

Article

New Technology for Desert Locust Control

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Abstract: Locust outbreaks usually begin in remote unpopulated areas following higher than average rainfall. The need to survey such areas has suggested that unmanned aerial vehicles (UAVs), often referred to as drones, might be a suitable means of surveying areas with suitable detection devices to survey areas and detect important locust concentrations. This would facilitate determining where sprays need to be applied at this early stage and would minimise the risk of swarms developing and migrating to feed on large areas of crops. Ideally, a drone could also spray groups of hoppers and adults at this stage. To date, tests have shown limitations in their use to apply sprays, although it has been suggested that using a fleet of drones might be possible. The use of biopesticide in these areas has the advantage of being more environmentally acceptable as the spray has no adverse impact on birds.

Keywords: locust; drone; unmanned aerial vehicle; early warning; preventive control; biopesticide



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1. Introduction

Since biblical times, vast numbers of desert locusts (*Schistocerca gregaria* Forskål, 1775) have periodically increased to such an extent that the plagues cause extensive damage to major crops. Locust upsurges occur infrequently and during a recession period, international organisations have not prioritized research, nor have governments in countries subject to locust plagues maintained in-country research, due to years of under-funding, so they are not prepared for locust surveillance and the control of locust swarms when they do occur.

Over the last 60 years, the onset of a plague has been detected at an early stage, but in 2019, the early onset of locusts was following cyclones in 2018 which resulted in heavy rain in the inhospitable deserts of Arabia. This allowed locusts to breed unseen in the wet sands. Strong winds in 2019 blew the growing swarms into the Yemen where they were undetected as the country was beset with a war.

Initially, the solitary insects typically occur at low densities across a recession area, but following a period of good rainfall, the locusts thrived and soon aggregated and formed swarms, which spread both eastwards to Iran, India and Pakistan, and westwards to East Africa, with Kenya experiencing its worst outbreak in 70 years. Back in the 1950s, despite vast areas being invaded by swarms, it was possible to use aircraft to spray insecticides, including dieldrin to protect crops and eventually reduce the plague [1] (Figure 1). Dieldrin was used to kill hopper bands that crossed barrier strips and as a very low dose in very fine sprays to kill swarms of desert locust. However, due to increased concern over persistent insecticides affecting non-target species, the use of dieldrin was banned at meeting organised by FAO in 1988 [2]. Following this meeting, the FAO Pesticide Referee Group was established to advise which insecticides could be used. At the same time, CABI organised the international LUBILOSA Programme project, which led to the production of a biopesticide, based on *Metarhizium acridum*, to control locusts. This major development provides control of locusts that does not harm people or the environment [3,4]. Today, we need to bring together new technology to improve the detection of locusts in remote areas and use biopesticide to control locusts before populations build up and swarms invade extensive farming areas. Once swarms arrive in new areas, the control

of adult locusts is rapidly needed before crop damage occurs. Biopesticide acts slowly so insecticides that can achieve high mortality within 24 h are needed. Nevertheless, the least hazardous insecticides should be selected in terms of mammalian toxicity and environmental protection.

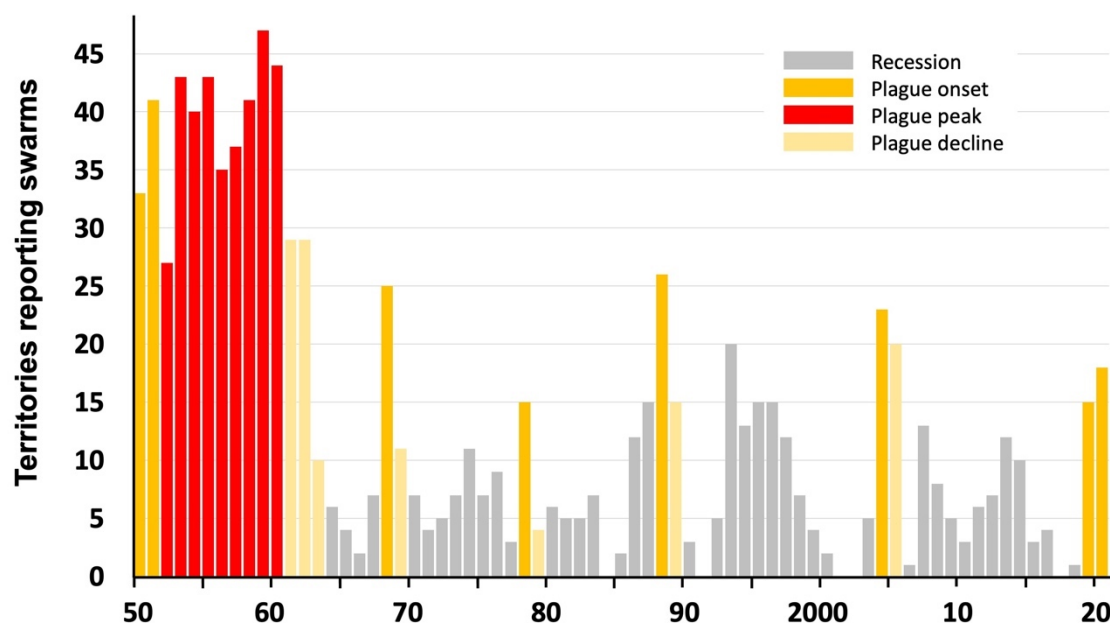


Figure 1. The number of countries in which desert locusts were detected since 1950, with fewer countries having an onset of major desert locust activity (i.e., major upsurges and plagues) since 1965. Control has been achieved sufficiently early to avoid a major plague, but in 2019/20 the locusts spread without early detection (updated from [5,6]).

2. The Initial Signs of a New Upsurge

During a recession, locusts survive in small numbers as solitary insects in arid areas in sparsely populated areas from the Atlantic Ocean to Northwest India, but particularly in the Middle East. After a period of above average rainfall that provides the vegetation, the locust population in these areas can increase rapidly, which translates into spectacular hopper band movements and swarms which migrate. Using phenomenological models using gridded monthly data, Tratalos et al. [7] suggested that desert locust dynamics are influenced by endogenous factors and rainfall, and that broad patterns of locust upsurges and declines can be forecast with some degree of success using data on only these factors.

Locust monitoring has relied on ground-based surveys, which have required individual searches in areas with a history of locust activity, albeit at long and irregular intervals to notify the national locust control units and share the information with neighbouring countries and international agencies [8]. As the population increases, and desert locusts often aggregate to lay eggs, and as they are extremely sensitive to density changes, this rapidly triggers their phase transformation, resulting in their movement in swarms to new areas. The phase transition is a continuous, cumulative, and easily reversible process that can take place within a short period (from 4 h to 32 h) in the desert locust [9,10]. Studies in China have indicated the presence of an aggregation pheromone in the migratory locust, *Locusta migratoria* (Linnaeus, 1758) [11], but as Voss hall [12] discusses, it is not clear whether pheromone traps could assist in detecting the presence of locusts, or whether a chemical could be found to block the receptor to prevent aggregation. The latter may not be desirable as it would not reduce locust populations but rather disperse large numbers of locusts over even larger areas, making the control of locust concentrations nearly impossible.

3. Detecting Where the Locusts Can Be Found after a Recession Period

Satellite imagery has been used for finding and mapping emerging vegetation in the desert. Data collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra Satellite and the Normalized Difference Vegetation Index (NDVI) are measures of the health and greenness of vegetation based on how much red and near-infrared light is reflected. According to Tratalos and Cheke [13], there is evidence of a positive relationship between NDVI and the presence of grasshopper populations, probably because grasshoppers were found in areas with higher rainfall. This helps to monitor and forecast the desert locust [14] by assessing whether the ecological conditions are favourable to locust survival, breeding, and gregarization, but needs to be accompanied by thorough observations on the ground for making decisions regarding control interventions against the initial locust congregations. This significantly reduces the costs and contributes towards changing the paradigm of locust control from curative to preventive [15]. According to FAO, current satellites can provide continuous estimates of rain-producing clouds and ecological conditions, such as vegetation development and soil moisture, which are important factors for monitoring desert locust habitats and forecasting locust development. Related to soil moisture, observed differences in grass abundance and size contribute to locust gregarization [16]. The temporal, spectral and spatial characteristics of the sensor instruments onboard these earth observation satellites provide a wide range of sensing capabilities [17].

In 2018, the FAO initiated trials with a long-range fixed-wing drone to examine areas where locusts could be present by mapping areas of green annual vegetation. Ideally, the drone needs a range of at least 100 km or more and should be solar powered. Searching vegetation is possible with lightweight multispectral sensors with near-infrared (NIR) and/or red-edge bands, as well as hyperspectral sensors that provide spectral separability [18]. For locust work, the drone initially needs to detect green vegetation by flying at optimal heights to obtain imagery that can be processed easily and rapidly in the field, so the team can decide where to intensify survey efforts, again with the drone, to detect locust concentrations using optical images that could warrant control [19,20]. The drones need to be easy to operate both manually and automatically, as well as be robust, affordable and simple to maintain locally in locust-affected countries. As a result of three years of trials and refinement, the dLocust drone developed by HEMAV (Figure 2) became available for use in locust-affected countries in 2020 [21]. Imagery is processed in-flight so that when dLocust completes its long-distance survey, the results are immediately available and handed over to the eLocust3 tablet used by field teams for recording and transmitting survey and control data in real time [22,23]. In this way, the team does not need to carry an additional computer to the field. The eLocust3 tablet was also used to plan the dLocust flight and operate the drone. Using drones for surveillance with appropriate detection equipment will enable larger areas to be surveyed in contrast to using ground teams which may only be able to survey limited accessible areas.

Small multi-rotor drones with propellers positioned parallel to the ground may provide a more stable flight and vertical take-off ability, but these are liable to damage from flying locusts. At present, small drones are restricted to carry a limited quantity of spray (only 10 kg) and have a limited endurance of around 10–15 min productivity for locust control, due their small size and limited battery life. The drones need to be easy to control both manually and automatically, as well as be robust, affordable and easy to maintain locally in locust-affected countries.



Figure 2. Fixed wing drone for desert locust monitoring (source: FAO [24]).

4. Applying the Biopesticide in Remote Areas at the Initial Stage of Hopper Development

Studies have been carried out in West Africa to establish the importance of using the biopesticide known as “Green Muscle®”, and based on the entomopathogenic fungus *Metarhizium acridum* [25,26]. The storage methods for fungi would be as dry conidia, perhaps with clay diluents, or in oils [27]. The LUBILOS project focused on developing an oil formulation [28] suitable for ultra-low volume (ULV) application, a technique already well established for locust control. Early studies in South Africa in trials against Vth instar Brown locusts (*Locustana pardalina* Walker, 1870) used a large micro-light aircraft fitted with Micronair AU7000 atomisers to apply *Metarhizium flavoviride* isolate IMI 330189. Dry conidial powder was formulated in a paraffinic oil to apply approximately 2.0×10^{12} conidia per hectare with volume application rates of 1.0 and 2.5 L/ha with the atomiser blades set at three angles (25, 35 and 45°). Up to 98% mortality was obtained where locusts were in open top field enclosures, with the 2.5 L/ha apparently obtaining more consistent results [29]. As pointed out by Bateman [30], the key problems for further research and development would be the logistics and supply of consistently reliable formulations for application at a large scale, and the determination of mechanisms for effective dose transfer in the field. Since the development of the mycopesticide known as “Green Guard®”, more than 100,000 ha have been treated with the FI-985 isolate of the fungus *Metarhizium anisoplae* var. *acridum*, since operational use began in Australia in 2000 [31].

At present, attempts to control locusts have been limited to using ground equipment with hand-carried spinning disc sprayers or using truck mounted equipment. Developments with ground equipment now include a ground positioning system (GPS) on truck-mounted sprayers to provide precision while applying ULV insecticide sprays along parallel tracks whilst also recording the position of the sprayer so that a record of the treatment is obtained and analysed.

The biopesticide, now marketed as Novacrid[®] from Elephant Vert (isolate EVCH077 of *Metarhizium acridum*), is a dry powder supplied in sachets, which is mixed with an appropriate oil before application at ULV rates of 1 L/ha and 0.5 L/ha. Oil formulations were tested in a range of commonly used spinning-disk sprayers, including the hand-held Micron Ulva-Plus and vehicle-mounted Ulva-Mast [3].

The enormous advantage of using the biopesticide for locust control is that it lacks adverse side-effects on biodiversity. In a study in Niger, Green Muscle[®] was sprayed operationally, using 107 g viable conidia per hectare, where the population of adult locusts, birds and vegetation greenness were previously simultaneously assessed along two transects from 12 days until 23 days after treatment [32]. Locusts started dying five days post-spray and the biopesticide reached its maximum effect one–two weeks after the spray, with 80% efficacy at day 21. After spraying, kestrels took significantly more of the larger female (75–80%) than smaller male (20–25%) locusts. This indicated that avian predation increased the impact of the biopesticide by removing more of the adult female locusts. No direct or indirect adverse side-effects were observed on non-target organisms including locust predators, such as ants and birds.

Where areas are accessible, ground equipment can spray up to 300 ha a day at a fraction of the cost and logistical effort. Similarly, aircraft can spray large areas at relatively low cost, but substantial logistics are required to support aerial operations.

Using a drone at present requires a trained operator, transportation for the drone with the spray formulation, an engine-powered generator and fuel for recharging the batteries. Drone battery technologies are expensive, and the number of charges is limited with existing technologies to less than an estimated 500 charges or only 75 h actual spraying before new batteries are required. Clearly, more research and development are needed to determine the most effective design, and operating procedures are needed to facilitate the control of hoppers prior to the expansion of the locust reaching plague status, with appropriate guidance and standard operating procedures (SOPs) for training to enable drones to be used effectively in certain situations to minimise the formation of swarms.

At present, there is little information available on how to treat desert locusts with drones in a safe and effective way. Solid scientific-based field testing is required. From there, guidelines and standard operating procedures (SOPs) can be developed, and training provided before using drones. The FAO is clear that these are very important steps that cannot be omitted.

5. Current Trials

5.1. Kenya

Drones were tentatively used in 2020 to determine whether their use would be effective. In Kenya, the main focus was to target hoppers and roosting locusts with better efficiency to develop SOPs for the optimal use of the technology. A DJI Agras T16 drone, fitted with a 16 L tank, six rotors, and programmed for operation in Auto and manual modes, was used to treat a 6.5 m swath applying 4.8 L/minute and treat 10 hectares. According to the manufacturer, the drone was fitted with either XR11001VS or XR110015VS fan nozzles which can apply 3.6 to 4.8 L/min, respectively.

The drone (Figure 3) can be operated at up to 3 km at a flight altitude of 2.5 m from the operator and spray at a maximum operational flight speed of 7 m/s. There were 16 nozzles operating from the height of 2.5 m above the canopy, so the drones automatically adjusted to maintain this height. As per the manual, the pilot controls the flight and the volume sprayed. The intention was to spray as per the recommendation on the pesticide label, so various flight parameters to determine which one results closest to the recommended dosage were tried with different heights and flying speeds.



Figure 3. Drone spraying locusts in trees in Kenya (source: CABI [33]).

5.2. India

The operation of drones was examined by deploying them initially for spot application, including high trees, dense plantation and inaccessible areas in association with ground control teams for effective control operation. Fifteen drones were each equipped with a 10 L tank and supplied with eight batteries so that 1 hectare could be treated in 15 min, and a drone could cover 12–15 hectares during a day. Flat fan nozzles were used for spraying a mixture of two insecticides, supplied as per EC formulations. They contained 5% lambdacyhalothrin and 2.8% deltamethrin. Insecticide in the range of 100–120 mL was mixed with 10 L of water. A total of 1753 L of the mixture was applied using 15 drones over 60 days, covering 7017 hectares in a total of 2007 h.

The flight height was 12.2–13.7 m. Flying speed depended on whether the target was in a tree or in fields and ranged from 10 to 20 km/h. Swath width depended on wind speed and ranged from 1 to 5 m. The volume of spray applied was 10 L per ha. The mortality of locusts was between 50 and 90% at various locust stages.

No ULV formulations were sprayed and no ULV nozzles were used in drone spraying, but if used, the area coverage would increase 10 times.

The overall indications to date are that:

- (a) The small multi-copter drones do not have an adequate lifting and endurance capacity to treat more than a small area;
- (b) Most have hydraulic pressure nozzles that spray too high a volume so the area that can be treated is very limited. The power requirement to pump the volume of water would be better deployed by using ULV sprays applied with a rotary atomiser;
- (c) Even when applying a ULV spray with rotary atomisers, the small payload (10–15 kg) carried by drones limits the area that can be treated with significantly higher operating costs than existing ground sprayers. Spraying small areas of trees on which locusts can be resting is one example as the target is not easily accessible with ground equipment;

- (d) Most commercial drones are not designed for ULV products, as pumps, hoses and plastic materials are not compatible with the formulations being used;
- (e) There is a question over durability in desert environments with sand and dust drawn across exposed electric motors from multi-rotor types;
- (f) Battery cost and operating costs are high with limited duty cycle—400 × before they need to be changed;
- (g) A larger payload drone (100 kg+) may offer better potential to fill the gap between using ground equipment and manned aircraft.

Ideally, locusts are controlled by the aerial application of ultra-low volume (ULV) sprays from c. 10 m height applied at one litre per hectare, using a spray with droplets of 120 µm volume median diameter (VMD) [34], while smaller droplets using 70–100 µm VMD sprays are applied with ground equipment. A narrower and more effective droplet spectrum is provided by rotary atomisation.

6. Conclusions

At present, the main use of drones will be to improve the surveillance of remote areas where locust populations can increase following more intense rainfall, especially when improvements in the effectiveness of deep learning and computer vision algorithms facilitate the efficiency of spotting the build-up of locusts to form swarms so that appropriate measures can be taken sooner [35]. Further research is needed to examine the effectiveness of drones which carry an increased payload of spray and are equipped with rotary nozzles to apply ultra-low volume sprays in remote areas and extend surveillance over larger areas, but also target sprays at hoppers to reduce the development of swarms. Where swarms have invaded new territories, rapid action insecticides applied as ULV sprays will continue to be needed. With concerns over climate change, surveillance and the ability to minimise the formation of swarms will be more important. In addition, in war or insecurity zones, any control of locusts will remain difficult and realistic mitigation measures will need to be carefully designed and implemented [36].

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Conflicts of Interest: The author declares no conflict of interest.

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Graham A. Matthews is a Professor Emeritus at Imperial College, Silwood Park (UK). His research within the International Pesticide Application Centre (IPARC) was on the application of pesticide technology, involving testing equipment suitable for vector control for the WHO and on applying pesticides for crop protection. Early in his career, he was involved in cotton pest research in Africa. Prof. G.A. Matthews was a member of the Pesticide Advisory Committee of the UK Department for Environment, Food and Rural Affairs from 2000 to 2004, and Chairman of the FAO Expert Panel on Locust Pesticides from 1989 to 2015. He is the author of numerous publications and books, including *Pesticide Application Methods* in 1979, now in its fourth edition, and most recently *Pesticides, Health, Safety and the Environment* (second edition—2016) and a *History of Pesticides* (2018).