust.The combined toxic effect of botanical pesticide prepared from caraway, wintergreen, and orange oils at low concentration was found effective as it causes mortality, affect mobility and ventilation of the locusts. It also acts as antifeedant (Abdelatti & Hartbauer, 2020). When offered as a diet, Nerium oleander has been shown to inhibit the ovarian development of desert locusts (Bagari et al., 2015). Other essential plant oils against locusts include garlic extracts/oil (*Allium sativum*), cumin (*Cuminum cyminum*), and jatropha oil (*Jatropha curcas*) (Bashir & El shafie, 2017; Mansour & Abdel-Hamid, 2015; Mansour et al., 2015). The botanical insecticides are highly effective against locusts and to be non-toxic. Therefore, the use of botanicals is safer than chemical insecticides.

Chemical method

Insecticides and baits were used in the 1880s, but after the 1940s–1950s, they were replaced by less expensive specks of dust and sprays due to their high toxicity and negative impact on human health (Latchininsky & Van Dyke, 2006). Chemical insecticides such as carbamates, pyrethroids, phenyl pyrazole, and benzoylurea can be used to combat desert locusts (Dobson, 2000). Because of their effectiveness, low cost, and extended durability, these insecticides were the most common for locust control. The most commonly used materials for swarm control against the Desert Locust are fenitrothion and malathion. It's highly successful, with area dosages of around 400 g ha^{-1} estimated to kill half to one million adults per liter. In *S. gregaria*, the use of phenyl acetonitrile (PAN) suppresses the cellular immune response, resulting in a high mortality rate. The primary chemical and microbial pesticides are vehicle-mounted or aerial ultra-low volume

(ULV) spraying (Nguyen & Symmons, 1984). Spraying overlapping swaths of tiny droplets of a concentrated pesticide formulation onto locusts at very low dose rates is known as ULV spraying. If the infestations are tiny, handheld sprayers can be used to spray the pesticide directly on the bands. Vehicle-mounted sprayers are used to treat larger infestations. Before the wing development, the spraying of the band to the immobile young hopper should be carried out (FAO, 2020a; FAO, 2020b). The chemicals used for locust control are given in Table 2.

Table 2. Insecticides suitable for desert locust control

Recommended Insecticides	Application dose (g a.i. ha^{-1})	Pesticide solution rate (L ha^{-1})
Malathion	900	1.0
Organophosphate chloropyriphous	225-240	1.0
Lambdacyhalothrin	20	2.5
Diazinon	400-500	0.4-0.5
Synthetic pyrethroids deltamethrin	12.5	1.0

(Source: FAO, 2020a; FAO, 2020b)

The government of Nepal (GON) has released the name of insecticides and their appropriate doses listed in the table below (Table 3).

Table 3. Insecticides that control desert locusts

Insecticides	Application dose (g a.i. ha^{-1})	Insecticides per liter of water (mL L^{-1})	Insecticides per hectare (mL ha^{-1})	Pesticide solution (L ha^{-1})
Malathion 50%EC	125	3	1850	600
Lamdacyhalothrin	20	0.77	400	600
Chloropyriphous 20%EC	225	1.88	1125	600
Deltamethrin 2.8%EC	12.5	0.75	450	600
Deltamethrin 11% EC	12.5	0.20	120	600

(Source: GON, 2020; Adhikari, 2020).

Spraying pesticides on infested cropland remains the most effective and widespread-treatment method, but this comes with considerable drawbacks (Melvin, 2020). The best time to spray is late at night or early in the morning. Locusts congregate in large numbers on the bushes at this time to rest. Insecticides sprayed at this time have a lot of control. However, the non-judicial Journal of synthetic insecticide application could lead to pest resistance and increased environmental risks (Ahmad et al., 2020). The locusts did not become gregarious when given drugs that blocked serotonin's action or a compound that inhibited serotonin output. Controlling locusts with a drug that targets the serotonin receptor may be a viable alternative to using chemical pesticides (Usha, 2020).

Integrated pest management

Chemical pesticides are widely used to control locust infestations, a significant concern, and alternatives are becoming increasingly important (Lecoq, 2010). Integrated Pest Management (IPM) is a broad ecological pest control solution. Natural enemies, such as ducks, which help in locust control, are susceptible to locust invasion (FAO, 2016). Similarly, electronic devices which produced ultrasound help to reduce swarms of the desert locust. Likewise, nets that are sprayed with garlic or neem can help to repel different locusts and grasshoppers in small nurseries and kitchen gardens (Shrestha et al., 2021). The pathogenic fungi *Metahizium anisopliae* var. acridum has been prepared for ULV (Ultra Low Volume) spraying field-infested locust. It is also called a Green

Muscle (Van Huis et al., 2007). Likewise, many other *Metahizium spp* conidia can help mitigate the locust by penetrating and invading the body tissue of insects. Both biological controls and the use of pesticides can be costly: pests become increasingly resistant to insecticides, and plant breeders must renew the genetic resistance of plants to insect pests on a regular basis. The conservation of established existing natural enemies, crop rotation, intercropping, and the use of pest-resistant varieties are all part of integrated pest management.

Conclusion

Swarms of Desert Locusts have posed a significant threat to crops. They are the migratory and devastating pests that attack the crops of different countries in Africa and Asia causing food insecurity in the world. Local crop protection is not feasible. Other countries carry out different control strategies. The various insecticides and baits have been used to control locusts, but they have adverse effects on human health and the environment. As a result, the best control methods are now integrated pest management (IPM), survey and surveillance reporting. The proper advancement and adaptation of modern technologies can assist in the management of desert locusts. For the effective management of desert locusts, monitoring, mechanical, biological, botanical, chemical pesticides should be integrated.

Author declaration

The authors declare no conflicts of interest. All authors contributed equally in all stages of preparation of this manuscript. Similarly, the final version of the manuscript was approved by all authors.

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