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Locust Control Management: Moving from Traditional to New Technologies – An Empirical Analysis

Anil Sharma[1,2]*

[1]Formerly Plant Protection Officer (Entomology), Locust Circle Office, Jalore (Rajasthan), India
[2]FAO-Trained Desert Locust Master Trainer for India, India

Abstract

The desert locust (*Schistocerca gregaria* Forskal) has caused great losses to agriculture in Africa, the Middle East and South West Asia. Their annual migrations take them downwind where winter, spring and summer rains fall for breeding. During the period 1863 to 1962 there were ten plagues in India and 18 upsurges from 1963 to 2012. Traditional desert locust control methods were used which were not successful. Newer technologies in the form of pesticides, ULV spraying, GPS, GIS tools, Satellite data imagery, RAMSES and elocust2 with the computers have been introduced for quick data management and analysis for planning desert locust control. The impact of newer technologies for locust control management in India for last 50 years has been successful. The South West Asia and the Middle East countries have taken responsibility for monitoring the breeding grounds and applying plague prevention strategy for desert locust control in the outbreak areas and by exchanging desert locust infestation information through FAO. The early prevention strategy for desert locust control has achieved its original objective of preventing damage to major agricultural zones in invasion area and helps protect the crops of small farmers as well as grazing grounds for the livestock.

Keywords: Desert locust; Locust control; Locust control management; new technology for locust control; Locust control in India

Introduction

Devastating locust invasions have been recognized as a major threat to agriculture and mankind since ancient times. The infestations of locusts which ravages vast areas of land under a variety of vegetation which affects wild plants, pastures, forests and cultivated plants at different stages vary greatly from year to year and from country to country resulting in heavy crop losses and also setting in motion a chain reaction with far reaching effects such as famine, disruption of trade, abandonment of cultivation, diversion of labour, heavy expenditure on control measures and so on.

Globally, about 64 countries representing 20% of land surface (approximately 30 million square kilometers) is subject to ravages of the desert locust during plague period. During recession when desert locust population occurs at low densities infestation is confined to 16 million square kilometers arid areas in 30 countries of North Africa, Middle East and Northwest India. These countries were subjected to periodical invasions of locust swarms which attacked almost all varieties of natural and cultivated vegetation often resulting in famines and immense economic losses. Locust invasions are dramatic, sudden, cover large areas in a short period and almost all green in their path is destroyed. It is the destructive potential which is dreaded as locusts come so suddenly in such large numbers and swarm across international boundaries and due to this reason locust invasion attract so much public attention and cause international concern. Locusts are invertebrate animals with highly migratory habits, marked polymorphism and voracious feeding behavior. They are able to take rapid advantage of the climate and geography can survive in temperature range from 0 degree to 60 degree and can speed up or slow down their life cycle.

Difference between locusts and grasshoppers

Both locusts and grasshoppers belong to the same family of insects known as Acrididae (legs unequal in size, antennae shorter than body, tarsi–3 jointed, auditory organs on the first abdominal segment, ovipositor short). Locusts differ from grasshoppers because they have the ability to change their behavior and physiology, in particular their color and shape (morphology) in response to changes in density. Adult locusts are capable of forming large migratory swarms which behave as a unit and may contain thousands of millions of individuals or the non-flying nymph or hopper stage which form bands. A band is a cohesive mass of hoppers that persists and moves as a unit. When the locusts exist as gregarious individuals then they migrate during day time in swarms containing many millions of individuals. When the locusts exist as solitary individuals then distinction between locust and grasshoppers breaks down completely. Thus locust is the name given to the swarming phase of short horned grasshoppers, some species of which under favorable climatic conditions congregate, move together as bands and swarm over long distances crossing over countries and continents rapidly stripping fields and enormously damaging crops. Some species swarm over short distances and are confined within a country to certain defined ecological zones. In general, most grasshoppers do not form bands or true swarms. The distinction between locusts and grasshoppers is not clear - cut since some of the latter do form bands (e.g. *Melanoplus, Acridoderes, Hieroglyphus* sp.) or small loose swarms (e.g. *Oedaleus senegalensis)*. Locusts such as the Tree locust have never been known to form bands.

The desert locust (*schistocerca gregaria* forskal)

The life cycle of the desert locust consists of three stages: egg, hopper and adult and duration of the life is 2-6 months on an average. The eggs

***Corresponding author:** Anil Sharma, Formerly Plant Protection Officer (Entomology), Locust Circle Office, Jalore (Rajasthan), India and FAO-Trained Desert Locust Master Trainer for India, India, Tel: 02925-222236; E-mail: anilsha2@rediffmail.com

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are laid by females in pods in the moist sandy soil at a depth of about 10 cms. Egg pods are laid at intervals of 7-10 days. Gregarious females usually lay 2-3 egg pods, each with about 60-80 eggs. Solitarious females mostly lay 3-4 times. Each pod contains 100-160 eggs. The rate of egg development is dependent upon soil temperature and moisture. There is no development below 15 degree centigrade. The period of incubation decreases from about 70 days at 19 degrees centigrade to 10-12 days at 32-35 degrees centigrade. Rates of egg development have been found to be characteristics of particular seasonal breeding areas and can be used to forecast dates of hatching. After completing the incubation period the eggs hatch and nymph (young ones) emerges. There are five instars in gregarious population and 5-6 instars in solitarious individuals. In each instar there is growth of nymph and the colour of the solitarious hopper is green throughout all instars but the gregarious hoppers have characteristic colouration of black and yellow. The rate of development of nymph is mainly dependent on temperature, from about 22 days under hot conditions (mean air temperature approx. 37 degrees Celsius) to over 70 days under cool conditions (mean air temperature approx. 22 degrees Celsius). Fifth instar hopper moults into the adult state. This change is called fledging and young adult is called a fledgling. After this there is no further moulting and the adult cannot grow in size but gradually increase in weight. Fledglings gradually become hard and able to fly. Locusts in this condition are called immature adults. The period of sexual maturity of adults is very variable. If conditions are suitable, the adults may mature in 3 weeks. More usually, however, they migrate downwind until they encounter favourable breeding conditions, which may be thousands of kilometers away. Under cool and/or dry conditions they may remain immature for as long as 8 months. Young immature gregarious adults are pink but old ones may become dark red or brown under cool condition. On maturation adults become bright yellow. Males mature before females but oviposition usually commences within two days of copulation.

The desert locust exhibit two distinct behavioral phases – the solitary phase – when individual actively avoid one another and – the gregarious phase – when they form marching hopper bands (mass aggregations of flightless nymphs) and swarms (adult aggregations with high mobility). Both these stages of gregarious phase, hopper bands and swarms are capable of devastating crops and pastures [1-3]. A series of complex interaction between high rainfall, high survival rates, the lush green vegetation and the behavior wherein there is an increase in the rate at which hairs on the back legs are touched by other locusts in a group is responsible for change from the solitary to gregarious phase [4]. The desert locust only migrate to invasion areas in the form of swarms once they begun to gregarise [5]. Dense groups that have strong cohesion among individuals migrate long distance together are swarms and their size may range from less than one to 300 sq miles. The biggest swarm recorded in India being 1200 sq miles. One sq mile of locust swarm may weigh about 150-200 tonnes and consumes 200 tonnes food daily. The swarms have been known to travel over 250 km in a day and as much as 4500 km in a month and may fly 2000 km at a stretch and at height of 7000 ft. and fly generally at the speed of 12-15 km per hour and on an average 9-12 hours per day, generally move into areas of low level convergence of winds (Inter Tropical Convergence Zone) and move down wind, fly during day time and settle by nightfall. En route mature ones settle on ground for breeding while those not yet mature fly on. A copulating and laying swarm usually stays in the same area for 3-4 days.

Solitarious adult occur at low density or individually, starts flying after dusk on warm evening and can migrate long distances during night. During day time they fly or flush only when disturbed and fly low, settle quickly, eats it own weight of food per day (about 2.5 gm) and are generally bigger than its gregarious counterparts. The desert locust has no fixed or static outbreak area where a swarming population can be observed and controlled, as in the case of the Red Locust and the African Migratory locust. On the contrary, the Desert locust is able to breed, when suitable conditions prevail, in any part of its distribution area. The desert locust is one of the most difficult insects to control on a national basis due to the vastness of its distribution area, pronounced adaptability to utilize wide range of environmental conditions, migratory nature and the potential ability of swarms to fly thousands of kilometers, and the speed at which they can move from one part to another. Thus the presence of swarms in any country is a threat to other countries, even though these countries may be thousands of kilometers away from the source of invasion. This fact calls for the importance of international cooperation in desert locust control.

As the desert locust belt is so vast and includes many countries and places that vary in many ecological, geographical and climatological aspects and in view to control this pest the International Conferences have divided the Desert Locust belt into following five regions and each region consist several countries having special desert locust cycles and movements. The activities between all these five regions are coordinated by the FAO. Its breeding seasons have also been demarcated. For example there is a particular cycle for the eastern region where movements of swarms occur in India, Pakistan, Iran and Afghanistan. There is also a cycle of this pest in East Africa, in North and West Africa and in the Arabian peninsula and the North East countries.

1. South West Asia Region—India, Pakistan, Iran and Afghanistan.
2. Near East Region—Iraq, Jordan, Kuwait, Lebanon, Saudi Arabia, Syria, turkey, Egypt, United Arab Republic, Bahrain, Yemen Arab Republic and the People's Republic of Southern Yemen.
3. East African Region—Ethiopia, Djibouti, Somali Republic, Sudan,Kenya, Tanzania and Uganda.
4. Northwestern African region—Algeria, Libya, Morocco and Tunisia.
5. West African Region—Chad, Dahomey, Cameroun, Gambia, Ivory Coast, Mali, Mauritania, Niger, Senegal and Upper Volta.

Main breeding seasons along with names of important areas are as under

I. Winter-breeding (November-December)

Coastal plain bordering the Red Sea and the Gulf of Aden, coast of South-East Arabia and the Mekran coast of Iran and Pakistan.

II. Spring breeding (January-June)

Western Sahara, Mauritania, South and Central Algeria, Libya, Chad, Red Sea and gulf of Aden coastal plain, South, Central, Eastern Arabia coastal plains and interior Afghanistan.

III. Summer breeding (July-October)

Southern fringes of Sahara extending from Mauritania to Sudan, the interior coastal area of Ethiopia and Southern Arabia, Mekran, Tharparker and Cholistan desert of Pakistan and desert areas of Rajasthan, Gujarat and Haryana in North West India.

Seasonal migration

Seasonal migration of the desert locust is influenced by the climatic factors such as temperature, wind and vegetation. Solitary locust fly at night for a few hours whereas the yellow gregarious swarms can fly for 12-15 hours in a day in warm weather and may settle just before or just after sun set depending on the availability of lush green vegetation on the ground. The height of the flying swarm is limited by the temperature and they fly between 1500 and 1800 meters above ground [6,7] (Figure 1). The desert locust adults and mature swarms use downwind air for their flight and in this manner these swarms travel great distances.

Recession, upsurges and plagues

Recessions are periods without widespread and heavy swarm infestations during which the species reverts to transiens and solitarious phases and these periods of recession may be regional.

Outbreaks occurs when areas become favourable for breeding due to good rains and lush green vegetation and the number and density of the desert locust population increase sufficiently to form bands and swarms.

Upsurges are periods in which a widespread and very large increase in locust numbers initiates contemporaneous outbreaks followed by two or more successive seasons of transiens-to-gregarious breeding that occupies an expanding area in complementary breeding areas in the same or neighbouring desert locust regions.

Plagues occur when wide spread infestations of swarms and hopper bands affect extensive areas and generate large numbers of reports during the same year and in each of several successive years [8,9] or in one or more years [10,11]. Outbreaks and upsurges form successive stages in the continuum of plague development [12-14].

There is no evidence of any regular periodicity in the onset of the plague. Plague may affect all major regions within the invasion area simultaneously or separately but because of the mobility of swarms no region remains permanently uninfected during a major plague. Major plagues arise as a result of rapid increase in numbers in recession population. Such increase occurs when wide-spread heavy and prolonged rains occur in several successive breeding areas. The Plagues are of varying duration and occur at irregular intervals, mostly depending upon meteorological conditions.

Traditional desert locust control methods

Often, individual farmers do nothing when faced with locusts or grasshoppers. But they also developed a variety of cultural and physical controls before the availability of chemical ones. Physical and cultural control methods continue to be practiced, alone or in combination with chemical control, especially against small infestations in crops or hopper bands near croplands. For example, some farmers combine the use of pesticides with fire, burning roosting locusts at night. The farmers dug trenches and herded hopper bands into deep trenches and buried them. Some traditional control methods are sometimes ineffective, e.g., plowing fields infested with pods. Most traditional controls have been replaced by the use of chemical insecticides. The first chemical treatment, used in India from the 1800s through the 1940s, was sodium fluo-silicate and sodium arsenate poisoned bait. Baiting could be done by unskilled labor, but buying, storing, and transporting tons of wheat bran for bait made these costly, remote breeding sites was missed, and sometimes the pests did not eat the bait.

In the 1940s and 1950s, first ground, and then aerial, spraying techniques were introduced and the persistent organo-chlorines BHC (benzene hexachloride) and dieldrin became the insecticides of choice. The BHC was first used for desert locust control in India in1949 and it became a popular desert locust killer. Spraying of aldrin insecticide against desert locust control by air was conducted in 1951. Due to shortage of water in the desert Exhaust Nozzle Sprayer was invented in which exhaust gases from the vehicle were used for atomizing the pesticide in fine droplets which was carried by the wind onto the target. In the 1960s, dieldrin was most often used against Desert Locust hopper bands and BHC against adult swarms. Initially, dieldrin and the other persistent pesticides seemed to be a major technological advance. Dieldrin, for example, remains toxic for 30 to 40 days on vegetation and longer in soil, despite rain or sun. Hopper bands were controlled

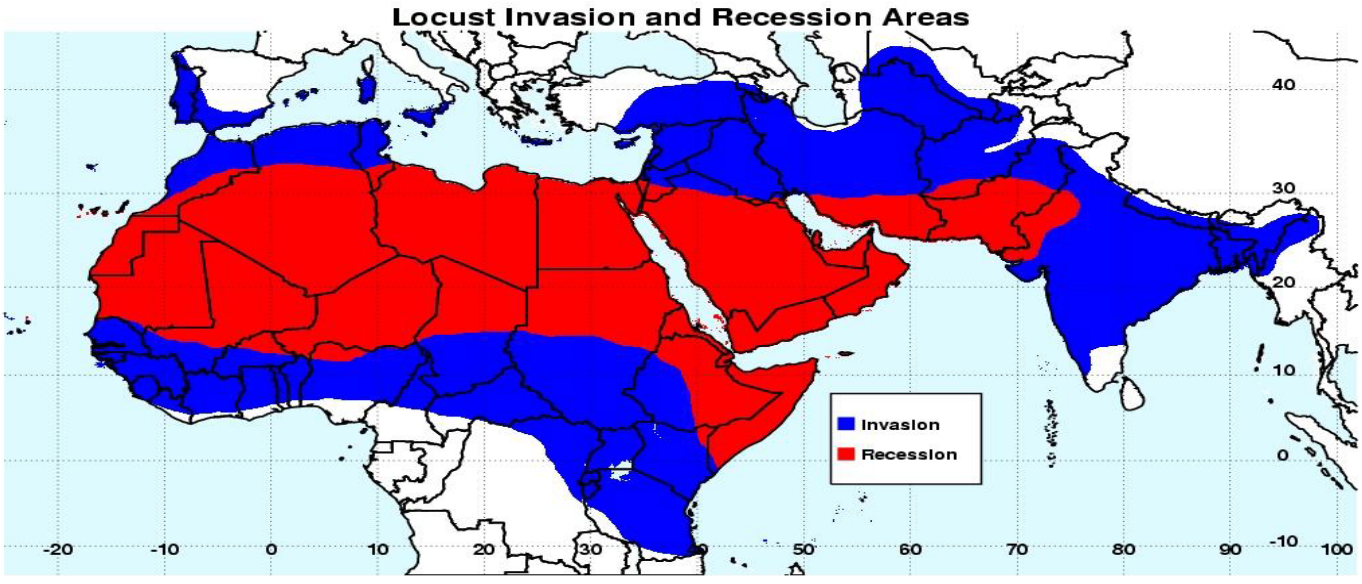

Figure 1: The invasion and recession areas of the Desert Locust (after Waloff, 1966).

by spraying swathes of vegetation with dieldrin, forming "barriers" in front of marching bands. Since dieldrin acts as a stomach poison that accumulates over time, the insects eventually ingested a lethal dose by eating treated vegetation. Low doses were effective and re spraying were unnecessary, even if a second hatching occurred. Concern mounted in the 1970s regarding the heavy use of persistent pesticides. DDT, the prototype persistent organo-chlorine, was banned by the United States in 1972. The United States cited dieldrin's carcinogenicity, bioaccumulation, hazards to wildlife, and other chronic effects and banned dieldrin in 1974.

The type of insecticides used in desert locust control programs has shifted markedly away from the persistent organo-chlorines such as dieldrin, BHC, aldrin, and lindane to organophosphates. The insecticides most commonly used now a day's for controlling desert locusts in India are fenitrothion and malathion .These organophosphates are principally contact insecticides with short residual action (2 to 3 days).

The sterile insect technique has successfully eradicated tse-tse fly from Zanzibar and successfully applied against a number of other fruit fly, moth and screwworm pests. This technology could not be applied for desert locust control due to the life cycle of the desert locust, its vast breeding ground areas and its ability to migrate long distances. The biopesticide developed from entomopathogenic fungus *Metarhizium acridum* used for desert locust particularly hopper control in Africa and Australia has not been used in India for locust control.

Some other methods which are used for control of the desert locust adult and hopper populations by the farmers are as follows:

1. Beating or trampling on the hoppers
2. Digging up egg pods or plowing fields infested with egg pods
3. Scattering straw over roosting sites and then burning it
4. Lighting fires or making noise to prevent swarms from settling in crops
5. Driving hoppers into trenches and burning, drowning, or crushing them
6. Use of flame throwers

New technologies

The turning point for acquiring newer technologies for desert locust control came in1993. This year saw large scale swarm incursions from the West which soon spread in many areas which were eventually controlled by dusting BHC on settled swarms and hopper bands in the field and by spraying liquid insecticides by air. The use of the BHC was banned in 1993. A technique using much smaller volumes of spray liquid, called ultra-low volume (ULV) spraying, was initially developed in the 1950s for use against the Desert Locust, and is now the most efficient and commonly used method. It is defined as applying between 0.5 - 5 liters of spray liquid per hectare, although between 0.5 and 1.0 litre per hectare is preferred for ULV locust control. This small quantity of concentrated insecticide is not mixed with water or any other liquid; the special formulation, known as a ULV (UL) formulation, is usually supplied ready to spray. In order to spread such small volumes over the target, the liquid must be broken up into small droplets light enough to be carried easily by the wind. To prevent these small droplets evaporating in the hot conditions that are typical during locust control operations, ULV formulation are based on oil rather than other solvents such as water or petrol fractions which may be too volatile, i.e. evaporate too quickly. These small droplets do not deposit (land on surfaces) very easily. They fall very slowly, so tend to be carried sideways by the wind rather than sedimenting (raining down) on to horizontal surfaces. In addition, if they are too small or the wind is too light, they tend to go around objects rather than hit them, somewhat like smoke. However, if the droplets are the right size and there is sufficient wind, they deposit by impaction on vertical surfaces such as vegetation or locusts.
Special sprayers are required for ULV spraying if the insecticide is to be used safely and efficiently. ULV sprayers can be carried by an operator (portable sprayer), mounted on a four-wheel drive vehicle (Vehicle-mounted sprayer) or on an aeroplane or helicopter (aircraft-mounted sprayer), The principle of use is the same for all of them, but the scale and speed of operation and certain practical limitations are different.

Currently desert locust infestations are sprayed with Ultra Low Volume (ULV) formulations of contact pesticides by using microULVA, ULVAmast and by Micronair AU 8115 sprayers on ground. The ULV spray technique is designed to spray overlapping swaths of small droplets of a concentrated pesticide formulation on to locusts at very low dose rates. The pesticide can be directly sprayed on bands with hand held sprayers if the infestations are small. Larger infestations are sprayed with vehicle mounted sprayers. The FAO provided Geographical Positioning System, installed RAMSES system with GIS tools on computer for quick data management and analysis by the national organization. The FAO also provided Satellite data imagery for planning the desert locust surveys according to the green vegetation availability in the field on a regular basis. The survey was made easier for the locust surveyor by the FAO by providing the e-locust2 equipment wherein the surveyor can send all the field data collected from the field itself to the national Headquarter for data analysis. Computers were provided for quick data analysis and transmission of the information with internet facilities.

Preventive desert loust control in Indian perspective

Plagues of the desert locust develop within a larger recession area that extends from Mauritania and southern Morocco eastwards through Arabia to the Rajasthan desert in India [8,15] and plagues continue to occur despite the implementation of the preventive control programmes since the 1960s. The aim of Uvarov's original plague prevention strategy was to avoid crop damage in the major agricultural areas of Africa, the Near East, Iran and Indo-Pakistan [16,17]. In this paper I shall discuss that for the past 50 years (1963-2012) desert locust control programs have achieved the original objective of preventing swarms from major cropping areas and that an early intervention strategy for the desert locust [18] should further reduce the duration and extent of plagues of this pest.

During upsurges substantial breeding gives rise to very large increases in both locust numbers and in the area infested. Swarms become sufficiently large and cohesive to reach the next seasonal area and breed successfully on the rains falling there. Early intervention is defined as destroying bands and swarms as soon as possible after first gregarization in order to reduce the total size of each subsequent generation with the ultimate aim of preventing plagues, or at least reducing their geographical extent and duration [19]. Field evidence indicates that control can destroy the final upsurge stage and preventing plagues from developing and expanding. No upsurge since 1964 has reached the full plague stage typical of earlier years. Successful plague prevention depends on timely control and an effective early warning system. Recent improvements at the national level include use of computers, GPS, GIS tools and e-locust2. The new products based on satellite imagery that can distinguish sparsely vegetated locust habitats from bare soil with reasonable reliability are transferred electronically

from FAO to national locust unit to plan surveys. The desert locust control has been effective due to changes in anti-locust techniques which is more effective and improved safety for operators, inhabitants, livestock and the environment.

Plague cycle in india

The attack of this pest used to occur in a sort of 'cycle' a period of 5-6 consecutive years of widespread breeding and swarm production and damage to crops, called the Plague period, followed by a period of 1-8 years of little activity called the Recession period, again to be followed by another spell of plague and so on. Since 1863, ten such locust plagues at intervals of 1-8 years have occurred in India.

Discussion

During pre-independence days, each of the princely States and Provinces in India had a different administrative set up of its own and it was not possible to put up a common front against locust. There was no coordinated policy or a central coordination organization to destroy locusts, though sporadic attempts were made in restricted areas in a few States or Provinces. There was no joint or concerted anti-locust action by all concerned and heavy losses to crops and other vegetation, leading or contributing to serious famines resulted. Following the Desert locust plague of 1926-31 the Imperial Council of Agricultural Research sponsored a scheme of research on the Desert locust in 1931. After the termination of the locust scheme in 1939, the Govt. of India established a permanent Locust Warning Organisation with a nucleus staff under the supervision of the then Imperial Entomologist to the Govt. of India. The main functions of the then Locust Warning Organisation were to survey the locust habitats in the desert, issue warning to the States likely to be affected by locusts and to assist them in carrying out control operation in the event of the locust attack. Locust control at that time was entirely the responsibility of the local governments even in the desert areas. In October 1946, with the establishment of the Directorate of Plant Protection, Quarantine and Storage under the Ministry of Agriculture, Government of India, at New Delhi, the Locust Warning Organization was strengthened.

The desert locust control management throughout the world was influenced by Uvarov's preventive control strategy of treating bands and swarms as soon as they formed in outbreak areas [20-22]. This strategy was adopted by India as it was helpful to avoid crop damage in agricultural areas. This strategy was first used for controlling the locusts in 1955-56 and bore good results. Encouraged with this and armed with new technological advancement in the form of new lethal pesticides, means of transport, better understanding of the life cycle of the desert locust and with the help of aircrafts for spraying the pesticides it was possible to control the desert locust and put an end to the plague cycle of 1959 to 1962. Ever since then the India is free from any desert locust infestation of the dimension of a plague population. Any development in locust population in the winter and / or spring breeding belts leads to the increase in the locust population in India being at the eastern end of the desert locust breeding belt. Routine monitoring surveys are a regular feature in India and the basic data needed for early warning that is collecting, transmitting and analyzing information on locusts, weather and habitat are now displayed in computer based geographical information systems. The e-locust2 equipment transmits the field data to the national headquarter from the field itself. Early intervention requires adequate and well trained staff to monitor locust populations continuously and to treat the bands and swarms rapidly whenever they are formed. India has got a national organization with survey and control responsibility with operational readiness and further manpower can be mobilized at a short notice for making the preventive control against desert locust a success. With further scientific advancements in the knowledge of the behaviour and biology of the Desert locust through research, finding out of more potent insecticides, formulation of better strategies and tactics as well as global cooperation and coordination brought out by agencies such as the Food and Agriculture Organisation of the United Nations and sincere and prompt national awareness of the gravity of the locust problem, it would be possible to keep this formidable and ancient pest at bay.

We have with us the details of the plagues occurring in India for the last 100 years from 1863 to 1962 (Table 1) and the duration of recession period. We also have the details of the desert locust upsurges data for the last 50 years from 1963 to 2012 also showing the years in which no infestation was recorded (Table 2). A comparison of the two tables brings to the fore following conclusions:

1. Only known poisonous chemicals were used for locust control in the form of baiting. This method was costly, laborious and not much effective.

2. Other methods such as plowing egg field, burning roosting locusts, driving the hoppers in trenches and burying or burning or drowning or trampling them or beating the drums, lighting fire to stop the locusts from settling had marginal effect on their control compared to the modern day technology.

3. Most of the countries were in the process of defining their boundaries (armed conflicts) and did not have a well maintained organization for desert locust control and early warning system.

4. To cap it all the two phases of the desert locust – the solitarious and the gregarious were thought to be two different pests as late as 1921 when Uvarov postulated phase change theory.

5. Information on desert locust migration was not made available to neighboring countries as most of them were not on good terms.

6. Most of the breeding grounds were inhabitable, inaccessible and unreachable.

7. Very little was known about the desert locust life cycle and it was considered as God's wrath. No appreciable research work was done during 1800 to 1925.

8. There were no good roads and means of transport were limited and land routes were not clearly defined in the desert and the possibility of lost in the desert was always there.

9. Many countries established National Locust Control Organisations to combat this menace once its life cycle was deciphered

Plague period	Recession period
1863-1867	3 years
1869- 1873	4 years
1876-1881	9 years
1889-1898	3 years
1900-1907	6 years
1912-1920	7 years
1926-1931	10 years
1940-1946	4 years
1949-1955	5 years
1959-1962	Recession continuing

Table 1: The duration of plagues in India during the last 100 years.

S.No.	Year	Locust infestation	Action taken	Remarks
1	1963	No infestation	Nil	Nil
2	1964	Upsurge	Control operations organized	Successfully controlled
3	1965	No infestation	Nil	Nil
4	1966	No infestation	Nil	Nil
5	1967	No infestation	Nil	Nil
6	1968	Upsurge	Control operations organized	Successfully controlled
7	1969	No infestation	Nil	Nil
8	1970	Upsurge	Control operations organized	Successfully controlled
9	1971	No infestation	Nil	Nil
10	1972	No infestation	Nil	Nil
11	1973	Upsurge	Control operations organized	Successfully controlled
12	1974	Upsurge	Control operations organized	Successfully controlled
13	1975	Upsurge	Control operations organized	Successfully controlled
14	1976	Upsurge	Control operations organized	Successfully controlled
15	1977	No infestation	Nil	Nil
16	1978	Upsurge	Control operations organized	Successfully controlled
17	1979	No infestation	Nil	Nil
18	1980	No infestation	Nil	Nil
19	1981	No infestation	Nil	Nil
20	1982	No infestation	Nil	Nil
21	1983	Upsurge	Control operations organized	Successfully controlled
22	1984	No infestation	Nil	Nil
23	1985	No infestation	Nil	Nil
24	1986	Upsurge	Control operations organized	Successfully controlled
25	1987	No infestation	Nil	Nil
26	1988	Upsurge	Control operations organized	Successfully controlled
27	1989	Upsurge	Control operations organized	Successfully controlled
28	1990	Upsurge	Control operations organized	Successfully controlled
29	1991	No infestation	Nil	Nil
30	1992	No infestation	Nil	Nil
31	1993	Upsurge	Control operations organized	Successfully controlled
32	1994	No infestation	Nil	Nil
33	1995	No infestation	Nil	Nil
34	1996	No infestation	Nil	Nil
35	1997	Upsurge	Control operations organized	Successfully controlled
36	1998	No infestation	Nil	Nil
37	1999	No infestation	Nil	Nil
38	2000	No infestation	Nil	Nil
39	2001	No infestation	Nil	Nil
40	2002	No infestation	Nil	Nil
41	2003	No infestation	Nil	Nil
42	2004	No infestation	Nil	Nil
43	2005	Upsurge	Control operations organized	Successfully controlled
44	2006	No infestation	Nil	Nil
45	2007	Upsurge	Control operations organized	Successfully controlled
46	2008	No infestation	Nil	Nil
47	2009	No infestation	Nil	Nil
48	2010	Upsurge	Control operations organized	Successfully controlled
49	2011	No infestation	Nil	Nil
50	2012	No infestation	Nil	Nil

Table 2: Year wise locust upsurge data of India from 1963 to 2012.

and actively helped each other by providing research data, pesticides and man power under the aegis of FAO since 1951. This along with the introduction of newer technologies as and when they became available helped reduce the losses caused by the desert locust worldwide and particularly in India.

10. During the last 50 years after the end of the plague cycle of 1959-1962 to 2012 there were 18 upsurges which were controlled successfully whereas in 32 years the desert locust population did not increase to such level as to warrant any control. This may be due to the change in the rainfall pattern, long drought periods and rise in the temperature range in the desert due to change in the climate and global warming effects.

11. It may also be noted that after the upsurge of 1978 the frequency of upsurges is declining and the period when the desert locust population

did not increase to such level as to warrant any control increasing from 1 year to seven years. The upsurges during 1986 to 1990, 1993 and in 1997 may have developed from swarm incursion from the west when the desert locust infestations were present in Middle East and African countries and that India lies on the last lag of Eastern breeding ground. These upsurges were promptly controlled by using organo-chlorine and organo-phosphate insecticides.

12. This increase in the period when the desert locust population did not increase to such level as to warrant any control increasing from 1 year to seven years is a good sign and it reflect that there exists a preventive desert locust control strategy in the countries of South West Asia and the countries of the Near East region and the countries are actively involved in its control. This has been made possible by the active role being played by Food and Agriculture Organisation of the United Nations by providing information on desert locust infestation in its monthly Desert Locust Bulletin. The information in the FAO Bulletin is used by the countries to plan their control strategy well in advance.

Conclusion

Now a day's developmental activity in the desert by the people for agricultural purpose is bound to reduce the desert area and thereby changing the ecology of the desert. The Indira Gandhi Nahar Project is aimed at bringing Himalayan water to the desert for agricultural purpose as the land is very fertile and farmers are getting good crop yields. It is expected that the desert locust will also adapt to new environment as it has done in past to survive in adverse conditions. Whatever it may be it is established in India that preventive control method encompassing early intervention for desert locust bands and swarms control is best suited to maximize agricultural production ,is economically viable and environment friendly due to less use of the pesticides. This has been made possible by the use of latest technological developments in the form of ULV spraying technique, GPS and GIS tools and e-locust2 with the active assistance from the FAO in the last fifty years as a member of Commission for controlling the desert locust in the South West Asia region (SWAC). Thus we see that the early prevention strategy has achieved its original objective of preventing damage to major agricultural zones in invasion area. This strategy has also reduced the size of upsurges and time for control thus helping to protect the crops of the small farmers on one hand and the grazing grounds for the livestock on the other.

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