Understanding Locust Plagues

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Massive crop losses due to pests have been a global problem for centuries, as demonstrated by the biblical example of the plagues of Egypt. Although today we are equipped with scientific knowledge which previous generations did not have, the problem is still far from being solved. Between 2001 and 2003 losses for different crops due to animal pests, pathogens and weeds varied from 50 to 80% across 19 regions worldwide [1]. Sixteen to eighteen percent of this loss was due to insect pests, despite the wide range of insecticides available [2]. This reality most significantly affects the poorest populations in the world where crop losses combined with unstable political situations often lead to malnutrition and famine. Even when these extreme manifestations do not occur it entrenches poverty.

> **"Solitarious locusts become behaviourally gregarious in just 2 to 4 hours"**

The desert locust *Schistocerca gregaria* is one of the insect pests contributing to this devastating crop loss problem. The semi-arid and arid deserts of Africa, the Near East, and South-West Asia are the natural habitats of the desert locusts. Although there is little agricultural land in these areas, once the swarms of locusts are formed they migrate to other regions, causing devastating agricultural losses. During locust plagues, desert locusts migrate to more fertile regions spreading over an enormous area of some 29 million square kilometres, extending over or into parts of up to 60 countries [3]. This is more than 20% of the total land surface of the world. Estimates for 8 countries of Africa and Near East alone has shown that for a ten year period (1987 to 1996) the total costs of desert locust management were around US $3.2 million in Yemen to US $129 million in Morocco [4, 5].

At present, the primary method of controlling desert locust swarms is with mainly organophosphate chemicals applied in small concentrated doses [6]. However, there are two major concerns against using these insecticides. Firstly, organophosphates are associated with many health problems, and many organophosphate pesticides have been banned or had their use severely restricted in many countries [7]. Despite this, their use persists in the developing world. Secondly, these insecticides not only kill target pest species, but also kill the natural enemies of those pests. This disturbs the natural ecosystem and paradoxically facilitates the entrenchment of the pest problem [8].

A better understanding of locust biology, especially the processes driving the extreme phenotypic changes leading to swarm formation, could potentially help to tackle these problems. Recent insights into the neurobiology of the desert locust, *Schistocerca gregaria*, are already helping to grasp what turns them from solitary and relatively innocuous insects into the active members of a destructive swarm.


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The first step towards the understanding of this process involved the identification of two radically distinct phases in *Schistocerca gregaria*: the solitarious phase and the gregarious phase. Research on this phenotypic phenomenon has shown that locusts in these distinct phases differ in behaviour, colour, morphometry (size and shape), endocrine physiology, reproductive development and fecundity [9]. Solitarious locusts show predominantly green or light brown coloration, are larger in size than gregarious locusts, their movements are slow and controlled, their reproductive cycle is slower than in gregarious locusts and they tend to avoid other locusts. By contrast, gregarious locusts are marked by primarily brown, yellow or black coloration, are highly active, have faster development and reproduction processes. Critically, gregarious locusts are attracted to each other and form coherent swarms. The identification of the two phases in the 1920s was a milestone in developing the understanding of how the locust swarms are formed and come to cause devastating crop losses.

Unsurprisingly, before the 1920s the two phases of the desert locust *Schistocerca gregaria* were classed as two separate species. It was not until 1921 that Boris Petrovitch Uvarov first formulated the phase theory of locusts and

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opened the door to the study of how locusts transition from one phase into the other [10]. Subsequent research showed that, although colour and morphometric changes develop slowly in locusts during their lifetimes and even over several generations, behavioural changes are much faster. In the presence of tactile, visual and olfactory stimuli from other locusts, solitarious locusts become behaviourally gregarious in just 2 to 4 hours – a very fast neurobiological overhaul that changes mutual repulsion to mutual attraction, increases the activity of the locusts and also changes their posture and gait. The mutual attraction in gregarious locusts sets in place the necessary conditions where group size can snowball as different bands of locusts coalesce into ever larger bands. This behaviourally self reinforcing cycle is hard to break. This is the major reason why only the life span of the locusts and the resources available can limit the duration of swarm existence. Another reason is the slow solitarisation rate. It is significantly slower than that of gregarisation – even after a week of isolation there is little change in acquired gregarious behaviour, and a high mortality rate is observed in isolated gregarious locusts.

Only in the last ten years have some neurochemical changes behind this process been identified. The juvenile hormone, which regulates the metamorphosis processes in many insects, was the first popular choice for research in locust phase change control. Although juvenile hormone was shown to be important in determining body size and colour in locusts, research in the 1990s and 2000s has shown that it does not play a significant role in behavioural changes [11]. The behavioural transformation is instead accompanied by changes in the levels of multiple neurotransmitters, neuromodulators and neurohormones within the central nervous system. Of particular importance was the finding that serotonin – a chemical compound which can act as a neurotransmitter or a neurohormone in a large array of organisms including humans – showed a very pronounced increase during the gregarization period in solitarious locusts [12]. Subsequently, serotonin was shown in 2009 to be a major factor driving the process of gregarization [13].

These discoveries place us closer towards understanding the mechanisms that drive swarm formation and give hope for the future – could serotonin receptors in locusts be a unique molecular target which could be manipulated to prevent the swarm formation? Or could further research lead to even more elegant and less expensive solutions to the problem of locust plagues? These questions are still to be answered. The global problems stemming from the crop loss incurred by locusts remain to be solved. On a positive note, there are organisations working to address the problem. Most significantly, the Locust Watch established by the Food and Agriculture Organization of the United Nations (FAO) coordinates desert locust control and works with other regional and national programme organizations that implement control measures [14]. Of course these measures are still limited, but the infrastructure for dealing with the problem exists and, hopefully, when better solutions arrive it will not take long to implement them. ■

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