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Integrated Management Practices against Desert Locust, *Schistocerca gregaria* (Forskal) in India: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Locusts are the most dangerous agricultural pests. They are belonging to family Acrididae. Gregarious locusts travel in swarms from one location to another in adult form. The desert locust,

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Schistocerca gregaria (Forskal), is one of the grasshopper species that cause crop damage and can fly up to 150 km in the direction of the wind. The present state of knowledge on its biological regulation employing microbes and plant extracts is discussed. *Metarhizium flavoviride* was among the first fungi to be identified in the laboratory and field as a bio-control agent against desert locust. Following extensive investigation, with integrated pest management stratedies using these bio-controls would be a viable option for controlling desert locust infestations. Against the desert locust, IPM (Integrated Pest Management) approaches that emphasize the successful combination of chemical and biological insecticides with prediction and monitoring technology have been encouraged. Recent experimental investigations and researches are mainly focusing on identifying viable answers through financial collaboration between governmental and non-governmental organizations. The authors highlighted the loss in the agricultural sector due to desert locust infestation, as well as its sophisticated control and management solutions, after evaluating publications from numerous journals, magazines, and symposia.

Keywords: Bio-control; bio-pesticides; desert locust; microorganisms; botanical extracts traditional control methods.

1. INTRODUCTION

"Locusts are a group of various species of short-horned grasshoppers in the Acrididae family. (Order: Orthoptera). Locusts are distinguished from grasshoppers by their swarming abilities, body shape, size, and colour changing morphological characteristics" [1]. "When adult locusts congregate in large numbers, they exhibit gregarious behaviour known as swarming" [2,1]. "Swarms of S*. gregaria*, including millions and billions of individuals, can travel up to 150 km in the direction of the wind, according to" Zhang et al. [3,4,5]. "Swarms of desert locust can fly large distances up to 150 km in the direction of wind [3] containing a group of millions and billions of individuals [5] reported that before covid-19 pandemic during 2019-20, locust attack was reported in some districts of Rajasthan and Gujarat. Government of Rajasthan has reported that a total area of 1,79,584 hectares of 8 districts of the state was affected by locust attack during 2019-20. The State Government of Gujarat has reported that crop loss due to locust attack was observed in a total area of 19,313 hectares of 2 districts of the State during the year 2019-20".

Fig. 1. Desert locust *Schistocerca gregaria* (Forskal)
https://researchgate.

Systemic Position:

Kingdom: Animalia
Phylum Arthropoda
Class: Insecta
Order: Orthoptera
Suborder: Caelifera
Family: Acrididae
Subfamily: Cyrtacanthacridinae
Tribe: Cyrtacanthacridini
Genus: *Schistocerca*
Species: *Gregaria*

Table 1. Important species of locusts in the world

S. No.	English Name	Scientific Name
1	The Desert Locust	*Schistocerca gregaria*
2	The Bombay Locust	*Nomadacris succincta*
3	The Italian Locust	*Calliptamus italicus*
4	The Moroccan Locust	*Dociostaurus morocannus*
5	The Red Locust	*Nomadacris septemfaciata*
6	The Brown Locust	*Locustana pardalina*
7	The South American Locust	*Schistocerca paranensis*
8	The Australian Locust	*Chortoicetes termenifera*
9	The Tree Locust	*Anacridium moestum*.
10	The Migratory Locust	*Locusts migratoria manilensis*

1.1 Invasion in India

"The desert locust is an international pest affecting around 60 countries, and cause heavy damage to the crops in certain countries namely mainly Afghanistan, Africa, Arabia, India, Iraq, Pakistan, and Persia. It is known to be migrate in swarms from one country to another leaving behind famine. Adult locust swarms can fly up to 150 km (93 miles) a day with the wind and adult insects can consume roughly their own weight of fresh food per day. A very small swarm consumes almost the same amount of food that 35,000 humans eats in a single day. Swarms of locusts come far away from East Africa to Iran on the way to Pakistan and finally arrived in India in (2020), causing crop damage in parts of Madhya Pradesh, Gujarat, Haryana, Uttar Pradesh, and Rajasthan. The desert locust is often a solitary insect found in desert and scrub regions of Northem Africa, the Sahel (region comprising Burkina Faso, Chad, Mali, Mauritania, and Niger), the Arabian Peninsula (e.g., Saudi Arabia, Yemen, Oman), and parts of Asia to Western India" [2]. With the arrival of the monsoon, locust swarms typically invade India's Scheduled Desert Area via Pakistan for summer breeding in June/July.

Pink immature adults fly high and cover great distances from one location to another during the day, aided by westerly breezes from Pakistan. The majority of these pink immature adults spend the night in trees and fly throughout the day. Heavy rains over the India-Pakistan border offer ideal breeding conditions for locusts. If allowed to grow unchecked under favourable conditions, locusts can build massive swarms capable of destroying trees and crops across large areas. Locusts have short, thick antennas and are around 2 inches (5cm) length. Because of climatic changes, they reproduce in great numbers and become a nuisance.

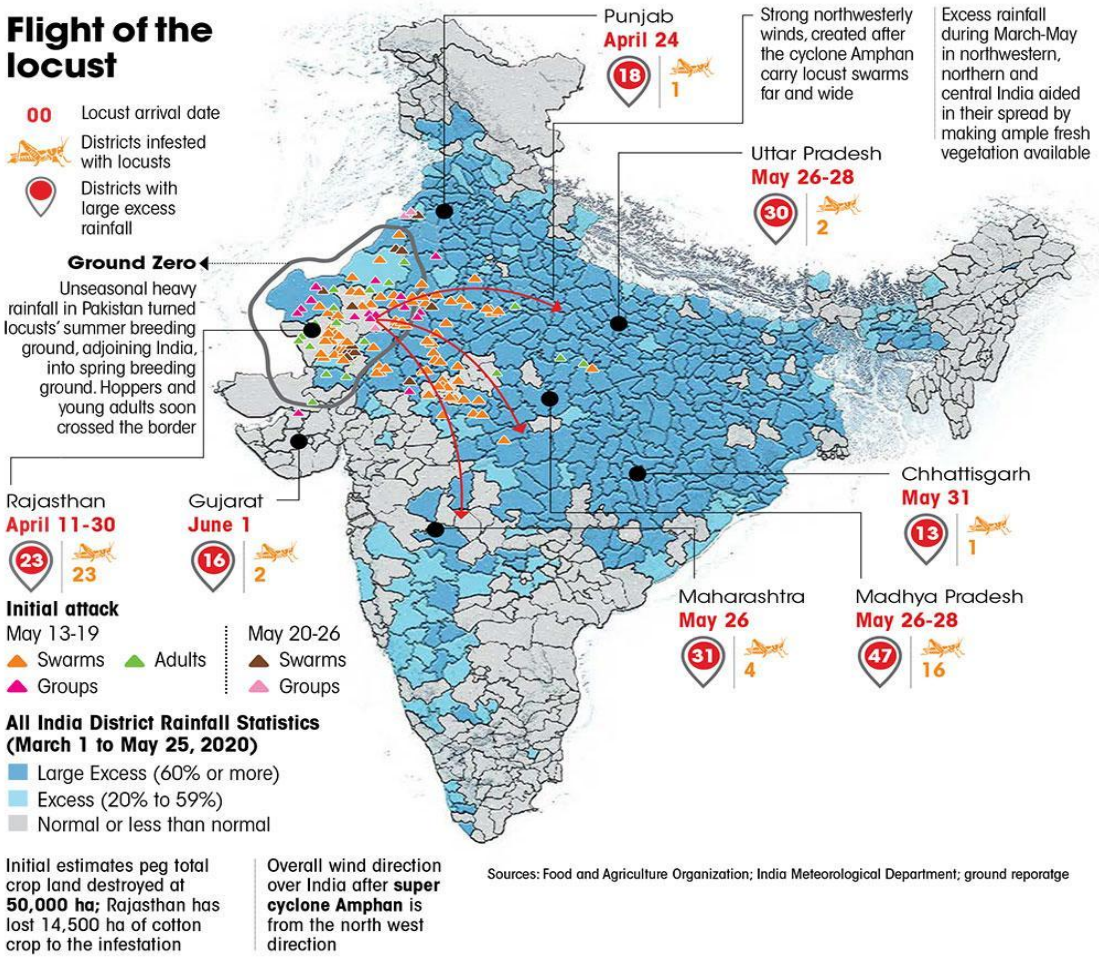

Fig. 2. All India district rainfall statistics
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The Starting from 11th April, 2020 till 25thAugust, 2020, control operations followed in 2,79,066 hectares area in States of Rajasthan, Madhya Pradesh, Punjab, Gujarat, Uttar Pradesh and Haryana by Locust Circle Offices (LCOs). State governments conducted locust control programmes in 2,87,374 hectares of land in Rajasthan, Madhya Pradesh, Punjab, Gujarat, Uttar Pradesh, Maharashtra, Chhattisgarh, Haryana, Uttarakhand, and Bihar until August 25, 2020. The recent locust outbreak wreaked havoc on standing crops and vegetables across India's Central and Western regions, including Rajasthan, Punjab, Haryana, and Madhya Pradesh, with Rajasthan suffering the worst. Despite the fact that locusts infiltrate Rajasthan every year from neighbouring Pakistan, Uttar Pradesh was hit for the first time in the last three decades or so. According to a recent report given to the Centre by the state agriculture department, locust swarms hit 61 of the 75 districts in Uttar Pradesh between April and May, and then again in July.

The risk of swarm migration to the Indo-Pakistan summer breeding area has virtually abated, according to the Food and Agriculture Organization's Locust Status Update of August 24, 2020. FAO organises a weekly virtual meeting on Desert Locust for South-West Asian nations (Afghanistan, India, Iran, and Pakistan). So far, 23 virtual meetings of technical officers from South West Asian countries have taken place.

1.2 Map of Scheduled Desert Area

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1.3 Map of Scheduled Desert Area

Fig. 3. Map of scheduled desert area
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1.4 Identification

"The mature female of S. *gregaria* lays many eggs that are held together by a foamy secretion in batches termed egg pods, which are commonly found in bare moist sandy soil" [1]. "Gregarious phase locusts lay fewer eggs than solitarious, often 70 to 80 in the first laying, 50 to 60 in the second, and less than 50 in the third" [2]. "S. *gregaria* hopper complete it life cycle 30 to 40 days and goes through five to six nymphal stages" [6]. "solitarious hoppers shed their skin five to six times during this stage, while gregarious hoppers shed their skin five times" [7]. "The colour of an immature adult varies from light to dark pink colour according to weather and becomes sexually mature in a few weeks or months" [2].

1.5 Damaging Stage

Bushes are occasionally defoliated, but locusts cause more damage to flowering stage or when they settle on bushes in such huge numbers that their weight breaks the branches. These are especially vulnerable to attack by immature swarms, which prefer to roost in trees. It causes harm to the host at any stage of crop development. They eat leaves, shoots, flowers, fruit, seeds, stems, and bark and are polyphagous. Pearl millet, maize, sorghum, barley, rice, grazing grasses, sugarcane, cotton, fruit trees, date palms, banana plants, weeds, vegetables, and fruits are all eaten.

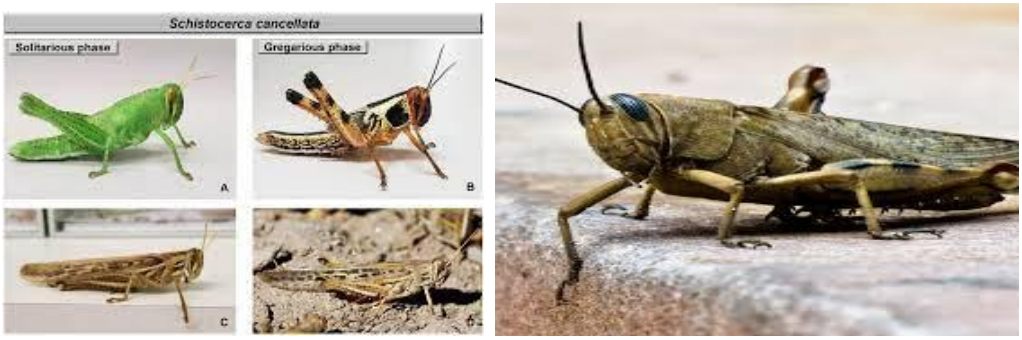


Fig. 4. Identifying features of locust

Fig. 5. Habitat of locust

1.6 Difference between Grasshopper and Locust

Grasshopper	Locust
➢ Size -38-50 mm long	➢ Size -38-50 mm long
➢ Colour – brown, Yellow, Green.	➢ Green when solitary but turn orange, Brown or Yellow when matured.
➢ Long, thin antenna and the ability to jump.	➢ Antenna is short and thick
➢ A grasshopper comparatively covers a very small distance.	➢ Have powerful wing ability to fling long distance.
➢ A grasshopper is specifically a solitary insect.	➢ Locust cover vast distance in its lifetime.

1.7 Locust Phases

Locust is generally found in two phases

(i) **Solitary,** when it is so called inactive and individual locust live scattered.
(ii) **Gregarious,** In times of high activity, the individuals have a tendency to stick together, reproduce quickly, and form swarms that leave the breeding grounds and invade distant regions, sometimes even crossing multiple countries. In addition to behavioural differences, the two phases may typically be separated by colour and a few physical and morphological characteristics.

1.8 Biology of Desert Locust

Life cycle: Locust life cycle has three distinct stages (i) Egg, (ii) Hopper and (iii) Adult.

Egg:

Eggs are placed in pods in moist sandy soil at a depth of about 10 cms at 7 - 10 day intervals. Gregarious females often lay 2-3 egg pods with 60-80 eggs on average, according to Cressman. (2001). Female solitaries often lay 3-4 times per year, with 150-200 eggs on average. The rate of egg development is affected by soil moisture and temperature. Below 15°C, no development occurs. [8]. When the ideal temperature is between 32-35°C, the incubation period is 10-12 days.

Table 2. Locust phases

Characteristics	Solitary phase	Gregarious phase
Behavior	Do not form groups or swarms Roost, bask, feed and move as individuals Hoppers move short distance, adults fly as individuals at night	Form persistent and cohesive groups, bands and swarm Roost, bask, feed and move together Very mobile, fly as swarms by day. Hoppers move in band.
Colour	Early instars of hoppers are uniformly green, while the last two instars may be brown. Adult peach-colored buffer; pale greyish brown. Males turn pale yellow when they reach sexual maturity. Female show no colour change on maturation at low density.	Hoppers have black pattern on yellow or orange background Adults are rosy pink when fledging, but as they get older, they turn grey or brownish red, and as they reach sexual maturity, they turn yellow. Men are smarter.

Fig. 6. Biological cycle of desert locust

Nymph:

"This stage starts with hatching an egg into a nymph called hopper" [1]. "S. gregaria hopper grows in about 30 to 40 days and goes through five to six stages" [6]. "In these stages, solitarious hoppers lose their skin five to six times while gregarious hoppers shed their skin five times [7], which is known as moulting, and the stages between moulting are known as instars" [1]. "After hatching, the first instars are white and turn to black within 1 to 2 hours" [9]. The pace of development in the hopper is temperature dependent. It takes 22 days when the mean air temperature is high, say 37°C, and up to 70 days when the mean temperature is low, say 22°C.

Table 3. Life stage of locust

Ist Instar	Newly hatched are white but turns black in 1-2 hours.
IInd Instar	Head is larger and pale colour pattern is conspicuous.
IIIrd Instar	Two pairs of wing buds projects on each side of thorax
IVth Instar	Colour is conspicuously black and yellow.
Vth Instar	Colour is bright yellow with black pattern.

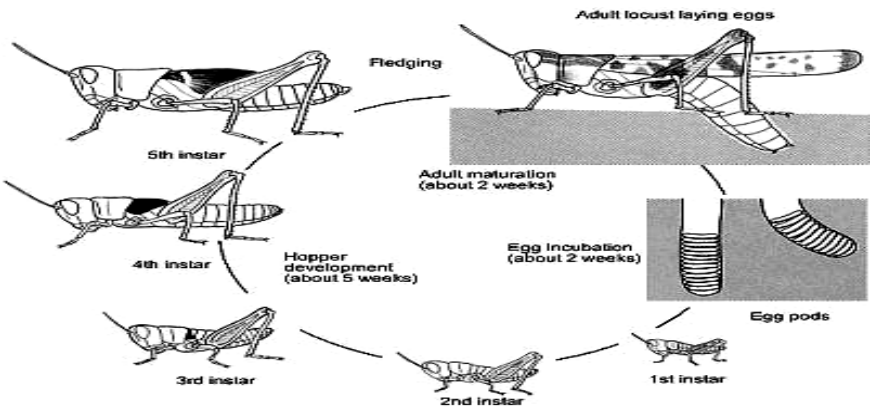
Adult:

The Vth Instar nymphal instar moults into adult stage. This transition is known as 'fledging,' and the young adult is known as a 'fledgling' or 'immature adult,' indicating that they are sexually immature. In ten days, the fledgling's wings harden and it matures into an immature adult [1]. Adults can mature in 3 weeks in favourable conditions, and 8 months in chilly and dry conditions. During this stage, the adults flies thousands of km in quest of good breeding conditions. Young immature adults are pink, but as they age, they turn dark red or brown, according to Steedman [2]. Adults mature to a bright yellow colour. Males reach maturity before females. Oviposition begins two days after copulation.

Control:

Role of locust warning organization:

- In the roughly 2 lakh sq. km. Scheduled Desert Area in the States of Rajasthan and Gujarat, maintain regular vigilance through field surveys to prevent crop losses due to locust.
- Through quick management measures, prevent an increase in the locust population in SDA and the entry of locust swarms into India.
- Hold Indo-Pak Border talks to exchange information about the locust situation between the two nations in order to efficiently monitor the situation and guarantee readiness to address any potential locust threats.
- Instruct farmers, government officials, and staff members who deal with locusts on the newest pest control techniques.
- Tell state employees, BSF agents, and Panchayat Raj institutions to contact the local LWO office as soon as locust activity is recorded in their districts so that necessary action can be taken.
- The publication of the Desert Locust Situation Bulletin every two weeks to update all interested parties on the evolving locust situation in India.
- Investigate the bio-effectiveness of insecticides and bio-pesticides for the management of locusts at the Field Station on Investigation on Locusts (FSIL) in Bikaner.



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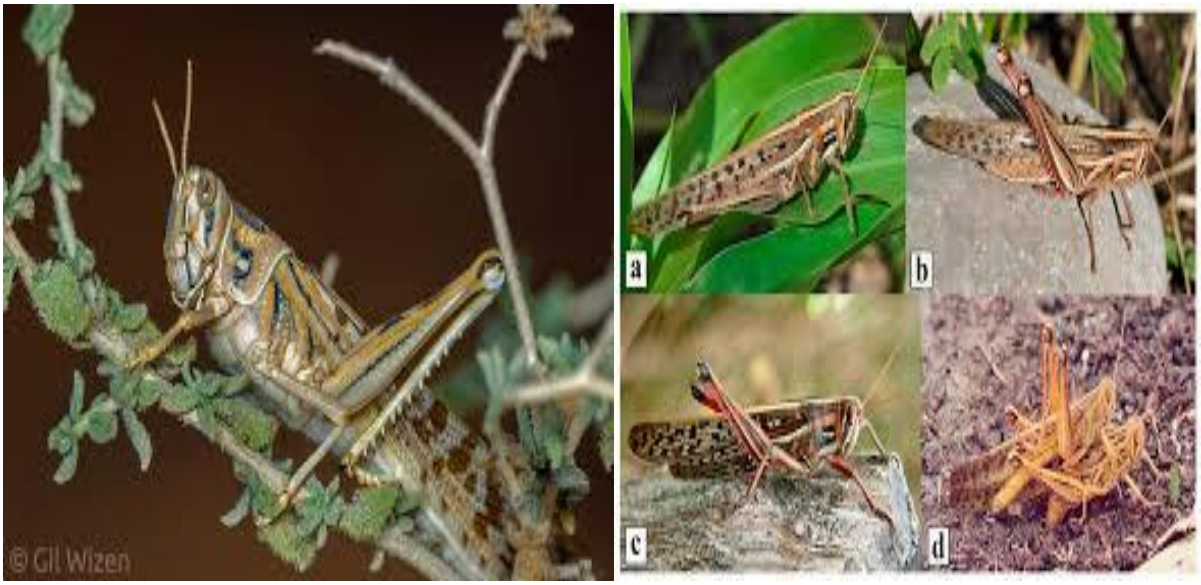

Fig. 7. Life cycle stage of desert locust
https://www.google.com/

Cultural practices:

Use during the early/initial stages of locust attack, Train/orient farmers to implement these on their farms.

- Deep summer ploughing for exposing the eggs
- Trimming and cleaning the farm bunds.
- Scattering straw over roosting sites and then burning it.

Mechanical method:

- To prevent locust swarms from descending on the crop, make a loud noise in the harvested field by hitting empty tins/metal plates, drums, radios or any other electronic sound system. (Ibrahim et al., 2013).
- car movement from the contaminated area to the fresh area to be monitored for roosting locust swarms on the car roof top and treated as needed with chemicals
- If a hopper band is seen marching, set fire to dry grass or garbage in front of the hopper band to kill the nymphs [10].
- Dig a ditch 2 feet deep and 2 feet wide in front of the marching hopper band for trapping and killing with any of the insecticides listed here [11].
- Making noise enhances a swarm's unpredictability, which helps to reduce its number and split it apart [4,5].
- They are dormant until the light shines brightly enough for a mosquito net to catch the desert locusts.

Fig. 8. Cultural practices

Biological control:

- Depending on availability, bio-pesticides like *Metarhizium acridum* (mycoinsecticide) can be employed in the early stages of a locust invasion while the intensity is low [12].
- Spraying 2.5 x 10 conidia/ha of the insect pathogen *Metarhizium anisopliae* (strain IMI 330189) (Oil formulation) [13].
- As a preventative precaution, spraying crops with *Neem*-based pesticides (*Azadirachtin* 1500 ppm) @ 5 ml/lit combined with a spreading agent like soap solution [14].
- Common and rose-colored starlings. There are 25 perches per hectare for the common birds (*Pastor roseus* and *Sturnus vulgaris*).
- Use predators of eggs include crickets, blister beetles, and ground beetles.
- Use Parasitoids include flesh flies, tachinid flies, and tangled veined flies [15].

1.9 Use of Botanical Extracts as Bio-control Agents

In this analysis, 27 plant species from 20 families were identified as having been tested against desert locust, however the findings were mixed. The most investigated plant species were *Azadirachta indica* and *Melia volkensii*, both of which are members of the Meliaceae family and are known to contain biologically active limonoids. *Calotropis procera*, *Fagonia bruguieri*, and *Peganum harmala* followed. *Petroselinum sativum* had the highest frequency of representation (21%). The majority of these investigations, however, employed crude extracts, and the active components against desert locust were not identified.

"Several studies have confirmed that essential oils are effective against desert locusts and could be used as natural controls. A unique blend of plant oils was produced that demonstrated high harmful effects on desert locust after a single spray application. *Carum carvi*, *Citrus aurantium* dulcis, and Gaultheria procumbens essential oils were combined. Surprisingly, a mortality rate of 80% was recorded within 24 hours of treatment" [14]. "Furthermore, essential oils derived from ten different plant species were topically evaluated against desert locust. *Allium cepa* oil was shown to be the most harmful to locusts, followed by *Petroselinum sativum* oil. *Pelargonium radula, Cuminum cyminum, Ocimum basilicum, Origanum vulgare*, and *Matricaria chamomilla* were all studied and exhibited varying benefits against the locust" [13].

1.10 Use of Microorganisms as Bio-control Agents against Locust

Only a few fungi and bacteria have been documented to be effective against the desert locust. Because of their diverse host range and natural occurrence, entomopathogenic fungi have the potential to be the most versatile bio-control agents. They are also slower acting than pesticides, making them ideal for early infestations. When administered to the soil surface rather than as a spray, entomopathogenic fungi and nematodes can be more effective.

Table 4. List of bio-control agents for desert locust

S. No	Scientific name	Common name	Family
1	*Azadirachta indica* (A. Juss.) Brandis	Neem	Meliaceae
2	*Melia volkensii* Giirke	Melia	Meliaceae
3	*Fagonia bruguieri* D.C	Fagonia	Zygophyllaceae
4	*Allium cepa* L.	Onion	Amaryllidaceae
5	*Petroselinum sativum* Hoffm.	Parsley	Apiaceae
6	*Cuminum cyminum* L.	Cumin	Apicaceae
7	*Jatropha curcas* L.	Physic nut	Euphorbiaceae
8	*Ocimum basilicum* L.	Basil	Lamiaceae
9	*Matricaria chamomilla* L.	Chamomile	Asteraceae
10	*Origanum vulgare* L.	Oregano	Lamiaceae
11	*Zizyphus lotus* (L.	Jujube	Rhamnaceae
12	*Rhizophora mucronata* Lam.	Mangrove	Rhizophoraceae
13	*Carum carvi* L.	Caraway	Apiaceae
14	*Citrus aurantium* L.	Orange	Rutaceae
15	*Gaultheria procumbens* L.	Wintergreen	Ericaceae

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Table 5. Microorganisms against desert locust

S. No.	Microorganism	Effect on desert locust
1	*Metarhizium anisopliae* var. acridum Driver & Milner	❖ Enhanced acidic phosphatase (AcP) activity for autophagy and defence ❖ Behavioral alterations ❖ Biochemistry and antimicrobial defences altered ❖ Less energy reserves and poor flight capacity [16]
2	*Metarhizium flavoviride* Gams & Rozsypal	❖ Reduction dispersal of hopper bands into small groups ❖ Reduced daily food consumption ❖ Significant reductions in flight activity and food consumption ❖ High mortality in sparse vegetation than in dense vegetation [17]
3	*Serratia marcescens* Bizio (Bacteria)	❖ Induced fever [18]
4	*Beauveria bassiana*, Entomophthora, and *Steinernema carpocapsae* (Nematode)	❖ High mortality rates, although the nematode was more effective than fungi in less time [19]
5	*Pseudomonas aeruginosa* (Schroeter) Migula (Bacteria)	❖ Pathogenic bacterium of the desert locust [20]
6	*Bacillus cereus* (Bacteria)	❖ High insecticidal activity

Insect Growth Regulators

- ❖ Diflubenzuron, Teflubenzuron, and Triflumuron can be used to inhibit cuticle synthesis.

Chemical Control:

- ❖ "Insecticides and baits were utilised in the 1880s, but because to their high toxicity and detrimental influence on human health, they were replaced by less expensive specks of dust and sprays after the 1940s-1950s" [21].
- ❖ Fenitrothion and malathion are the most often utilised compounds for swarm control against the desert locust [22].
- ❖ Vehicle-mounted or aerial ultra-low volume (ULV) spraying is the major method for applying chemical and microbial inecticides [23].

Cautions:

- ❖ Individual farmers should not take locust swarm control tactics. The infestation can be reported to the nearest locust warning centers, and their assistance can be requested for management.
- ❖ Apply during cool hours: 7:00 to 10:00 a.m. or 5:00 to 7:00 p.m.
- ❖ Wear protective clothing/face mask, hand gloves/goggles/head hat while applying this combination, and leave the field as soon as feasible.
- ❖ The crop should not be harvested for seven days after this treatment.

Table 6. Chemical control

Sl. No.	Chemical Name	Dosage		
		a.i.(gms)/ha	Formulations (gm/ml)/ha	Dilution in water(lit/ha)
1	Chlorpyriphos20% EC	240	1200	500
2	Chlorpyriphos50% EC	240	500	500
3	Deltamethrin 2.8%EC	12.5	500	500
4	Diflubenzuran 25%WP	60	250	Need based
5	Fipronil 5% SC	6.25	1.25	500
6	Lambdacyhalothrin 5%EC	20	400	500
7	Lambdacyhalothrin 10%WP	20	200	500
8	Malathion 50%EC	925	1850	500
9	Malathion 25%EC	925	3700	500

Fig. 9. Field study and control measures
https://www.google.com/

Traditional Methods of Locust Control:

Fig. 10. Traditional methods of locust control

Integrated pest management:

"Chemical pesticides are frequently used to control locust infestations, which are a major concern, and alternatives are becoming more relevant" [24]. IPM (Integrated Pest Management) is a broad ecological pest management strategy. Natural enemies that aid in locust management, such as ducks, are vulnerable to locust invasion. (FAO, 2016). Similarly, electrical gadgets that create ultrasound aid in the reduction of desert locust swarms. Similarly, netting sprinkled with garlic or neem can help repel various locusts and grasshoppers in small nurseries and kitchen gardens [25]. "M *anisopliae* var. acridum, a pathogenic fungus, has been produced for ULV (Ultra Low Volume) spraying of locust-infested fields. It is also known as a *Green Muscle"* [26]. Similarly, several other *Metarhizium spp.* conidia can aid in locust control by entering and infiltrating insect body tissue. Both biological controls and pesticide use can be costly: pests become increasingly resistant to insecticides, and plant breeders must constantly renew the genetic resistance of plants to insect pests. Integrated pest management includes the preservation of established natural enemies, crop rotation, intercropping, and the use of pest-resistant varieties [27-32].

2. CONCLUSION

Desert locust has been a devastating pest in deserts of North Africa, the Middle East, and Southwest Asia. The swarm outbreak leads to

food insecurity as the insect feeds on various parts of plants such as leaves, shoots, flowers, fruit, seeds, stems, and even bark. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Symmons PM, Cressman K. Desert locust guidelines: Biologyand behaviour. Rome: Food and Agriculture Organization; 2001. Available:http://www.fao.org/ag/locusts/common/ecg/347
2. Steedman A. Locust handbook. 3rd ed; Chatam. United Kingdom: Natural Resources Institute. 1990;204.
3. Zhang L, Lecoq M, Latchininsky A, Hunter D. Locust and grasshopper management. Annu Rev Entomol. 2019;64(3):15-34. DOI: 10.1146/annurev-ento-011118-112500, PMID 30256665.
4. FAO. Locusts. Food chain crisis; 2020a. Available:http://www.fao.org/food-chain-crisis/how-we-work/plant-protection/locusts/en/
5. FAO. Desert locust upsurge – global Response Plan; 2020b. Available:http://www.fao.org/emergencies/resources/documents/resources-detail/en/c/1276739/
6. Cressman K. Monitoring desert locusts in the Middle East: An overview. Yale School of Forestry and Environmental Studies [bulletin]. 1998;103(5):123-40.
7. Joshi M, Varadharasu P, Solanki C, Birari V. Desert locust (*Schistocera gregaria* F.) outbreak in Gujarat (India). Agric Food Newsl. 2020;2(6):691-3.
8. Eltoum M, Mohamed MS, Hamid A. Detection of change in vegetation cover caused by desert locust in Sudan. E-newsletter. 2014;2(6):47-52.
9. Claeys I, Simonet G, Van Loy T, De Loof A, Vanden Broeck J. cDNA cloning and transcript distribution of two novel members of the neuroparsin family in the desert locust, Schistocerca gregaria. Insect Mol Biol. 2003;12(5):473-81. DOI: 10.1046/j.1365-2583.2003.00431.x, PMID 12974952.
10. Sharma A. Locust control management Moving from traditional to new technologies– An empirical analysis. Entomol Ornithol Herpetol Curr Res. 2014; 4(1):1-7.
11. Wiktelius S, Ardö J, Fransson T. Desert locust control in ecologically sensitiveareas: need for guidelines. AMBIO J Hum Environ. 2003;32(7):463-8. DOI: 10.1579/0044-7447-32.7.463, PMID 14703905.
12. Matthews G. Critical issues in plant health: 50 years of research in African agriculture. Outlooks Pest Manag. 2019;30(3):136-7. DOI: 10.1564/v30_jun_10
13. Hunter DM, Latchininsky A, Abashidze E, Gapparov FA, Nurzhanov AA, Medetov M, et al. The efficacy of Metarhizium acridum against nymphs of the Italian locust, *Calliptamus italicus* (L.) (Orthoptera: Acrididae) in Uzbekistan and Georgia. J Orthopt Res. 2016;25(5):61-5.
14. Patel SM, Nagulapalli Venkata KCN, Bhattacharyya P, Sethi G, Bishayee A. Potential of neem (*Azadirachta indica* L.) for prevention and treatment of oncologic diseases. Semin Cancer Biol. 2016; 40-41:100-15. DOI: 10.1016/j.semcancer.2016.03.002, PMID 27019417.
15. Long Z, Hunter DM. Laboratory and field trials of Green Guard (Metarhizium anisopliae var. acridum) (Deuteromycotina: Hyphomycetes) against the oriental migratory locust (Locusta migratoria manilensis) (Orthoptera: Acrididae) in China. J Orthopt Res. 2005;14(1):27-30. DOI:10.1665/1082-6467(2005)14[27:LAFTOG]2.0.CO;2.
16. Xia Y, Dean P, Judge AJ, Gillespie JP, Clarkson JM, Charnley AK. Acid phosphatases in the haemolymph of the desert locust, *Schistocerca gregaria*, infected with the entomopathogenic fungus Metarhizium anisopliae. J Insect Physiol. 2000;46(9):1249-57.

DOI: 10.1016/S0022-1910(00)00045-7, PMID 10844143.

17. Hunt VL, Charnley AK. The inhibitory effect of the fungal toxin, destruxin A, on behavioural fever in the desert locust. J Insect Physiol. 2011;57(10):1341-46. DOI: 10.1016/j.jinsphys.2011.06.008, PMID 21729702.
18. Bundey SR, Raymond S, Dean P, Roberts SK, Dillon RJ, Charnley AK. Eicosanoid involvement in the regulation of behavioral fever in the desert locust, *Schistocerca gregaria*. Arch Insect Biochem Physiol. 2003;52(4):183-92. DOI: 10.1002/arch.10081, PMID 12655606.
19. Ashrafi SH, Zuberi RI, Hafiz S. Occurrence of *Pseudomonas aeruginosa* (Schroeter) Migula as a pathogenic bacterium of the desert locust, *Schistocerca gregaria* (Forskål). J Invertebr Pathol. 1965;7(2):189-91. DOI: 10.1016/0022-2011(65)90036-4, PMID 4953369.
20. Reda M, Mashtoly TA, El-Zemaity MS, Abolmaaty A, Abdelatef GM, Marzouk AA. Susceptibility of desert locust, *Schistocerca gregaria* (Orthoptera: Acrididae) to Bacillus cereus isolated from Egypt. Arab Universities J Agric Sci. 2018;26(2):725-34. DOI: 10.21608/ajs.2018.16005
21. Latchininsky AV, VanDyke KA. Grasshopper and locust control with poisoned baits: A renaissance of the old strategy? Outlooks Pest Manag. 2006;17(3):105-11. DOI: 10.1564/17jun04
22. Arthurs S. Grasshoppers and locusts as agricultural pests. Encyclopedia of entomology. 2008;1690-4.
23. Rachadi T. Barrier treatment with fipronil to control desert locust *Schistocerca gregaria* (Forskal, 1775) hopper bands infesting a large area in Mauritania. Int J Pest Manag. 2010;45(4):263-73.
24. Lecoq P, Auffray E, Brunner S, Hillemanns H, Jarron P, Knapitsch A, et al. Factors influencing time resolution of scintillators and ways to improve them. IEEE Trans Nucl Sci. 2010;57(5):2411-6. DOI: 10.1109/TNS.2010.2049860
25. Shrestha S, Thakur G, Gautam J, Acharya N, Pandey M, Shrestha J. Desert locust and its management in Nepal: A review. J Agric Nat Resour. 2021;4(1):1-28. DOI: 10.3126/janr.v4i1.33197
26. Van Huis A, Cressman K, Magor JI. Preventing desert locust plagues: optimizing management interventions. Entomol Exp Appl. 2007;122(3):191-214. DOI: 10.1111/j.1570-7458.2006.00517.x
27. Cressman K, Van der Elstraeten A, Pedrick C. An innovative tool for crop pest control. Retrieved from. 2016;12(2):44-48;. Available:http://www.fao.org/3/a-i6058e.pdf
28. Ibrahim AG, Oyedum OD, Awojoyogbe OB, Okeke SSN. Electronic pest control devices: A re-view of their necessity, controversies and a submission of design considerations. Int J Eng Sci (IJES). 2013;2(9):26-30.
29. Nguyen NT, Symmons PM. Aerial spraying of wheat: A comparison of conventional low volume with ultra-low volume spraying. Pestic Sci. 1984;15(4):337-43. DOI: 10.1002/ps.2780150403
30. Raghavendra KV, Gowthami R, Lepakshi NM, Dhananivetha M, Shashank R. Use of botanicals by farmers for integrated pest management of crops in Karnataka. Asian Agri Hist. 2016;20(3):173-80.
31. Roychoudhury R. Neem products in Eco-friendly pest management for food security. Pestic Sci. 2016;5(3):545-62.
32. Van Huis A. New developments in desert locust management and control. Entomol Exp Appl. 1992;3(2):11-8.

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