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Review Article

Locust Attack: Managing and Control Strategies by the Government of Pakistan

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Abstract: During outbreaks of *Schistocerca gregaria*, the desert locust swarms, and plagues known to infest numerous regions across wide areas of Asia and Africa. The locust devours large amounts of crops and rangeland flora. Recently the locust outbreak began in June 2018 in Saudi Arabia's distant areas and entered in Pakistan March 2019, destroying main crops such as cotton, wheat, rice and maize in many districts across Baluchistan, Punjab, Sindh and Khyber Pakhtunkhwa provinces. On February 1, 2020, a national emergency was proclaimed, and the Plant Protection department countered by launching monitoring and prevention activities with the help of other institutions in Pakistan, as well as global and bilateral organizations. Surveillance and control activities were carried out with the majority of the insecticide formulations being oil-based ultra-low volume, nonconventional and green technology approaches. In addition, the Pakistani government devised a comprehensive phase wised management strategy as well as a National Locust Control Center with fast retort troops deployed in critical areas. Additional surveillance and control measures are needed to stop or alleviate desert locust-related agriculture damages. The unusual characteristics of the desert locust, as well as the size and frequency of swarming events, make developing and implementing IPM measures difficult. The state of prospective integrated measures to control locusts is discussed, as well as proactive and preventive intervention options.

Keywords: Crops, Damage, Locust, Management, Pakistan, Ultra-low volume

1. INTRODUCTION

Locust, *Schistocerca gregaria* (Orthoptera: Acrididae), outbreaks have recently ravaged agricultural and natural vegetation around the world, causing tremendous damage and jeopardizing food security [1]. Due to exceptionally heavy rainfall in desert locust habitats and a lack of surveillance, political disagreements, and poor accessibility of those habitats, huge desert locust plagues and swarms travel over the Arab World, Central Africa, India, and Pakistan. Despite technological advancements in locust monitoring, prediction and management measures, the threat and harm induced by locust pests are still prevalent, affecting hundreds of millions of human lives. Desert locust is the old transborder insect pest that destroys practically all fields and rangeland plants in wide parts of Asia and Africa [2].

The migratory pest undergoes 'phase change' from solitary withdrawal to sociable cluster behaviour in reaction to environmental conditions linked with extensive vegetation flushes that sustain considerably increased desert locusts numbers and densities become crowded when water becomes foliage fades and limited [3], a pheromone-modulated transition from locust's lonely phase to physically and behaviorally different sociable stage enabling grouping into nymphal bands and adult groups occur [4]. Gregarized desert locust occurrences have occurred intermittently during the previous two millennia, usually originating in known breeding regions the majority of the

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important breeding grounds are in isolated, rugged terrain which is frequently plagued by instability [3].

The 2003–2005 desert locust outbreak impacted more than eight million people in twenty countries [5] resulting in a projected yield loss of million $2.5 [1]. Pakistan lies within the geographical distribution of the desert locust, but the repercussions of locust activity there have not been documented in journalism until now. This study is to explain the timeline, feedback, and consequences of the latest locust outbreak caused in Pakistan, as well as food security threats and their further strategies to control locusts through their early approaches of IPM and green technology.

2. LIFE CYCLE

Grasshoppers are found in tropical, moderate grassland, and desert habitats and number around 10,000 species. Locusts are a category of 18–21 species that can fly across distant locations and are one of the first migratory pests to affect crops. Desert locusts (*S. gregaria*) are the most common locust species, with roughly ten subspecies found in Europe, Asia, Africa, and Arab countries [6]. These are the greatest and mainly dangerous insect groups when it comes to crops and food sources [7].

Locust is a major issue due to its capacity to traverse vast rang and quick grow populations, although the migratory locust, *Locusta migratoria* is the most common species [8]. Female locust life cycle ranges from 3 to 6 months and she can lay roughly 100 eggs every day. The larvae grow quickly, maturing in around 20 days [9]. Temperatures 25 - 32°C with humidity of 85-92 % and soil humidity of 15-18 % are ideal for locust growth [10]. Drought diminishes vegetative wrap, which shields the eggs until rainy circumstances are favorable for spawning [11]. The Supplementary Information contains more information about locust biology.

The enormous movement of locusts is triggered by changes in neurotransmitter serotonin levels [12]. Hyperpolarization suppresses the leg muscle fibers' post-synaptic potentials, weakening the depolarized excitatory post-synaptic response and enabling the locust to jump one hundred times its body length [13]. Locusts can fly constantly for over 10 hours a day, covering distances of approximately 150 km [14]. In comparison to other species, the

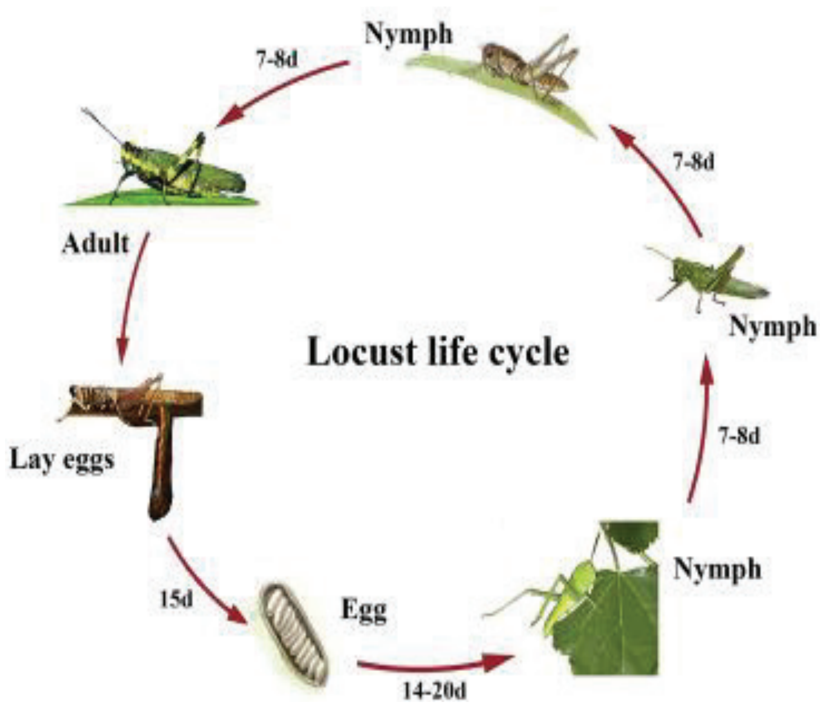

Fig. 1. Life cycle of locust

desert locust may replicate a single generation in less than a month, which is six times more rapid than other locust species [15]. The individuals can live up to three months, which, along with their rapid expansion, results in a 20-fold increase in population every generation [16].

3. SOUTH ASIA'S RECENT DESERT LOCUST ACTIVITY: A REGIONAL PERSPECTIVE

Asia encompasses Afghanistan, Bangladesh, India, Iran, Sri Lanka, and Pakistan as significant agricultural countries, with the majority of the people, engaged in subsistence agriculture [17]. The Thar Desert, along with the southern sections of the India–Pakistan border, is a prominent desert locust breeding location in Asia. Between 1947 and 2021, desert locust behavior along the India–Pakistan border was not constantly evaluated, and outbreaks were not managed [18]. From 2012 through the most current outbreak (2018–2021) in South Asia, a minimum of five noteworthy locust outbreaks occurred [19]. The latest upsurge originated in the Arabs' distant areas and arrived in Iran, Africa, and Yemen in June 2019, damaging millions of tons of crop production. Swarms of locusts infiltrated Pakistan from Iran and began breeding there due to favorable climatic circumstances [20-21]. The plague was the worst upsurge of locusts affecting many regions, during the years 2020–2021, the crisis in South Asia deepened affecting many countries including Pakistan [3].

4. DESERT LOCUST ACTIVITY IN PAKISTAN

Pakistan has been affected by significant desert locust swarms four times in the previous 100 years: 1926, 1952, 1962, and 1992 [22]. Due to conflicting needs, Pakistan's preparation worsened during the interval, as the 1992 attack happened 27 years until the latest incident. In the latest occurrence, Pakistan's Space and Upper Atmosphere Studies Commission identified locust susceptible zones based on plant communities, type of soil, history, or environmental circumstances [23]. About 36.9 % of Pakistan has been identified as being vulnerable to locust plague [24].

Swarms that formed in Saudi Arabia started spreading west over Africa, Yemen, and east to Iran by late 2018. Swarms had spread to Pakistan by March 2019, as well as Kenya and Uganda in East Africa [25]. By June, locusts had infested crop fields in different districts of Baluchistan in Pakistan [26] and had damaged cotton and other vegetable crops in different districts of Sindh Province. The damages and many crop losses have been occurred and reported in Punjab, Sindh, and Baluchistan [27]. The gregarious feeder's locust widens in different regions of Cholistan, Nara, and Thar deserts along the Pakistan-India border in mid of 2019, damaging 68,000 km^2 [28] and damaging 33 % of field crops [29]. Locust plagued different areas of the Korangi and Malir districts of Karachi [30]. Locust movements increased dramatically on the sides of desert borders during the May-June rains [31].

5. IMPACTS OF LOCUST DAMAGE

Crop damage by locusts compounded the negative consequences of two to three years of famine and an increasing situation of declining water supply [32]. In addition, the country has had 12 years of significant financial rise; the sugar price, such as, had increased, while wheat edible prices jumped 15% in 2020 [33]. Mangoes, potatoes, cotton, cumin, and fodder grasses were all hit hard by swarms [34]. In wheat, chickpea, and potatoes serious attacks and crop losses of about 15 percent occurred estimated at approximately US $1.2 billion [23].

During the winter season losses were estimated to be US $2.2 billion and US $2.9 billion for the Kharif season at a theoretical 25 percent damage [23]. Natural calamities and harsh environments, for example, famine, floods, and high saline soil afflicted the most susceptible areas, contributing to food insecurity. Due to harsh circumstances, the Khyber Pakhtunkhwa government declared agricultural emergencies in 35 districts [31]. To diminish agricultural dangers caused by locusts, a national emergency was stated on February 1, 2020 [1]. The National Disaster Management Authority of Pakistan recorded locust swarms in 61 districts across the country.

6. PAKISTAN'S GOVERNMENT ADOPTED STRATEGIES

To combat the current desert locust outbreak, Pakistan's government adopted proactive measures in coordination with the United Nations' Food and Agriculture Organization and neighboring nations' aid agency partners. In February 2020, Pakistan's cabinet approved a brief three-phased National Action Plan for locust management which comprises threat measurement scenarios and set up of surveillance and control efforts connected to dates of cultivation and the utilization of agricultural land [35]. Through surveillance and control, Phase 1 aims to restrict the intensity and growth of desert locust populations while extenuating human and ecological concerns. This entailed obtaining climate data in high-risk areas to enhance target control efforts. By April 26, 2020, 76.9 percent of Pakistan's land had been surveyed and 5.5 percent, had been implicated with pesticides [33].

During the second phase, which ran from July 2020 to December 2020, government make a strategy to protect crops that were connected to domestic and overall locust monitoring and control networks, providing instant aid to growers and livestock owners and strengthening national capability for advance caution and interference [35]. The Ministry of National Food Security and Research's power to control desert locusts was further bolstered by the improvement of Food Security and Nutrition Information [36].

During the 3rd phase, the government allocated $76.1 million of funds to the economic year 2021 to boost Pakistan's Project Management Unit's ability to plan accomplishments and surveillances to create desert-free regions from locusts, which began after December 2020 [36].

6.1 Chemical Measures

Most insecticides used in control activities were conventional synthetic insecticides, with accessibility, protection, cost-efficient, and environmentally compatible influencing insecticide selection and application timing [38]. Diflubenzuron, IGR is one of the most extensively used as a substitute for traditional pesticides as IGRs prevent arthropods from molting, and vertebrates are unaffected [39-40]. The majority of pesticides used against locusts were made with ultra-low volume oil-based formulations administered with special spray equipment [40].

6.2 Integrated Pest Management (IPM)

To accomplish ecologically friendly and long-term pest management, Pakistan's government created a National Integrated Pest Management Plan. While reducing or eliminating the danger of insecticide resistance is one of the aims of IPM [41]. Locust epidemics are infrequently enough already to prevent this. Desert locust resistance to any of the insecticides used against them in natural conditions has not been reported, so IPM will concentrate on facilitating effective interventions, locust control economics (including insecticide costs), and implementation of increasingly ecologically sound measures and pesticide manager and sprayer protection.

In Pakistan, no pesticides used to combat desert locusts are classified as class A (extremely hazardous) or class B (very dangerous), according to the WHO. If low-toxicity techniques are employed, human intoxication from eating sprayed locusts could be minimized as well. This may also help to decrease the accumulation of pesticide containers that are occasionally used to keep drinking water and eating food for humans and farm animals without being decontaminated [42].

Because of the particular nature of locust biology, upsurges, and management, a flexible solution based on IPM-compatible components is required, Although, biopesticides have been used to control swarming locust species in Pakistan and they have not been well assessed under outbreak settings in Somalia [43]. In comparison to typical synthetic pesticides, they are temporary and degrade as the temperature increases. Suspicions about human and environmental safety are another impediment to biopesticide application and many continents have uttered concern that entomopathogen isolates discovered in one locust-affected region will cause an exotic risk to other nearby countries.

The most promising and available method at the moment is intervention timing, which focuses on the early stages of gregarization. Extensive control in reproduction regions from a single pesticide treatment on foliage and crops is not a viable tactic because long-term, broad-spectrum organ chlorinated insecticides have wide residues in the environment and broad-spectrum in nature and have not been in use since the 1980s [3].

The intervention of low residual pesticides is planned with higher accuracy to provide early detection needing monitoring that is effective enough to identify the start of phase transition. As a result, monitoring technologies must be able to track desert locust activity across time, both during and between episodes. This entails analyzing geo-historical locust activity and control as well as using GIS imagery and meteorological data [44] to get an absolute understanding of propagation within Pakistan.

Integrations of locust density, food supply abundance, or clustering which can signify the start of gregarization in locust-favorable combinations, are likely to be used as intervention thresholds [45]. Further tools for detecting the onset of gregarious behaviour to timely intervention such as sensors for semiochemicals related to phase transformation in desert locusts, may be developed in the future [3]. Due to disparities between different environments, monitoring population density alone is unlikely to be sufficient for projecting gregarization [44].

Climate patterns determine rainfall levels, wind speed, and direction are markers that influence mating and swarms' migration, affecting early intervention thresholds. Although no effects on solitary desert locusts were observed, Pakistan could help from the study that revealed a swarm displacement cycle in Northwest Africa. According to a swarm displacement cycle study, soil dampness persistence in low-lying places after rainfall promotes the growth of green vegetation, which provides food for desert locusts. Phase transformation anticipation, which has improved control in Morocco [46] can be used in Pakistan, especially when synchronized with India. Other characteristics of spatiotemporal desert locust aggregation patterns will aid in the streamlining of surveillance efforts to trigger early action. Nymphal bands, for example, avoid particular plants and sleep in clumps on sparsely scattered trees and huge shrubs at dusk. Also, when temperatures rise over a certain threshold for flight, swarms of insects search for shelter in the covering interiors of small bushes but do not those rest in giant plants [47]. Such findings can be included in surveillance efforts in Pakistan aimed at establishing the best time to intervene early in the case of desert locusts.

6.3 Green Strategies

Hazardous pesticides should be replaced with green solutions in locust management since pesticides are harmful to human wellness and have longer consequences for wildlife habitats [48]. Microorganisms that are fungus and bacteria, for example, have been used successfully in combination with harmful plant species in innovative biological pest control [49]. Wasp larvae, mites, spiders, and birds, for example, can reduce epidemics by up to 90% by predating larvae and growing locusts [50].

It is critical to conserve these natural enemies' ecosystems and biotopes, for example, through tropical forests [51] which, when intercropped with late-growing crops like alfalfa and fruit trees are effective measures [52]. Additional effective mitigating measures include achieving more than 50 percent foliage coverage by using locust-toxic and wild plants in conjunction with animal husbandry feeding strategies [53]. Converting lowland areas into fishponds and shrimp farms as part of the landscape shapes a different viable way to manage locust upsurge [54]. Meanwhile, the burning of plants and lighting of bonfires in the dark are effective to control locusts [55-56].

Physical traps and optical and mechanical devices were used to limit plague outbreaks in risk-bearing areas. When combined with exact Bayesian prediction modeling, these traps provide a cost-effective and long-term solution [57]. Because locusts have phototaxy, stimulating them with specific light and sound wave lengths improves trapping by interacting with their eyesight and sound via glutamate and dopamine neurophysiology [58].

Remote sensing is also being used to predict locust eruptions based on habitat greenness, which seems to be a more viable approach than typical satellite and radar data [59]. These technologies are not fully developed in general, and they will require central government support before they can be used on a broad scale for management and cure [60]. Supplementary Information contains more information about locust control.

6.4 Future Strategies for Locusts Controlling

There are currently two methods for controlling desert locusts. The first, reaction, is a standard response to outbreaks, upsurges, and plagues that pose immediate threats to agricultural production. Pro-action is the recommended technique, which comprises intervening while outbreaks are in the early stages of development, reducing them before they become epidemics. Both techniques rely on synchronization, but the reaction is haphazard and not acknowledged as a well-thought-out strategy [61]. Pro-action on the other hand has decreased the number of important occurrences by remaining ready to combat gregarious locust populations, whether they arise inside or beyond the regions [62].

The best managing technique is prevention, which is intervening early enough to prevent epidemics from occurring in the first place. While there is no way to avoid outbreaks at this time, continuous study and coordination efforts could lead to the discovery of a way to keep locust populations in their lonely phase indefinitely. Preventive skills will require fully efficient collaboration at international, regional, domestic, and local dimensions to impose timely control in breeding areas [61]. Although the majority of major outbreaks have occurred outside of Pakistan [3] Pakistan must be ready to mobilize people and material resources to confront swarms from neighboring countries as well as epidemics in the deserts along the Pakistan-India border. The National Locust Control Center was formed during the most recent outbreak to collect statistics on desert locust activity, which affected more than 38 % of the country [63].

Increased precipitation in South Asia is expected as the seas and oceans warm which increases the incidence of Indian Ocean Dipole-influenced weather-related events around the world [64]. As a result, it is expected that the intensity and frequency of episodes to increase. These potential highlights the necessity for governments to work together on a global level to improve proactive interference [3]. Each locust-swarmed country must maintain desert locust management capabilities throughout recessions and possibly integrate effective control strategies to meet human and ecological safety concerns.

7. CONCLUSION

From 1912 to 2020, there have been seven significant locust outbreaks that have all been linked to prolonged droughts, mild winters, and the occurrence of substantial spring and summer precipitation. The agricultural industries, which are the cornerstone of national economies and social stability, are severely affected by the pandemic. To reduce outbreaks, environmentally friendly alternatives to hazardous pesticides must be developed. The utilization of microbes, insects, and birds in biological control approaches helps to manage outbreaks while minimizing the harm that pesticide use does to the environment and agriculture. Additionally, reforestation of arable land reduces local climatic changes, leading to reduced temperatures and less precipitation, while also attracting more birds, which raises the predation rates of locusts. Although green technologies like light and sound stimulation appear to be effective, they are difficult to use and require additional technological advancement, particularly the integration of remote and modeling, before they can be used on a large scale.

8. CONFLICT OF INTEREST

The authors declare no conflict on interest.

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