Food and Agriculture
Organization of the
United Nations

Technical guidance on desert locust

Early warning system and sustainable management of transboundary pest, with special reference to desert locust (*Schistocerca gregaria* [Forskål]) in South Asia

Technical guidance on desert locust

Early warning system and sustainable management of transboundary pest, with special reference to desert locust (*Schistocerca gregaria* [Forskål]) in South Asia

Food and Agriculture Organization of the United Nations
Bangkok, 2022

Required citation:

FAO. 2022. *Technical guidance on desert locust – Early warning system and sustainable management of transboundary pests, with special reference to desert locust (*Schistocerca gregaria [Forskål]*) in South Asia*. Bangkok. https://doi.org/10.4060/cc0147en

ISBN 978-92-5-136234-1

Contents

Box

Figures

Tables

Abbreviations and acronyms

CABI	CAB International
CAZRI	Central Arid Zone Research Institute
CGIAR	Consultative Group of International Agricultural Research
CIBRC	Central Insecticide Board and Registration Committee
COVID-19	Coronavirus disease of 2019
DLIS	Desert Locust Information Service (FAO)
DOA&FW	Department of Agriculture and Farmers Welfare
DPP	Department of Plant Protection
DPPQ&S	Department of Plant Protection, Quarantine and Storage
EC	Emulsifiable concentrate
EPN	Entomopathogenic Nematodes
ETL	Economic threshold level
EWS	early warning systems
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
ICAR	Indian Council of Agricultural Research
ITK	Indigenous technical knowledge
LWO	Locust Warning Organization
NBA	National Biodiversity Act
NBAIR	National Bureau of Agricultural Insect Resources
NDMA	National Disaster Management Authority
PHI	pre-harvest interval
PPE	personal protection equipment
SDG	Sustainable Development Goal
SC	suspension concentrate
SDA	Scheduled Desert Area
SEWR	Surveillance early warning and response
SOP	Standard Operating Procedures
SUPARCO	Space and Upper Atmospheric Research Commission
SWAC	Commission for Controlling the Desert Locust in South-West Asia
SWOT	Strength–weaknesses–opportunities–threats analysis
ULV	Ultra-low volume
WHO	World Health Organization

Foreword

The right to food and nutrition security is a fundamental right of all people across the globe. Throughout Asia, agriculture is central to food security because of the food it produces, but also because it underpins the livelihoods of millions of farmers, the majority of whom are small-scale holders. Climate change and variability, invasive pests, and biodiversity loss progressively compromise agricultural production and lead to important crop losses. Especially in countries where development is lagging, pest attacks can bring about extreme poverty, income inequality and a lack of adequate nutrition, particularly among women and children.

Historically, locusts have plagued agrifood production in many parts of northern Africa, the Near East, and South Asia, routinely leading to widespread famine, social upheaval and loss of rural livelihoods. Though the desert locust (Schistocerca gregaria) poses a serious threat to food and nutrition security in many countries, there are also several other voracious locust species threatening agriculture in Asia. Weather anomalies, such as a heavy rain after a prolonged drought, create favourable breeding conditions, and plagues of locusts can rapidly propagate across agricultural landscapes without regard for national boundaries. Billions of locusts disperse in swarms, covering hundreds of kilometres in days, voraciously feeding on all standing vegetation in farmland and natural habitats. These transboundary pests have a protracted negative impact on agrifood supply chains and they compromise the availability of fodder and livestock production, derailing rural economic activities. In their desperation to deal with such locust outbreaks, farmers often resort to using broad-scale (aerial) applications of chemical pesticides, which negatively impact human and animal health while also harming the environment.

Given the fast and wide-reaching spread of locust swarms, inter-country collaboration and cooperation are crucial to track the quantity of locust populations and their movements, forecast outbreaks and to target measures to manage them. Remote sensing and drones are increasingly used to track locust populations and to pinpoint their breeding sites; pairing these approaches with meteorological data such as air movement, temperature, precipitation, locust outbreaks and migration pathways means that problems can be reliably predicted. International cooperation is also crucial to ensure the uptake of preventative measures, such as targeted interventions in breeding sites and non-chemical approaches such as biopesticides.

The technical guidance on sustainable desert locust management for 2022 to 2026 respond to this crisis. The guidance provide a path towards regionally coordinated efforts to manage the desert locust, to advance monitoring and early-warning activities, and to promote pest control practices (e.g. biopesticides) that protect human and animal health as well as the environmental. This approach will minimize the impact of the desert locust on Asian food and livelihood security while simultaneously advance pest management strategies that safeguard the environment.

The guidance contribute toward bridging the gap between “know-how” and “do-how” approaches in the plant protection programmes and policies of various Asia-Pacific countries.

I would like to thank the Centre for Agriculture and Bioscience International (CAB International) and the Asia-Pacific Plant Protection Commission (APPPC) for contributing to this valuable exercise, and also I would like to thank Yubak Dhoj GC, Senior Agricultural Officer (Plant Protection) at the Food and Agriculture Organization of the United Nations (FAO), for his work coordinating the project with CAB International in India. Undoubtedly, the technical guidance will serve as a compass for future efforts to sustainably respond to and manage these invasive pests in Asia-Pacific countries.

Jong-Jin Kim
Assistant Director General and Regional Representative
Regional Office for Asia and the Pacific
Food and Agriculture Organization of the United Nations

Acknowledgements

We would like to express our sincere gratitude to the Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific (FAO-RAP) for funding the work to develop a technical guidance for managing transboundary pests, of which this desk review, literature search and associated survey is a part.

We would like to thank all the resource people for their invaluable input, and for their time in responding to our online questionnaire. The content of the report was greatly enriched by the active participation and constructive feedback from workshop participants.

The editors of this report do not claim to be the originators of the material used. Main sources of information are cited, and all publications contained in them are acknowledged. The published work of other scientists and their contributions are gratefully acknowledged. Where images have been used, credit has been provided.

Our special thanks to the Indian Council of Agricultural Research (ICAR), the National Bureau of Agricultural Insect Resources (NBAIR), the Indian Institute of Maize Research (IIMR), the Indian Agricultural Research Institute (IARI), state agricultural universities, the University of Agricultural Sciences, Bangalore, the University of Agricultural and Horticultural Sciences (UAHS), Shivamogga, the Directorate of Plant Protection, Quarantine and Storage (DPPQ&S).

We would especially like to thank Dr Keith Cressman, Senior Locust Forecasting Officer, at FAO in Rome for sharing their global scale technological advancement and management suggestions for managing desert locusts.

Thanks is also due to Yubak Dhoj GC, Senior Agricultural Officer (Plant Protection) at the Food and Agriculture Organization of the United Nations (FAO), for his work coordinating the project with the Centre for Agriculture and Bioscience International in India.

Editors: Dr Malvika Chaudhary, Dr Sunil Kumar, Dr Manju Thakur, Kavitha S, Dr Krishna Kumar and Dr Ravi Joshi..

Executive summary

Although locusts are a type of grasshopper, they differ physiologically and in their behaviour. When environmental conditions allow, locusts multiply rapidly so that billions of them can aggregate and migrate vast distances devouring every growing green thing in their path. Plagues of locusts have been happening for a long time and are even referenced in the Old Testament of the Bible. The magnitude of damage and crop loss that they can cause is enormous and beyond imagination. They have been the cause of starvation across continents in the past. The desert locust, Schistocerca gregaria (Forskål) is the most widespread and destructive of all locust species. When they invade they can cover about 30 million km^2 and can include all or parts of 64 countries in the northwest and east of Africa, the Arabian Peninsula and Central Asia, including Afghanistan, India, the Islamic Republic of Iran and Pakistan, among others.

In general desert locust swarms originate in the undisturbed desert regions of North Africa, the Near East, and Southwest Asia. Locusts in the gregarious phase consume a wide number of plant species, grasses, shrubs and trees, and their expanding diet coupled with aggregation affects the agricultural crops resulting in often 80 to 100 percent crop losses.

In 2020, a desert locust outbreak affected several countries in Africa and Asia including India and Pakistan. In Pakistan, the invasion occurred in the southern irrigated plain – the lower Indus River plain where the climate is arid and sub-tropical. In India, it occurred mainly in the Thar region, which covers the southwestern parts of Punjab, Western Rajasthan, Kachchh and Northern Kathiawar in Gujarat. Locusts destroyed more than 200 000 hectares of crops in India since the beginning of May 2020, and another 600 000 hectares are threatened. According to the Food and Agriculture Organization of the United Nations (FAO), the estimated losses to agriculture due to locusts could reach USD 1.2 billion in Pakistan, considering a 15 percent damage level to wheat and potato.

Fortunately, excellent surveillance and monitoring through IT-enabled software in Africa and Asia, real-time advice, guidance on early warning systems (EWSs), preparedness, training and data sharing by FAO have helped to mitigate crop losses across the world. Movement of the locusts was monitored in real-time by using remote sensing (RS). FAO maintained Geographic Information System (GIS) technologies and an efficient surveillance system to further reduce the damage due to locusts by enabling appropriate regional specific integrated pest management (IPM) interventions suitable for different cropping systems. The locust-specific entomopathogen, Metarhizium acridum holds great promise in controlling locust damage; however, for it to function pests must be detected early. There are very few people trained on RS and GIS technologies in the countries where it is needed. Appropriate capacity-building interventions on geo surveillance should be strengthened with country partners for continuous maintenance of data bases in the long run. The available pest management interventions are insufficient to manage desert locusts. There is a need to test and validate new practices involving bioagents and to promote bio-intensive methods for managing locusts among the different stakeholders. The technologies standardized for locust management are more suitable for desert, barren and uncultivated areas, and more resources should be diverted to develop the technologies for desert locust management in cropped and agricultural land. State and regional authorities within India and Pakistan need more awareness of and knowledge about desert locust biology, surveys, reporting, control and safety, including how to use the eLocust3m smartphone app, and how to crowd source data that is linked to the national locust programmes (Department of Plant Protection [DPP] and Locust Warning Organization [LWO]) and the global EWS.

Well-orchestrated preparedness, cooperation and collaboration between India and Pakistan in the efficient management of locust swarms will create a pathway for a holistic, integrated system to manage locusts and prevent the huge crop losses that affect the poorest of the poor in the region.

Figure 1. *A summary of the guidance for the sustainable management of desert locusts in Asia*

Policy interventions based on existing regulations

Do - review policies for importing M.acridum to test and validate the available biopesticide for the region and then register it to make it available to the stakeholders.

Don't - override stringent policies, which will make it easier for locusts to be imported. Don't reinvent the wheel, but rather adopt data that can be shared to expedite registration of the biocontrol agents.

Strengthen surveillance, early warning systems (EWS) and emergency preparedness

Do - take to shareholders the georeferenced locust surveillance data along with remotely sensed data (satellite and drone) and pest risk modelling developed by FAO and used to develop a forecasting and early warning system for the region, especially in the agricultural domain for use of timely and well targeted pest advisories to minimize losses due to a locust outbreak.

Don't - make decisions that are not based on in-depth data and science.

Increase advocacy, awareness and knowledge about locusts

Do - disseminate information through mass awareness campaigns on locust management, make policy recommendations to ensure the long-term success of IPM technologies, coordinate aross sectors, media, communication framework.

Don't - use unclear messages and unscientific content.

Strengthen technical capacity of plant protection and extension system

Do - use an innovative and adaptive IPM platform for locust management, a regional network/ database of locust experts, create a sustainable model for capacity building for different stakholders, offer training on drone and ultra low volume (ULV) technologies, implement capacity development programmes with reflexive and action learning.

Don't - use general modules as uniform learning across the region.

Enhance implementation of integrated pest management for fall armyworm

Do - use knowledge and information management platforms to develop mechanisms and tools for disseminating IPM recommendations to different stakholders with the participation of the public and private sector. Use interactive tools to deliver information on IPM and capture adoption of practices. Disseminate information on IPM during potential and actual locust outbeaks. Test, validate and promote *M. acridium* and other bio control agents.

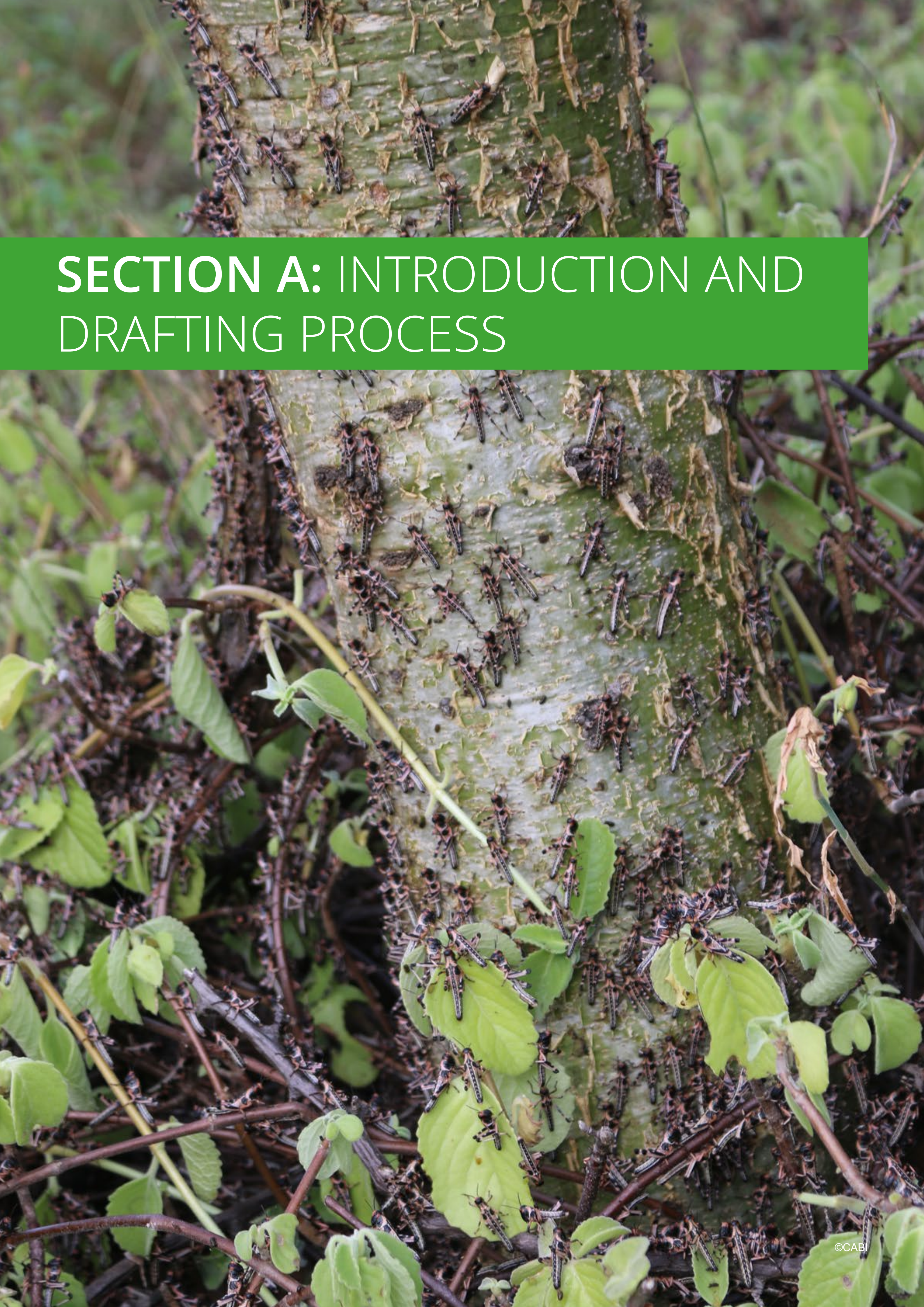
Don't - repeatedly and indiscriminately apply insecticides without adequate supervision, don't destroy natural parasites and don't spray at the first sighting.

Innovative research needs

Do - identify and evaluate the efficacy of natural indegenous enemies. Customize and improve the locust surveillance and forecasting models; Evaluate alternate chemicals and biopestcides in locust management; Identify any indigenous technical knowledge (ITKs) in locust management.

Don't - make recommendations untill the innovations are tested on CSEAS scale.

SECTION A: INTRODUCTION AND DRAFTING PROCESS



©CABI

1. Introduction

1.1. Desert locust South Asia – Present scenario and crop loss

The desert locust, *Schistocerca gregaria*, is one of the most notorious insect pests of the world. It inhabits the entirety of Northern Africa and Western Asia, and during its outbreak period it affects 64 countries between Morocco and India. A single swarm of locusts made up of several million individuals can rapidly devour every kind of plant in its way. The locusts in the gregarious phase consume a wide number of plant species, grasses, shrubs and trees, and this expansive diet coupled with aggregation affects agricultural crops resulting in extensive crop losses along the swarm pathway. Climate change, manifested through prolonged drought as well as sporadic and intensive precipitation, may favour recurring locust plagues in the future. Unfortunately, the pathway of the locust plague is through some of the poorest regions of the world. The threat to food and nutritional security in parts of Africa and Asia following a locust invasion can be catastrophic. Insufficient knowledge, lack of awareness of the factors leading to the migratory phase at the breeding site, the transboundary nature of the pest, a lack of coordination within and across the region, and the overwhelming swarm of the locust plague add to the challenge of managing them. Further, oviposition sites and factors influencing aggregation and damage are widely separated. Indiscriminate aerial sprays of ultra-low volume (ULV) pesticides will have a devastating impact on the landscape affecting long-term biodiversity, ecosystem services, human health and environmental sustainability.

Locust migration is a function of prevailing weather, wind direction and availability of greenery irrespective of region or landscape. There is only a small window of time to take the necessary prophylactic measures to mitigate damage in a neighbouring country or region. Often locust management decisions taken in one place do not consider the impact beyond the borders of their state or region. Cross-learning, coordination and cooperation form the basis of EWSs, and mitigation strategy has been well coordinated by FAO.

Considering the recent invasion of locusts into cropping areas and urban locations, there is an urgent need to develop coordinated, commonly accepted guidance that require all affected states and regions to work together with their existing EWSs for sustainable management. Available eco-friendly green products need to be considered seriously and they must be tested, validated and promoted in the region to manage locusts. This guideline will strengthen EWSs and sustainable management, while emphasizing the need for coordination the countries being invaded and those under threat.

Desert locust (*S. gregaria*) is the world's most dangerous migratory pest. It can potentially affect 20 percent of the Earth's surface (Mckeever, 2020). In 2020, a desert locust outbreak affected several countries in Africa and Asia including India and Pakistan.

Of 10 important locust species in the world, only four species are seen in India: desert locust (*S. gregaria*), migratory locust (*Locusta migratoria*), Bombay locust (*Patanga succincta*), and tree locust (*Anacridium sp.*). The invasion area of the desert locust covers about 30 million km^2, which includes, in whole or in parts, nearly 64 countries (DPPQ&S, GOI) such as Afghanistan, Egypt, Eritrea, India, Iraq, the Islamic Republic of Iran, Pakistan, Saudi Arabia, Somalia, Sudan, Uzbekistan and Yemen, among others. Crop loss can be extensive and has the potential to cause famine and starvation. The desert locust is the most widespread and destructive of all locust species due to its ability to reproduce rapidly, migrate long distances, and devastate crops (Cressman, 2016).

1.2. The need for technical guidance on transboundary pests

In the context of the desert locust, data on surveillance and control has been efficiently coordinated through national locust units in affected countries, such as the Locust Warning Organization (LWO) under the Directorate of Plant Protection, Quarantine & Storage in India and the Department of Plant Protection (DPP) in Pakistan. FAO's Commission for Controlling the Desert Locust in South-West Asia (SWAC) helps to ensure cooperation, information sharing and capacity-strengthening among its four-member countries (Afghanistan, India, the Islamic Republic of Iran and Pakistan) in the region.[1] While scientific, technical and logistical solutions are available, management is an issue both at the regional and national levels in Pakistan and India. Clear mandated procedures, which are dependent on the preparedness and maintenance of instituted resources, must be implemented quickly. Further, it is to the advantage of the region, especially Pakistan and India, to effectively use the locust-specific entomopathogenic fungus to minimize the use of insecticides. Strategically, the focus in the region should be agro-ecological zones and landscape rather than on political boundaries.

It is to be expected that events in Afghanistan will influence the stability of the region and thus, anticipatory planning of the regional context is needed in the event of a locust plague in the coming years. This requires political will and well-laid out procedures for collaboration. Pandemics such as the recent coronavirus disease 2019, and regional calamities such as sectarian violence and regional conflict can derail the effective implementation of the technical guidance. The strength of international organizations should complement national programmes to develop viable response strategies, which, with further coordination, can be harmonized across the region. In addition, the FAO Global Action Plan should be considered while devising any regional strategy for implementation.

1.3. The regional response and current gaps

Swarms of the desert locust have invaded the summer breeding areas along the Indo-Pakistan border in June 2020. This was accurately predicted and forecasted by FAO, which gave an early warning to both countries. Before this, the region had not faced substantial swarms for more than a quarter of a century. Large-scale invasions of migratory locusts into Rajasthan, Haryana, Delhi, Punjab, Gujarat, Madhya Pradesh and extending up to Telangana in India, and almost all of Pakistan required emergency initiatives and mitigation strategies through a regional regulatory framework.

The regional regulatory framework in both Pakistan and India as facilitated by DPP and LWO, respectively, with guidance from FAO came into action. Further, as a part of the regional regulatory framework, both India and Pakistan during their deliberations in the fourth Indo-Pakistan joint border meeting in 2019, mentioned that they faced similar difficulties with the most recent locust invasion, which included insufficiently trained staff, equipment shortages, a need for public awareness and challenges working in rough terrain. FAO's regional locust commission helped to strengthen national capacities to address these issues.

To understand the priorities, opportunities, challenges and limitations in managing invasive pests, the Centre for Agriculture and Bioscience International (CAB International) organized a consultative meeting during August and September 2021, to draft technical guidance for the desert locust in Asia. The focus was on understanding and suggesting improvements on a regional basis based on the experiences, lessons learned and needed interventions towards surveillance and early warning systems.

1 See more information at https://locust-hub-hqfao.hub.arcgis.com

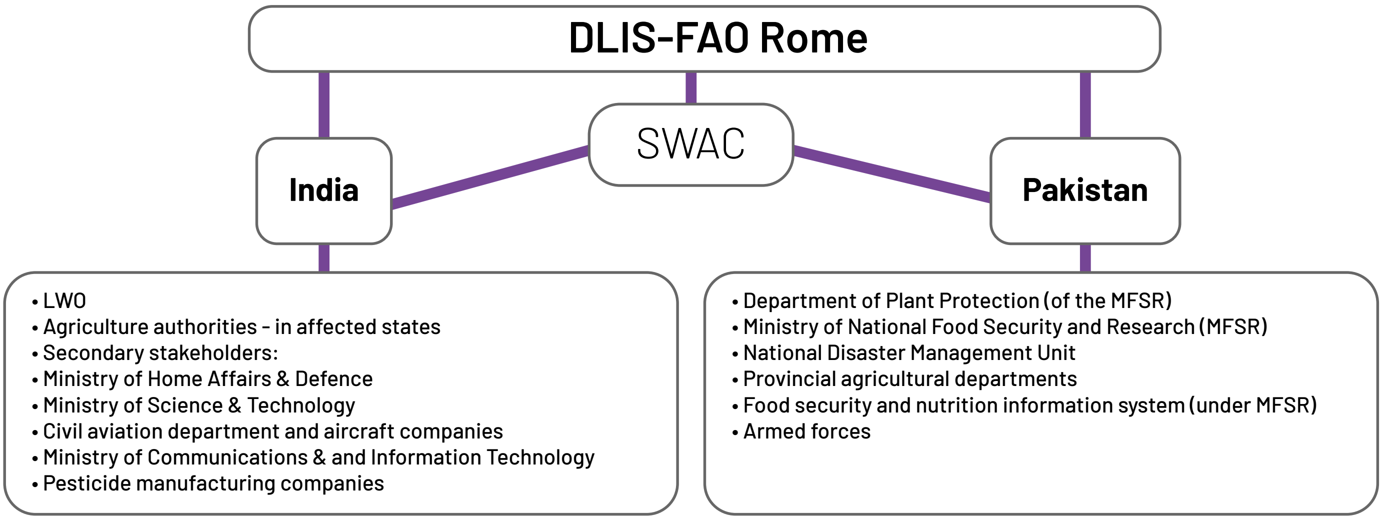
1.4. Regional status surveillance and early warning systems

The enormous size of the breeding areas and the rapid breeding that can lead to large numbers of locusts and subsequent migration requires regional and national preparedness based on a regular survey in the affected countries within the region and beyond. This data feeds into the global EWS that FAO's Desert Locust Information Service (DLIS) has been operating in Rome since the 1950s. The strategy to prevent locust plagues largely rests with the individual government and less with the farmers as area-wide operations through aerial sprays must be managed quickly. Many new technologies developed by FAO, including the eLocust3 suite of handheld digital tools for data collection in the field, the locust drone to extend survey coverage, and dashboards as online information resources are vital for surveillance and early warning. The latest session of SWAC in 2020 emphasized the importance of conducting joint surveys in Afghanistan, India, the Islamic Republic of Iran and Pakistan to supplement regular national surveys for effective surveillance and for forecasting the seriousness of the locust plague.

The Government of Pakistan has taken numerous anticipatory actions, in collaboration with FAO and via coordination with neighbouring countries, to address the locust threat and preparedness. In February 2020, the first phase of the National Action Plan (NAP) for locust surveillance and control was put into action. FAO has been providing both technical and operational support to the locust surveillance and control programme in the region since the early 1960s. The Space and Upper Atmosphere Research Commission (SUPARCO), a satellite communication and service provider, contributed to the demarcation of locust-prone areas in affected districts of Pakistan based on vegetation, soil type and other factors. The eLocust3g GPS satellite data communicators were used in remote areas that do not receive mobile signals and to facilitate monitoring and surveillance support for joint surveys and border meetings with neighbouring countries. National Disaster Management Authority (NDMA) and provincial agriculture departments, including the military when necessary, pooled resources to ensure surveillance coverage in areas prone to desert locusts.

In India, an android mobile-based application, known as eLocust3m, was rolled out during 2020 for the real-time reporting of desert locust infestations. Locust information officers took surveys (on foot and by vehicle) for locust infestations in their potential habitats. These surveillance teams used apps such as eLocust3, a handheld tablet and an FAO custom app that records and transmits data in real-time via satellite to the locust centres and to DLIS, which is based in FAO headquarters in Rome. This monitoring and data imagery give DLIS the locust locations and helps in send early warnings to countries at risk. Similarly, eLocust3m, from Penn State University in the United States of America is an application for smartphones that help geo-referenced reports of locust movements. Further, the satellite imaging can penetrate and identify moisture under the dry layer of soil, which is useful for locating the ideal spot where locusts tend to lay eggs. These established systems have been working efficiently, but consultations with stakeholders revealed a need to build capacity around these areas with state agricultural departments, especially since these are new technologies only recently introduced.

Figure 2. *Hierarchy of stakeholders at regional, national and local levels, who are the audience for the guidance.*



1.5. Regional status – management of desert locust

Countries affected by desert locusts adopt different management strategies to reduce the frequency, duration and intensity of the plague. Their strategies consist of regular surveys to provide early warning and contingency plans for early management of the locust population before the situation is out of control.

Some countries such as India try to rely on an established economic threshold level (ETL) of 10 000 adults/ha and 5 to 6 hoppers per bush before initiating control measures. Other countries wait until hoppers are adults to concentrate and form groups that can be good targets for treatment. Such concentrations may occur at lower densities depending on habitat and weather conditions. Control operations are not recommended when locust numbers are low, isolated and scattered because they would not be effective, and would be harmful to the environment, requiring large areas to be sprayed with large quantities of product to kill relatively few locusts. Currently, an integrated approach towards managing desert locusts consists of:

a) Cultural and mechanical methods

- Making loud noise in the cropped field either by beating empty tins/metal plates or lighting fires to try to disturb locusts and prevent them from landing on the crop. This tends to only shift the locusts from one farm to the next rather than reducing their numbers.
- Identifying and destroying nymphal and gregarious stages in locust endemic locations/regions.
- Spraying the first swath of migrating populations with recommended chemicals (see to Annex 5) to prevent the resurgence/outbreak of swarms.
- Stop the second generation of swarms from breeding and subsequently reduce the locust load for multiplication.
- If a hopper band is formed and observed marching, igniting dry grass or suitable material in front of the marching hopper band kills the nymphs but this may be harmful to the environment.
- Mechanical control methods such as digging trenches for hoppers to fall into or beating hoppers with branches are sometimes used as a last resort to try to protect crops.[2]
- Desert locust and mature swarms use downwinds for flight and hence the movement of a swarm could be used for EWS and management.
- A regional approach can be taken to control locust infestations in the adjacent country or region to prevent entry to a new region or country.

2 See more information at https://www.fao.org/ag/locusts/common/ecg/347_en_DLG4e.pdf

b) Chemical control

- Baiting was popular up until the 1950s but has been little used in recent years. It involves mixing insecticide dust with a carrier such as maize meal or wheat bran and scattering the mixture among or in the path of the locusts. A big disadvantage of this method is the amount of work involved in preparing, transporting and applying the large quantities of bait (5 to 15 kg/ha for marching bands and over 50 kg/ha for settled hoppers and adults). It is unsafe to handle and there can be a risk to livestock.

- Like baiting, insecticide dusting has the advantage that it can be carried out without specialist application equipment – a hessian bag of dust beaten with a stick has commonly been used. However, many countries have given up dusting because of the large quantities of product to be transported and applied (up to 10 kg/ha), and also because control is sometimes poor, especially with later instar hoppers and adults. There is also a substantial health risk to operators who may accidentally inhale the dust.

- Aerial spraying of a ULV formulation of a suitable, safer insecticide is used to manage hopper bands and swarms. (See Annex 3 for guidance on the application of chemicals for ground and aerial locust management.)

c) Biological control and other safer options

- An isolate of a fungus Metarhizium acridum, often referred to as Green Muscle, is specific to locusts and is known to be quite effective on both nymphs and adults but it is still not available in the region. Samples have been sent to India and Pakistan by SWAC for evaluation as part of the national registration process.

- In Pakistan, different species of small, parasitic wasps of the genus Scelio live off the eggs of locusts and hoppers. CAB International reported 9 species of Scelio associated with 16 species of the pest.[3] The female parasite burrows through the froth plug on top of the locust egg pod and uses a retractable, needle-like ovipositor to lay an egg in each locust egg. On hatching, the wasp larva feeds inside the egg and kills the locust embryo. In dry conditions, Scelio sp. adults can remain dormant in the locust egg for a month or more before emerging after the rains. This has yet to turn into an operational product.

1.6. Present scenario: challenges/barriers for desert locust management

For decades, many locust management interventions have included the cultural, mechanical, biological and chemical methods that were developed and promoted in the different regions. Apart from the chemical methods, other practices may not be effective during peak locust infestations. Using biological methods, predators and parasitoids are suitable during low locust incidence, but during a severe infestation, the number of locust populations will outnumber the bioagents. The type of method deployed for locust management depends on the intensity of the locust population, type of location (cropped or barren land), distance to residential areas, climate conditions, stage of the locust, etc. Moreover, the waiting period for locust management with any method should be shorter for effective management. The chemicals were identified for locust control and we need to focus more on locust management at different stages with the available chemicals. The use of chemicals will have adverse effects on the health of farmers and the environment. So there is a need to develop strategies for applying chemicals with different methods/spraying techniques that will do less damage to the environment and human health.

Barriers/challenges in different methods of locust management:

- Cultural and mechanical methods: These methods are suitable during limited locust infestations in cropped/agricultural areas. These methods are not based on scientific evidence and most of the interventions are considered as indigenous technical knowledge (ITK). The methods are not effective during severe/peak locust infestations.

- Biological methods: The action of biological methods is very low and not suitable during peak/large infestations. Sometimes the number of locust populations outnumber the bio agents and are not effective in managing the locust population. Moreover, the technologies are limited to use in small areas due to limited availability and restrictions in storing, transport, longevity, etc.

- Chemical methods: The available chemicals are effective in controlling large areas and during peak infestation. The main constraint includes the health of farmworkers and the impact on the environment due to the use of heavy doses of chemicals.

3 Locust Introduction biology and Management in Pakistan

1.7. Scope and objectives of the technical guidance

The goal of this proposal on the Early warning system and sustainable management of transboundary pests such as the desert locust in South Asia is to contribute towards creating a regional common agenda to promote IPM practices following established effective monitoring and surveillance through regional cooperation taking into consideration the overall strength, weakness, opportunities and threats of effective and sustainable management. The overall objective of the strategy is to set-up an IPM framework based on locust migration monitoring and an EWS and provide recommendations for efficient and effective management in South and Southeast Asia. The goal is to manage locust invasions and subsequent breeding as far as possible through effective biocontrol agents to reduce the reliance on insecticides, following early identification of potential breeding sites for timely application of the biocontrol agents and to reduce pesticide poisoning in food, water and the food chain, besides protecting valuable biodiversity and ecosystem services, which are key pathways in the Sustainable Development Goals (SDGs). Similarly, the goal is also to improve communication, coordination, cooperation and management decisions, which are essential to successfully mitigating various challenges in a complicated relationship between India and Pakistan.

Though the focal countries would be India and Pakistan in South Asia and the scope is limited to the desert locust, the findings will have wide ramifications across all nations and regions affected by the desert locust in Africa and in Central and South Asia. Countries such as Afghanistan and Nepal, which do not have specific national locust units and, in the case of Nepal, does not belong to SWAC, will benefit from better regional communication.

Objectives:

1. Maintain and expand the existing network and enhance the capacity to manage desert locusts through regular surveillance and monitoring in India and Pakistan.
2. Develop and strengthen the national and regional systems to suppress the risk factors for outbreaks/ invasions.
3. Coordinate the regional and national policies, standards and measures to reduce the risk of locust outbreaks making effective use of early warnings and IPM recommendations.
4. Reduce socio-economic environmental risks from locust infestation and damage.
5. Educate and promote biocontrol-based options in integrated locust management (e.g. use of M. acridum).
6. To document and understand the economic impact of locust invasions on the urban landscape.

2. Approach to drafting the guidelines

Initially, a desk review was conducted, including all information regarding the level of awareness of regional stakeholders about the following issues: desert locust infestation levels; damage on crops; natural enemies observed; plant protection measures; and national and regional management actions taken in response to the pest. This review identified the relevant institutes and resource persons working on desert locusts. A list of stakeholders and institutes was collated, and an email was sent to each resource person seeking their permission to proceed further in sharing their knowledge and data to develop the guiances. A survey questionnaire was also developed to obtain information that could not be gathered through the desk review. Then key informants were identified based on their knowledge and based on recommendations from various organizations. Online interviews were then conducted with these informants to understand knowledge gaps regarding surveillance and sustainable management. Thereafter, based on the key informant interviews and the responses to the questionnaires, a strength–weaknesses–opportunities–threats (SWOT) analysis was conducted. The results of this analysis were validated and endorsed by key resource people in validation workshops that were conducted in each focus country to ensure that the collated information was valid for the region as a whole. Understanding the weakness of countries made it possible to craft guidance that can be implemented in each country and to customize those guidances.

3. Results of the drafting process

A SWOT analysis was conducted to analyse strengths, weaknesses, opportunities and threats in the focus countries and the region regarding desert locust management. The aim was not necessary to identify solutions but rather to understand what can reasonably be achieved. The analysis of strengths and weaknesses focused more on current processes, human resources, physical and financial resources and policy, while the analysis of threats and opportunities focused on external factors, such as infestations in adjoining regions, markets and economic trends, political and economic regulations, etc. The results of the national SWOT analyses are shown in the figures below, while the overall conclusions derived from them at a regional level are provided in Box 1.

Figure 3. *SWOT analysis for India*

Strength	Weaknesses	Opportunities	Threats
India has strong information technology capabilities and space and drone technology that can be effectively harnessed for surveillance, data managment and real time monitoring. In a short time, india rolled out the android mobile based eLocust3m in 2020. Good use is made of RAMSES GIS for data management and analysis. They have the advantage of LWO.	Main weaknesses are a lack of integrated management on locusts, too dependent on chemical pesticides (due to ready availability of pesticides, no field trials so far on M. acridum and an inability to produce/import at short notice M. acridum) and a lack of anticipatory research.	Public and private laboratories engaged in biocontrol should be able to meet the demand for M. acridum and other biocontrols in future.	Stability in the north west region of India is volatile and any regional disturbance can derail locust management.

Figure 4. *SWOT analysis for Pakistan*

Strength	Weaknesses	Opportunities	Threats
Pakistan has reasonably good, well trained scientific human resources. They have the advantage of a DPP. Good use is made of eLocust3 tools for data collection and RAMSES GIS for data management and analysis. Help from China in the form of material support to fight locusts, is also a strength.	Inflation is high and food insecurity is looming with events in Afghanistan casting a shadow on Pakistan. The trust deficit with India is another factor. There is also a serious deficiency in high-level management and decision-making processes. The apps developed for Pakistan for locust management are incompatible with DPP, eLocust3, RAMES and FAPs global EWS.	It is an opportunity for everyone to prove that despite regional disturbance and economic hardship, it is possible to highlight food and nutritional security. A stable Pakistan contributes significantly to world peace and all efforts must be made towards this end.	Secretarian violence, political instability, regional disturbances and continued blacklisting by Financial Action Task Force remain major threats.

Box 1: *Key takeaways from the regional SWOT analysis*

- The members of SWAC familiarized themselves with many new technologies developed by FAO including eLocust3 (suite of digital tools), dLocust (drone to extend survey coverage) and dashboards as an online information resource tool.
- The region is fortunate to have well-established coordination mechanism technology structures laid out by FAO that allow seamless collaboration between India and Pakistan as well as other partners in the region throughout the year within the framework of SWAC.
- There is a need to use M. acridum for an evaluation trial and subsequent use after successful validation.
- There is very little awareness of the adverse effects of aerial sprays on biodiversity and ecosystem services.
- Despite FAO advocating the efficacy of M. acridum, efforts need to be focussed on testing it once it is imported.
- This provides an opportunity to demonstrate the power and impact of science-led international cooperation in mitigating hunger, poverty in one of the poorest regions.

SECTION B: TECHNICAL GUIDANCE

©CABI

4. Recommendations by key area

The DLIS at FAO headquarters in Rome, Italy monitors ecological conditions, weather and the desert locust conditions every day from West Africa to India and keeps governments informed of the risk to each country of invasion after analysing locust breeding and migration. The FAO's SWAC commission is the oldest of the three regional commissions that strengthen national capacities in the region. It was established in 1964 and consists of four member countries: Afghanistan, India, the Islamic Republic of Iran and Pakistan. The main activity of SWAC is the annual 30-days joint survey of the spring breeding survey of the southeast in the Islamic Republic of Iran and western Pakistan. In November 2020, the thirty-second session of SWAC was held virtually with member countries. They discussed the many challenges that were faced during the 2019 to 2020 desert locust upsurge, what went well and what did not as well as the lessons learned, which can be applied in future desert locust control campaigns. The members also familiarized themselves with many new technologies developed by FAO including elocust3 suite, and dlocust drone to extend their survey coverage, and dashboards as an online information resource tool. SWAC emphasized conducting joint surveys in the region. Thus, FAO has been providing support to the locust surveillance and control programme in India and Pakistan by providing both technical and operational support. However, certain key strategic interventions for more effective management of desert locusts are drafted as per the challenges interpreted after the discussions with the stakeholders. A book commemorating SWAC's fiftieth anniversary provides detailed information about the region.[4]

Basis of recommendations

Breeding sites and immature swarms are generally located in remote areas. It is difficult to identify those sites through traditional travel methods. It requires special infrastructure including vehicles, equipment, trained personnel and advanced surveillance systems and the availability of these resources is quite limited in some regions. Quick action is necessary since the reproductive potential of locusts is very high resulting in the exponential growth of desert locusts in a short time. The surveillance systems developed by FAO should be upscaled to other regions apart from India and Pakistan, and the experts from different institutes as well as stakeholders (public, private and international organizations) should be involved in the technology development, maintenance and dissemination. Different regions have adopted traditional management practices involving toxic chemicals, and the use of biopesticides or bioagents is quite limited in locust management. Through regional consultations, these barriers were discussed and the following strategies were crafted as per the stakeholders' requirements.

4 See more information at https://www.fao.org/ag/locusts/common/ecg/1185/en/SWAC50web.pdf

Table 1. *Challenges and barriers in locust management and possible recommendations for future strategy*

Challenges and barriers	Recommendations and future strategy
Identifying immature swarms settled in remote areas	Deploy remote sensing and GIS tools and technologies set by FAO (DPP, eLocust3, dLocust, RAMSES and FAO's global EWS, https://global-locust-network.mobilize.io/main/groups/43483/lounge) to identify the areas prone to these immature stages. Recommend appropriate management practices based on the intensity of the swarm.
The exponential growth of desert locusts causes increasingly larger swarms (increases 20 times every 3 months, or 160 000-fold in one year)	
Swarms not only threaten agriculture but also wreak havoc on livelihoods	
Supply of biopesticide often cannot keep up with demand during locust emergencies	Standardize on-farm production technologies to promote/disseminate validated bio pesticides for locusts in endemic locations. Identify new bio molecules/products to replace the use of toxic pesticides in small areas in early stage (hopper band stage). The new molecules should comply with FAO pesticides regulations (https://www.fao.org/ag/locusts/en/publicat/meeting/topic/572/i ndex.html).
Training for existing and new staff is often overlooked, given low priority or not carried out correctly or regularly	Develop a capacity development programme and communication plan to scale up the IPM interventions involving potential partners in training activities.
4WD vehicles are probably the most challenging item to manage. Newly purchased vehicles and even older ones are often attractive for other purposes that may be far from the desert and locust breeding areas	Enact policy guidance for vehicle purchasing and maintenance to monitor the breeding areas for in-time decision making.
Policies on importing the biopesticide Green Muscle for testing and validating	Initiate a policy dialogue with the relevant authorities for registering the biopesticide in country to get an import permit for research use.
Oil formulations of Green Muscle may not be suitable for cropping areas.	Facilitate Import of a strain and have discussions with inventors to license the strain for development of new formulations that are suitable for agricultural use.
Locust organisms for testing efficacy of green muscle are unavailable	Test on closely placed species for the bio efficacy of the fungus.
Cost-effective applications of biopesticides for vast areas not optimized.	Develop an app that can predict the need to apply biopesticides based on the pest models and weather parameters to keep the population under threshold.
No awareness among growers and operators regarding biopesticides	Develop a communication framework based on a mass extension programme in regional languages to create awareness. Develop training modules to build the capacity of farmers' extension workers and operators.

Figure 5. Technical and operational barriers in locust management

As per the challenges found above through the stakeholder consultations, strategies and key interventions were co-developed to identify the recommendation in each focal area. (See Annex 1 and Annex 2 for details of institutions and stakeholders consulted in the regions for the validation workshop.)

Key Area 1: Policy interventions based on the existing regulations

Highlight the policies on regulating biopesticides in countries (India and Pakistan). Central Insecticide Board and Registration Committee (CIBRC) and the National Biodiversity Act (NBA). Subsequent evaluation of the strain on the basis of importing it for research. The recommendation will include advocacy for importing the strain and consulting NBA to import it.

Coordinate with the company that manufactures Green Muscle to arrange for the product to be licensed to a local small or medium enterprise, and share related registration information, i.e. toxicological, etc.

Explore the policies of the aviation ministry and on the use of drones for spraying pesticides in cropping and non-cropping areas. An intervention is required when drones are used for this purpose especially in areas where there are people.

Policy guidance for purchasing and maintaining vehicles should be enacted so as to monitor the breeding areas for in-time decision making.

Develop standard operating procedures (SOPs) and guidance for the safe and effective use of drones for desert locust control.

Develop and disseminate existing SOPs on desert locusts to regional and state-level languages of India and Pakistan.

Key Area 2: Strengthen surveillance, early warning and emergency preparedness

Form a committee to look into maintaining and refreshing equipment. The committee will look after the operations related to vehicles by budgeting separate funds for repair, renewal and maintenance of old vehicles.

Survey and monitor locust breeding, development, migration, size of the swarm and pattern of movement all through the year for planning locust management strategy.

Organise mock drills to ensure the proper use of the devices developed by FAO to record and transmit survey and control data during field operations in real-time to the locust centre in the country for surveillance, early warning and emergency preparedness.

Continuously test for surveillance drone technology to map vegetation and to guide teams to potential locust infestations around a 50 to 100 km radius.

Communicate and create awareness of early warning and alerts, use FAO's GIS-based DLIS to predict, assess and report the scale, timing and location of locust breeding and migration across the region and on other continents (Locust Watch: www.fao.org/ag/locusts) in a relevant multi stakeholder environment.

Negotiate to establish a mandate for every region or country to consider a legal obligation to harness the data, analyse and warn the adjoining regions and countries of the locust plague as a component of EWS.

Continue surveillance after the swarm has passed to record the oviposition, development of next generation, natural enemies limiting the next generation and to collect samples and store them for future studies on locust physiology.

Develop, if necessary, or support existing simulation and prediction models based on DLIS data that will help in EWS and preparedness (https://global-locust-network.mobilize.io/main/groups/43483/lounge).

Choose ULV sprayers, aircraft, drones, chemicals, method of spray, regions to be demarcated, people to inform and a management system that will be authorized to make quick decisions. The window available for these decisions is often from 7 to 15 days.

Continue to use remote sensing products within the RAMSES GIS to monitor desert locust habits for breeding and migration potential. Use the survey for green vegetation, soil moisture and identify the areas prone/ sensitive to locusts.

Develop advanced simulation models that can predict locust plague size, migration pathway and potential crop loss.

Actively participate in SWAC meetings to learn of and to share any data on surveillance from other regions. (See Annex 4 for information in pest management decision guide for desert locusts.).

Key Area 3: Increase advocacy, awareness and knowledge/communication

Extend the locust database to more areas under locust threat (Afghanistan, Nepal) to disseminate alerts to stakeholders at all levels via SMS and email. Emergency response actions, public outreach and education and inter-organizational communication and coordination are key.

Advocate for environmentally safe biopesticides as an alternative to harmful chemical pesticides and convince policy makers through education and success stories from other parts of the world.

Create awareness among extension workers and plant protection specialists of the lifecycle, potential crop loss and the environmental hazard of aerial sprays.

Ensure there is communication in local and regional languages at the village level through cultural programmes, radio broadcasts, television and extension bulletin well before the swarm sets in. Use non-formal education methods such as theatre, comics, role play. Take information and technology to the grassroots level.

Engaging government partners to develop the data platform can showcase the potential of the system to be used in policy-level decisions and responses. It can be integrated as a tool for their agricultural planning.

Conduct workshop for human resource development on the use of online databases to strengthen EWS, outreach and co-ordination.

Conduct training on the safe use of pesticides, aerial sprays, applying drone technology and biological control for NPPO.

Conduct training in communication and mass media to facilitate awareness and preparedness about a locust attack.

Develop communication plans and capacity building strategies for the managers or experts to improve their management of field teams and equipment for locust management in different countries/regions.

Develop updated and tested contingency plans for execution based on early warnings of a locust outbreak that are being generated by the tools and technologies of FAO.

Key Area 4: Strengthen technical capacity of plant protection and extension system

Surveillance

Develop the capacity of state departments of agriculture in remote sensing, monitoring and surveillance of locusts in cropping areas using the eLocust3m smartphone app for crowd sourcing.

Conduct trainings to build the capacity of operators who can target spray ULV chemicals using drones.

Set up a separate wing on application of drone technology and management for covering a short radius of 100 km.

Ensure that vehicles are deployed in rugged terrain to effectively monitor and manage desert locusts.

Create an inventory and maintenance schedule for all equipment such as chemicals, sprayers, GPS, eLocust3, pumps, camping and personal protection to ensure that they are systematically managed, inventoried, updated, repaired and accounted for.

Developing human resource and training for existing and new staff is often overlooked, given less priority, or not carried out correctly or regularly. Without the proper skills and experience, it is nearly impossible to use the numerous available technologies to conduct a desert locust survey and control operations safely and effectively.

Innovative and adaptive integrated pest management platform for locust management

Build the technical and financial capacity of research institutions, universities, departments of agriculture, and engage other stakeholders to identify and review solutions related to locust management in specific regions.

Establish a research collaboration among the different countries to share information on current research and innovations between the regions to optimize time and resources.

Disseminate the information regarding potential locust management products/bio inputs or technologies through a partnership with the public and private sector.

Establish technology demonstration platforms and conduct demonstrations in farmers' fields and encourage the participation of stakeholders to ensure that locust management tools and technologies are tailored to the local conditions.

Create an awareness campaign in residential urban areas regarding the swarms that can create disturbances in urban settings.

Standardize the spraying techniques for the cropped area (location-specific cropping system) and for barren/ uncultivated land.

Key Area 5: Enhance implementation of integrated pest management

Establish a central command unit with clear responsibilities for the management structure and decision-making pathway for speedy implementation.

Procure the strain of *M. acridum* to make a suitable formulation of the biopesticide for application in an agricultural area.

Test, validate the use of biopesticide based on *M. acridum* through participatory research, and establish technology demonstration platforms to disseminate their use to larger communities of smallholders.

Increase the use of biopesticides by completing registration procedures and by enhanced awareness and knowledge of biopesticides for desert locust control.

Develop an app that can provide the required application of biopesticide at a given point of time to keep the level of pest below the threshold.

Review the use of chemicals currently used for locust management in terms of World Health Organization (WHO) classifications to ensure safety during operations.

Make decisions for implementing IPM of locusts based on high quality and reliable data considering the availability of the various innovative tools and technologies.

Institute locust management that is targeted, effective, and rapid, and which does the least damage to biodiversity and ecosystem services.

Establish follow-up procedures for post-control to identify and manage any residual infestations for further locust reduction.

Develop a mechanism to disseminate information of IPM interventions during potential and actual pest outbreaks. Managing a single hopper band with insecticides is effective, But identifying a single hopper band is difficult and time-consuming. Strategies to identify a single hopper band through remote sensing and GIS technologies should be explored.

Key Area 6: Innovative research needs

Basic research on locusts has come to a halt in Indian and Pakistan as there has been a long hiatus from locust swarms over the last 70 years. The swarms of 2019 to 2020 should serve as a wake-up call to initiate research in major research institutes in Indian and Pakistan. The following is where the focus for 2022 to 2026 should be:

- Native natural enemy surveys for indigenous isolates of the entomopathogens that are suitable for managing locusts or similar species should be conducted.
- In the absence of a locust population, conduct tests of the efficacy of bioagents on closely related species of locusts such as the desert locust, migratory locust, Bombay locust and the tree locust.
- Develop a combination application of two or more biopesticides to explore the possibilities of them having an additive effect on the management of locusts such as Entomofungus and Entomopathogenic Nematodes (EPN). Conduct an evaluation on grasshopper and locust egg pods.
- Standardize the technology for applying biopesticides using drones in different countries/regions.
- Conduct a socio-economic impact analysis on locust management using biopesticides.
- Test the use of repellents like neem-based products in cropped areas and locations close to a residential area so as to avoid the drift of chemicals.

In the interest of operators and growers, the current list of chemicals has been analysed as per its status on the WHO list of chemicals (2019), and as it relates to Asia.

Table 2. Scientific recommendations for different stages of the desert locust and the suitability of implementing them in Asia.

Stage of the locust/ cropping system	Recommended management practices	Status of chemicals as per WHO class of chemicals (2019)	Type of precautions needed for such interventions	Conditions suitable for South Asia and status of use of restrictions like pre harvest interval (PHI) and personal protection equipment (PPE) in use of chemicals
Oviposition holes observed in the cultivated fields	Initially dust with any insecticide (Quinalphos 1.5% DP or Chlorpyriphos 1.5% DP or methyl parathion 2% DP @ 25kg/ha) and then plough the field to kill the eggs and emerging nymphs.	Quinalphos & Chlorpyriphos: Moderately hazardous class II Methyl Parathion: Extremely hazardous class Ia	Avoid using toxic chemicals like methyl parathion in cropped and residential areas. Dusting/spraying with low toxic chemicals should be done in early morning or evening hours to avoid the drifting of chemicals to cropped or residential areas	Oviposition of desert locusts is very much limited in south Regions within Asia. If any oviposition holes are observed, the recommendations are suitable for south Asian conditions. The majority of the farmers in South Asia don't use PPE during chemical application and are not aware of the toxicity of different pesticides
Eggs begin hatching and nymphs observed	Spray bio-pesticide-Metarhizium anisopliae var. acridum/Paranosema locustae @ 75gms/15 lit of water or dust any insecticide quinalphos1.5% DP or Chlorpyriphos 1.5 % DP or Methyl Parathion 2 % DP @ 25kg/ha to kill the emerging nymphs.	Chlorpyriphos: Moderately hazardous class II Quinalphos: Moderately hazardous class II	Avoid using toxic chemicals like methyl parathion in cropped and residential areas. Dusting/spraying with low toxic chemicals should be done in the early morning or evening hours to avoid the drifting of chemicals to cropped or residential areas.	The recommendations are suitable for South Asian conditions but the product is not available for use by farmers
Formation of hopper band and observation of locust marching	Ignite dry grass or any trash in front of the marching hopper band to kill the nymphs. Digging a trench 0.6 m deep and 0.6 m wide in front of marching hopper band and then apply quinalphos 1.5 % DP or Chlorpyriphos 1.5 % DP @ 25kg/ha in the trench or if water is available, pour water in the trench.	Chlorpyriphos: Moderately hazardous class II Quinalphos: Moderately hazardous class II	Initially adopt mechanical and cultural measures followed by less hazardous chemical application. Dusting/spraying with low toxic chemicals should be done in the early morning or evening hours to avoid the drifting of chemicals to cropped or residential areas.	Burning of dry grass or any trash is not advisable in some parts of South Asia. Alternatively, low toxic chemicals are recommended. Considering small fragmented land holdings, it is not advisable to dig the trench for small and marginal farmers.
Roosting of locust hopper bands	Dusting of Quinalphos 1.5% DP or Chlorpyriphos 1.5 % DP or Chlorpyriphos 1.5 % DP or spray Malathion 96 % ULV @ 1.0 lit/ha with the help of ULV spray	Quinalphos & Chlorpyriphos: Moderately hazardous class II Malathion: Slightly hazardous class III	Initially at a low level of incidence, recommend biopesticides followed by chemical application.	The recommended management practices are suitable for South Asian conditions. Majority of the farmers in South Asia don't use PPE during chemical application and are not aware of the toxicity of different pesticides

Stage of the locust/ cropping system	Recommended management practices	Status of chemicals as per WHO class of chemicals (2019)	Type of precautions needed for such interventions	Conditions suitable for South Asia and status of use of restrictions like pre harvest interval (PHI) and personal protection equipment (PPE) in use of chemicals
Locust settled on the ground in an uncultivated field (large-area)	Dusting Quinalphos 1.5 % DP or Chlorpyriphos 1.5 % DP @ 25kg/ha or spray Malathion 96% ULV @ 1.0lit/ha with the help of ULV sprayer directly on the hopper band. Dusting of ULV formulations using vehicle mounted dusters/ULV sprayers.	Quinalphos & Chlorpyriphos: Moderately hazardous class II Malathion: Slightly hazardous class III	Avoid the drifting of chemicals to residential or cropped areas. (Dusting or spraying with low toxic chemicals should be done in the early morning or evening hours to avoid the drifting of chemicals to cropped or residential areas).	Aerial spraying or vehicle-mounted dusters/ULV sprayers are recommended with drones in South Asian regions. Depending on the intensity or area of occurrences, types of sprayers and spraying techniques can be decided. Note: Before using drones, approvals from concerned officials are mandatory.
Locust swarm invading the cropped area	Aerial spraying of ULV formulation of insecticide like Malathion 96% ULV @ 1 lit/ha with the help of ULV nozzles fitted on a helicopter/drones.	Malathion: Slightly hazardous class III	Dusting/spraying with low toxic chemicals should be done in the early morning or evening hours to avoid the drifting of chemicals to cropped or residential areas.	
Locust swarm settled in non-scheduled cropped or non-cropped area	Aerial spraying of ULV formulation of insecticide like Malathion 96% ULV @ 1 lit/ha or fenitrothion 96% ULV @ 0.5lit/ha with the help of ULV nozzles fitted on a helicopter/ drones.	Malathion: Slightly hazardous class III Fenitrothion: Moderately hazardous class II	(Dusting or spraying with low toxic chemicals should be done in the early morning or evening hours to avoid the drifting of chemicals to cropped or residential areas).	If the locust outbreaks appear in residential areas, avoid using chemicals and instead use alternate management practices. Most farmers in South Asia don't use PPE during chemical application and are not aware of the toxic nature of different pesticides

5. Technical assistance and resource mobilization

There is a need for technical and scientific support from international research institutes, such as CIMMYT, CABI, the International Rice Research Institute (IRRI) and other research institutes at the national level that can address the needs of the region. ICAR and the national research system in India can support the region in addressing diagnosis, identification and human resources development. Management of FAW at the regional level will require the financial support of organizations such as the Asian Development Bank, Australian Funds for International Agricultural Research, USAID, the World Bank, FAO, the SAARC secretariat, and many international research institutes such as IRRI, CIMMYT and the International Crops Research Institute for the Semi-Arid Tropics.

6. Monitoring and evaluation

6.1. Monitoring and evaluation at the country level

There should be clear monitoring of work carried out and planning for the next phase of work including uniform data collection template, on-time uploading of data to central database, etc. It is important to have technical and financial monitoring to assess whether the progress of the work is in line with the mandate of the project, and to monitor the expenditures sanctioned and incurred, extension bulletins and research papers published, and that there is a summary of important findings. Evaluations must include any diversion of funds, duplication of research, delay in implementation, report submission delays, and other factors. A template is needed for monitoring and evaluating the realistic progress of the project.

6.2. Monitoring and evaluation at the regional level

The biannual meeting was scheduled for late 2022 and is supplemented by monthly meetings by DLIS and Locust Watch. The focus of the meeting should evaluate the perceived threat, and any developments in Africa. The meeting is also for sharing data and drawing on the experiences and lessons learned from different regions and countries. Every effort must be made to fine-tune surveillance monitoring, sharing, human resources development and regional analysis based on real-time data. The meeting should be convened by FAO and international organizations for coordination.

The pattern of evaluation for scientific and technical progress at the regional level can be like the template developed above with small modifications. However, the focus of evaluation here should be more on facilitating mutual coordination and cooperation between India and Pakistan for managing locusts. The regional evaluation, with a focus, socio-economic analysis and an impact analysis should be the target for evaluation.

FAO and international organizations should facilitate the regional output and outcome for global linkage, and experts from each region can serve in the core committee to help FAO. A centralized management for implementation, coordination, data management is needed for smooth functioning. This responsibility must be with FAO and the international organizations the at regional level. At the national level, one responsible government official should take responsibility for coordination within the country and for liaising with FAO for regional co-ordination.

6.3. National forums and national task force meetings

The national forum should consist of officials from different levels of experts involving progressive farmer groups, officials from state and central level line departments, and public and private partners of national and international level organizations. The problems raised by the different stakeholders in locust management should be escalated to the national forum and accordingly and in-time decisions should be adopted. Dynamic advisory systems should be developed to enable the flow of information to the ground level operators for efficient management of locust outbreaks and to prevent the subsequent spread of locusts to other regions.

The national stake force meeting should be held preferably in November or December to monitor the progress each year and plan for the next year. The yearly conferences should address national progress, regional progress, difficulties in implementation, recruitment and procurement, data collection, and utilization of the budget. It is vital to indicate from the beginning that a no-cost extension of the project is permissible.

The data on desert locusts is available in the public domain, and awareness campaigns need to be conducted for large scale dissemination of the information among different stakeholders at the national and regional levels.

A final meeting should take place at least two to three months before closure of the project focused on the take-home points both nationally and regionally, impact analysis, scientific paper writing and preparation of the final report.

The take home results and impact are vital to crystallize the summary of achievements and their outcome and how it is making an impact across a spectrum of stakeholders. It is vitally important to project the achievements with clarity to policymakers so they can make the right decisions.

6.4. Publications: national and regional

Publications that combine data and analysis across regions, and countries on the severity of locust swarms, crop loss, decision support and process, bottlenecks, policy guidance all contribute to the science and the future policy framework regionally and globally. Publications also foster a better understanding and exchange of ideas among scientists. Some assistance with editing and clear writing by FAO or international organizations will be needed.

One of the best ways to ensure quality publications is to publish in peer-reviewed scientific journals in a grid, make a time-bound analysis each year of the mega data, and to spend a week or ten days of in discussions on and writing up the last part of the project. Publication costs must be reflected in the budget from the beginning to ensure the necessary resources to publish in international journals.

6.5. Impact analysis: social, economic, direct and indirect benefits

The impact analysis is a critical aspect of the work. It is essential from the output and outcome point of view, and it meets the expectations of the donor(s). Performing the analysis helps the entire team to understand the various socio-economic, environmental, livelihood and gender dimensions. IPM is both ecological and economic in its mandate. it requires careful planning before and after the implementation of the project to document and monitor the various indices that address the appropriate SDG. We need to evaluate and standardize the sustainable and scalable pest management technologies in different cropping systems in collaboration with public and private institutes. The tools and technologies in IPM for locust management should be economically viable, ecologically feasible and socially acceptable to different communities.

Bibliography

Cressman, K. 2016. Desert Locust. In: Biological and Environmental Hazards, Risks, and Disasters 87-105. Cressman, K., 2016. Desert Locust. In: Shroder, J.F., Sivanpillai, R. (Eds.), Biological and Environmental Hazards, Risks, and Disasters. Elsevier, pp. 87–105. ISBN: 9780123948472

FAO (Food and Agriculture Organization of the United Nations). 2020. Report of the FAO Commission for Controlling the Desert Locust in South West Asia. Thirty-second Session. Virtual Session by Zoom. 14–16 December 2020. FAO, Rome. 56pp.

McKeever, A. 2020. Locusts. National Geographic National Geographic Society.

Mahendiran, G., Subaharan, K., Mohan, M., Sampath Kumar, M., Sivakumar, G., Shylesha, A.N. & Bakthavatsalam, N. 2020. Is there a difference between grasshopper and locust. ICAR-NBAIR Publication series no. 10/2020. 9pp.

Rehman, A. Locust Introduction biology and Management in Pakistan. (Talk on Schistocerca gregaria Desert Locust: Introduction, Biology and Management.) Presentation. Geoscience. CAB International, Pakistan. https://www.researchgate.net/publication/349553095_Locust_Introduction_biology_and_Management_in_Pakistan

Annex 1: List of institutions consulted

Below is a list of the institutions and stakeholders who were engaged in key informant interviews and that participated in regional consultations, as part of the development of these guidances.

Stakeholders engaged in desert locust surveillance early warning and response (SEWR)

1. State Department of Agriculture (SDA), Gujarat, India
2. State Department of Agriculture (SDA), Rajasthan, India
3. Food and Agriculture Organization of the United Nations (FAO), Rome
4. Punjab Agricultural University (PAU), India
5. Indian Council of Agricultural Research (ICAR) – Central Arid Zone Research Institute (CAZRI)
6. Department of Plant Protection (DPP), Pakistan
7. National Disaster Management Authority (NDMA)
8. University of Faisalabad
9. MNS University of Agriculture, Multan, Pakistan
10. Centre for Agriculture and Bioscience International (CAB International), Pakistan

In addition, the consultations included independent consultations working in the agricultural sector from India and Pakistan in the region.

Annex 2: List of stakeholders that were consulted in the regional consultations/ guideline's validation workshop

No.	Name of stakeholder	Country
01	Dr Suwalal Jat	India
	Dr Vipin Chaudhary	
	Mr Bhansidhar	
	Dr PK Chhuneja	
02	Dr. Muhammad Ishfaque	Pakistan
	Dr. Muhammad Basit	
	Mr. Ikhlaque Dasti	
	Dr. Shafqat Saeed	
	Dr. Muhammad Sagher	
	Dr. Aamir Rasool	
	Dr. Ahmad Kamran Khan	
	Dr. Naeem Iqbal	
	Dr. Arslan Khan	
	Mr. Sohail Javid	
	Mr. Ghulam Rasool	
	Dr Muhammad Waheed anwar	

Annex 3: Guidance for applying chemicals for ground and aerial locust management

Principles of ULV application	ULV spray equipment / aerial spray system
• Ultra low volume (ULV) spraying uses small amounts of concentrated insecticide. In locust control, about 0.5-1.0 litre/hectare is applied. The insecticide is not mixed with water or solvent. It is oil-based to prevent evaporation and is usually applied ready to spray. • Droplets of spray are carried by the wind. In full coverage treatments, the insecticide is sprayed as overlapping swaths onto the control target so that a uniform deposit is achieved and the locusts receive enough insecticide. • Do not spray during the hottest part of the day (11:00-16:00 hr) when convection may occur and carry the spray up into the sky instead of down onto the locusts. • Do not spray at low wind speeds less than 1 m/s. • Do not spray at high wind speeds more than 10 m/s.	• A good ULV sprayer uses rotary atomizers (spinning discs or rotating cages) to produce droplets in a small size range (50-100 um). If droplets are too large or too small, control will be poor and insecticide wasted. For aerial spraying, use the following:Volume median diameter (VMD): 75-100 um angle: 35° (AU4000), 40° (AU5000) [(1)] • Emission height: 5-10 metres, depending on wind[(2)] • Aircraft/helicopter speed: 140-160 km/h in consultation with pilot • [(1)] at air speed of 160 km/h, 7000 rpm • (AU4000), 8000 rpm (AU5000) • [(2)] higher for milling and flying swarms and, possibly, barrier control

Source: SOP for desert locust in India, DPPQ&S, Govt. of India: http://ppqs.gov.in/sites/default/files/consolidated_sop_for_desert_locust_in_india_.pdf

Annex 4: Pest management decision guide for desert locusts

PEST MANAGEMENT DECISION GUIDE: GREEN AND YELLOW LIST

Desert locust management

Schistocerca gregaria

Prevention	Monitoring	Direct Control
• Identification and destruction of nymphal and gregarious stages in locust endemic locations/regions. • Spraying the first swath of migrating populations with recommended chemicals to prevent the resurgence/ outbreakof swarms. • Destruction of second generation of swarms from breeding and subsequently reduces the locust load for multiplication. • Taking a regional approach in controlling the adjacent country or region to prevent entry to one sown region or country.	• Survey for green vegetation, soil moisture and identify the areas prone/sensitive to locust. • Use of digital devices for recording and transmission of real time standard data to monitor locust movement across regions. • Use of Drones to survey inaccessible regions and to zero in on infestation and cover large areas to identify the vegetation prone to locust infestation. • Monitoring of Rain fall, soil moisture, & annual vegetation development by using remote sensing tools & technologies. • Use GIS to manage field data and analyse with remote sensing data to assess the current situation and predict the timing, scale, and location of breeding and migration. • Developing advanced simulation models that can predict locust plague, size, migration pathway and potential crop loss. • Active participation in SWAC meeting to share and know data on surveillance from other regions - Learning improved methods of surveillance and data share.	• Making loud noise by beating tins, plates etc., in cropped field or use of electronic system to prevent locust landing • Digging trenches to trap marching locust and bury, kill them • Igniting fire in front of marching locust band • Edible locust preparations • Collection and use as animal feed • Use of ULV of recommended insecticides as aerial spray • Mass multiplication of Metarhizium accidum and aerial spray on locust swarm • Spray of M. accidur on nymphs at breeding site • Use of predators and Parasitoids of Locusts • Spraying Entomopathogenic nematodes to kill emerging nymphs & nymphal band

Direct Control	Restrictions
Recommended for spraying on standing crop	
Chloropyriphos 20% & 50 % EC 240 g ai/ha	Moderately hazardous class II insecticide
Deltamethrin 2.8 % EC & 1.25 % ULV 12.5 ai/ha	Moderately hazardous class II insecticide
Difiubenzuron 25 % WP 60g ai/ha	Slightly hazardous class III insecticide
Fipronil 5 % SC & 2.92 % EC 6.25 g ai/ha	Moderately hazardous class II insecticide
Lambda cyhalothrin 5% EC & 10 % WP 20g ai/ha	Moderately hazardous class II insecticide
Malathion 50 % EC, 25% WP & 96 % ULV 925g ai/ha	Slightly hazardous class III insecticide
Recommended for spraying in desert area	
Fenvalerate 0.4% D 25 Kg/ha	Moderately hazardous class II insecticide
Malathion 5% DP 25 Kg/ha	Slightly hazardous class III insecticide
Quinolphos 1.5% DP 25 Kg/ha	Moderately hazardous class II insecticide

Annex 5: List of chemicals used for locust management

List of the Central Insecticide Board and Registration Committee India approved pesticides for control of the desert locust

A. Pesticides approved for control of the desert locust in scheduled desert area only

SI NO	Chemical	Dosage		
		a.i. (gms)/ha*	Formulations (gms/ml)/ha	Dilution in water
1	Malathion 96% ULV	925	1 000	NA
2	Malathion 5% DP	925	20 000	NA
3	Fenvalerate 0.4% DP	80 - 100	20 000 - 25 000	NA
4	Quinalphos 1.5% DP	375	25 000	NA

*grams of active ingredient per hectare

B. Pesticides approved for control of the desert locust on agricultural crops, acacia and other trees

SI NO	Chemical	Dosage			Dilution in water (ML/L)
		a.i. (gms)/ha*	Formulations (gms/ml)/ha	Dilution in water	
1	Chlorpyriphos 20% EC	240	1200	500	2.4
2	Chlorpyriphos 50% EC	240	500	500	1
3	Deltamethrin 2.8% EC	12.5	500	500	1
4	Deltamethrin 1.25% ULV	12.5	1 000	NA	NA
5	Diflubenzuron 25% WP	60**	240	Need based	-
6	Fipronil 5% SC	6.25	125	500	0.25
7	Fipronil 2.92% EC	6.25	220	500	0.45
8	Lambda-cyhalothrin 5% EC	20	400	500	1
9	Lambda-cyhalothrin 10% WP	20	200	500	0.5g
10	Malathion 50% EC	925	1 850	500	3.7
11	Malathion 25% WP	925	3 700	500	7.4g

Source: Directorate of Plant Protection Quarantine and Storage (PPQS), 2019, **Only for hopper control

Recommended list of insecticides for ULV spray against locust control in Pakistan

SI NO	Name of insecticide	Dose
1	Chlorpyrifos 40EC	5% solution
2	Deltamethrin	5% solution
3	Cypermethrin	5% solution
4	Fenpropathrin	5% solution
5	Lambda-cyhalothrin	5% solution
6	Bifenthrin	5% solution
7	Thiodicarb	5% solution
8	Carbaryl	1kg mixed in 25 kg sand

Source: Rehman, A. 2020

Contact information:

FAO Regional Office for Asia and the Pacific
FAO-RAP@fao.org
http://www.fao.org/asiapacific/en/

Food and Agriculture Organization of the United Nations
39 Phra Athit Road,
Bangkok 10200, Thailand

CC0147EN/1/05.22