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Desert locust (*Schistocerca gregaria, Forskl*) distribution, biology, management and its impact on agricultural production in Ethiopia: A review

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Abstract
Desert locust (*Schistocerca gregaria, Forskl*) is considered to be one of the most serious pests that cause a devastating amount of damage to crops and other agricultural products during the invasion. It is considered as the most dangerous migratory pest among the locust species because of its ability to reproduce rapidly, migrate long distances and devastate crops. Desert Locust has the largest distribution area, which extends from West Africa through the Middle East to East Asia. Eastern Africa has seen an upsurge of Desert locusts, spreading across several countries at rates not seen in decades. The consequences of Desert locust invasions can be disastrous for both the food security and livelihoods of the rural populations in affected areas. The invasions can result in the abandoning of crops and rural migrations. Damage can be considerable on all types of crops: annual rain-fed crops as well as perennial crops, tree cultivation, and irrigated crops which are even more sensitive since they are exposed throughout the year. Desert locusts invaded major areas in the Somali, Afar, Oromiya, Tigray and Amhara regions of Ethiopia regularly. The swarms of Desert locust also moved south across the Shebelle River in southeastern Ethiopia into the Juba River basin. Despite the recent and further possible Desert locust invasion in Ethiopia, there are no more systematic reviews conducted to assess the details on the invasion, impact on crop production and its possible control measures. Therefore the objective of this review is to highlight the invasion, Ecology, Biology, impact on crop production and control measures of Desert locusts.

Keywords: Control, Crop, invasion, locust**,** pest

1. Introduction

Locusts are a group of different species of short-horned grasshoppers belonging to the family Acrididae (Order: Orthoptera). These are a special type of grasshoppers having the capacity of changing their habits and behavior when in large numbers and are regarded as a major threat to agriculture from the beginning of human civilization (Joshi *et al,*) [1]. Locusts are generally differentiated from grasshoppers with their swarm-forming ability, body shape, size and color-changing morphological characteristics (Cymons and Cresman 2001) [2]. The Desert locust *(Schistocerca gregaria, Forskl)* is considered to be one of the most serious pests causing a devastating amount of damage to crops and other agricultural products during their invasions.

It has the largest distribution area, which extends from West Africa through the Middle East to East Asia (Abdela, 2004) [3]. Since 2019, Eastern Africa has seen an upsurge of desert locusts, spreading across several countries at rates not seen in decades. At the end of 2020, the situation was still critical in the whole region (ECPHAO, 2021) [4]. It is considered as the most dangerous migratory pest among the locust species because of its ability to reproduce rapidly, migrate long distances and devastate crops. Swarms of Desert locust can fly large distances up to 150 km in the directin of wind containing a group of millions and billions of individuals (Zhang *et al,*) [5].

The Desert locust lives in arid and semi-arid desert habitats, living solitarily when the climatic conditions are not suitable for breeding. Its geographical range varies from a recession area of 16 million km² covering more than 25 countries, when locust densities are low, to an invasion area of 29 million km² covering over 65 countries when locust densities are high (Vanderworf *et al*, 2004) [6].

This is more than 20% of the total land surface of the world. During plagues, the locust population increases in size and invades vast areas and more than 60 countries in Africa and Asia are affected at different degrees of infestation during the plague development, which normally occurs due to consecutive generations of successful breeding followed by favorabl sequences of heavy and widespread rainfall (Dutta *et al*, 2004) [7].

The consequences of Desert locust invasions can be disastrous for both the food security and livelihoods of the rural populations in affected areas. The risk of new infestations and continuous breeding could limit food and fodder availability. The likelihood of an impact on vulnerable households will remain high due to rising food prices. Damage can be considerable on all types of crops: annual rain-fed crops as well as perennial crops, tree cultivation and irrigated crops which are even more sensitive since they are exposed throughout the year (Cresman, 2016) [8] The invasions can result in the abandoning of crops and rural migrations. Pastorals zones are also subject to major destruction, affecting both total biomass production and its palatability for livestock.

Control campaigns commonly cost many millions of dollars and the large amounts of chemical insecticides used can have serious side effects on the environment. Desert locust control has made progress through better knowledge of their biology and ecology, more efficient monitoring, and more environmentally sound control strategies and with the development of biological products and the increasing use of high-level technologies such as satellite imagery and geographic information systems (Hasanali *et al*, 2005) [9].

In December 2020 and January 2021, Desert locust swarms migrated from breeding areas in eastern Ethiopia and central Somalia to southern Ethiopia and northern and central Kenya, according to (FAO, 2021) [10]. Desert locusts invaded mjor areas in Somali, Afar, Oromiyaya, Tigray and Amhara regions of Ethiopia regularly. Locust swarms also moved south across the Shebelle River in southeastern Ethiopia into the Juba River basin, subsequently crossing into prime rangeland for pastoral households' livestock in northern Kenya. Despite the recent and further possible Desert locust invasion in Ethiopia, there is no systematic review conducted to assess the details of the invasion, its impact on crop production and its possible control measures. Therefore the general objective of this review is to assess the invasion, Biology, impact on crop production and its control measures for Desert locust.

2. Literature review

2.1 Desert Locust Distribution

The Desert Locust is one of about a dozen species of short horned grasshoppers that can form adult swarms or, bands of wingless nymphs called hoppers. (Ibrahim *et al*, 200) [46]. The total area subject to invasion by Desert Locust swarms is the greatest known among all locusts, and cover the whole of west and north Africa, Eastern Africa, all countries of the Middle East up to Turkey and the southern of most Soviet Republics, Iran, Afghanistan, Pakistan and the northern half of India (Uvarove, 1955)[12]. Desert Locust have been record in the Atlantic Ocean (In 1989 the swarm reached the Caribean and the northern part of south America) the British Isles, the Mediterranean, Italy, Greace, the Red Sea, the Gulf of Aden, the Arabian Sea and Arabian Gulf (Meinzingen, 1993) [13].

2.2 The Economic Importance of the Desert Locust

Desert locust invasions normally cause great loss to the crops and pastures in a number of affected countries. They feed on a very wide range of plants, and there are four factors, which mainly contribute to its status as a major pest: the food intake per individual, the range of food plant and parts eaten, the frequency of occurrence of high-density population and the mobility of the population (Suliman, 2005) [45]. The largest invasion during the last 15 years occurred in 2004, in north and West Africa and it affected a number of countries in the fertile regions of the continent. In Sudan, particularly in Kordofan State, around 55% of the food crops were damaged during the 1987-1988 plague (Ibrahim, 2006) [15].

The largest crop losses occur when young migrating swarms of immature adults reach cultivated areas. They need to eat at least their own weight (2- 3 g) of fresh vegetation each day and possibly three times as much (Cecato *et al*, 2007) [16]. As swarms contain 50 million individuals per square kilometre, even a moderate size swarm measuring 10 km^2 could eat some 1000 tonnes of fresh green vegetation daily (DAFF, 2011) [17].

2.3 Desert Locust Ecology

The Desert Locust has the widest distribution among all the species and may invade millions of square miles though not all at the same time. The invasion area of the desert locust extends from India and Pakistan to West Africa through the Middle East, and the main factors affecting the desert locust breeding and spreading along these regions includes the rainfall, vegetation cover, soil types, wind, temperature and relative humidity (Sulman, 2005) [45]. The invasion area regions are characterized by annual rainfall averaging between 80- 400 mm, and precipitation can be extremely heterogynous in frequency and intensity, as well as differing regionally. Moreover, rainfall is the most important requirement for the Desert Locust breeding, because it orients the necessary environmental conditions for the breeding, development and multiplication. Rainfall is also found to be influencing the timing of certain developmental milestones in the egg indirectly through soil moisture, the developmental rate of nymphs and sexual maturation of adults through food (DAFF, 2011) [17].

Frequency of the rain and the duration of the rainy season allow two and a partial third generation of the desert locust to breed, at a higher rate of multiplication than normal, either due to more egg and/or greater survival occurrence, or after one or two high population growths, many approximately synchronous out-breaks appear and an upsurge begins (Van huis *et al*,) [18]. According to Abdella (2004) [3]. Desert Locust are attracted to habitats of high vegetation density and compact structure, because they probably need to protect themselves against unfavourable weather conditions and against the attack of the natural enemies, in addition to their need for food. Moreover, during the overcast conditions, they spend all day in the vegetation, and it is clear that they 11 spend most of their time in the vegetation in habitats consisting of large, dense low plants (Cresman, 2016) [8].

2.4 Damage caused by desert locust

Desert locusts are polyphagous insects which feed on various parts of plants such as leaves, shoots, flowers, fruit, seeds, stems, and even bark. Crops and non-crop plants including cereals, vegetables, fruit trees, sugarcane, cotton, pasture grasses, and weeds are eaten by the insect. Single insect is estimated to consume green vegetation equivalent to their body weight (2 g) in a day (Shower, 2002) [19]. It is reported that in a day a small 1 sq. km swarm consumes the same amount of food as 35000 people (FAO, 2020) [44]. The damage caused by locusts is even mentioned in the Bible and Quran. The swarms are more dangerous as they are capable of creating large populations, dense bands and can migrate many hundreds and even thousands of kilometres in a very short period of time which make them capable of causing heavy damage in a very short period (Lecoq, 2003) [21]. So, these pest outbreaks can create critical conditions for food security and livelihoods of people in affected areas (Long and Hunter, 2005) [22]. As these swarms can affect a large portion of the world such whole continents get affected and among them Africa is most susceptible to locust attack.

2.5 Impacts of Desert locust on Crop Production in Ethiopia

Pasture and browse condition depicting a slightly worse situation in areas invaded by the Desert locust compared to the other areas that were not invaded especially in parts of Somali, Oromia regions. Community members, however, estimated a significant reduction in pasture availability of 50 percent or more in - Somali (61%), Afar (54%), Tigry (59%) Oromia (31%), Dire Dawa (35%), Southern Nations, Nationalities, and Peoples' Region (SNNPR) (22%) and Amhara (28%) compared to normal situation prior to the invasion of the locusts based on the report of Joint Assessment Findings (JAF, 2020) [23]. Most of these areas received adequate Karan and Deyr rains in 2019 that came after a prolonged dry spell. The table summarize the crop loss caused by Desert locust on different cereal crops and vegetables.

Table 1: Estimated Crop Loss (quintals)

Region	Total Cereal Lost	Maize	Sorghum	Wheat	Barely	Vegetable	Total
Afar	202 882	3 633	175	614	0	453	4 874
Amhara	96 780	0	15 430	0	0		15 430
Dire Dawa	31 050	300	1 150	0	0		1 450
Oromia	1 228 352	3 813	32 238	5 000	0		41 051
SNNP	134 420	1 748	2 410	0	0		4 158
Somali	1 026 132	30 000	41 271	18 805	0		90 076
Tigray	843 241	1 847	20 956	11 769	6 005		40 577
Grand Total	3 562 856.	41 341	113 630	36 188	6 005	453	197 615

***Source*:** FAO 2020

Figure 2 shows that Desert locust has damaged different crops but the worst affected was cereal especially Sorghum where 113 639 hectares were affected followed by maize (41 341 ha) and wheat (36 188 ha). Oromia was worst affected with total cereal loss of 1 228 352 quintals (122 835 MT) on 41 051.4 hectares of cropland. Somali region experienced the second largest cereal crop loss of 1026 132 quintals (102 613 MT) on 90 076 ha of cropland. Tigray region was third with 843 241 quintals (84 324 MT) lost on 40 577 ha of land (JAF, 2020) [23].

2.6 Impact of climate change on locust swarm

Climate plays a major role in insect distribution in the world and so it has been anticipated that changing climate will also likely change pest outbreak patterns (Wang *et al*,. 2019) [24].FAO has already stated that the pest outbreak is an 'unprecedented threat' to food security and livelihoods in regions that are already vulnerable to climate change (EAIOC 2020) [25]. Similarly, these locust outbreaks also depend on climate as they require moist soil for egg incubation, they prefer to migrate to those areas where recently rainfall has occurred in order to get plenty of green vegetation to feed and breed (Tratalos, 2010) [26]. So the region with exceptional weather events due to climate change becomes more susceptible and gets heavy damage by locust swarms outbreak (20). Also, these swarms are getting more prevalent in the present context due to increase in deforestation, industrialization, urbanization and all other human activities which increase greenhouse gases mainly methane and carbon dioxide on earth. This increased concentration of carbon dioxide gases results in enhancement of rainfall, soil moisture level, vegetation growth which increases the size of the locust swarm and its outbreak frequencies. Moreover, from autocorrelation analysis and autoregressive integrated moving average (ARIMA) analysis it has been observed that endogenous factors and rainfall play role in determining the size of the territory occupied by locust swarms and hopper bands across the entire range of the species (Clauesen, 2003) [27].
These locusts outbreak frequency are also affected with change in frequency of both flood and droughts as during decades it has been observed that it becomes highly abundant in increased frequencies of both flood and droughts (Stige *et al*, 2007) [28]. Unusual weather and climate causing locust outbreak can be easily illustrated with year 2020 as the outbreak has been regarded as one of the worst in the last 25 years. As this outbreak occurred due to unusual climatic condition like successive heavy rains and cyclones in the Empty Quarter in the Arabian Peninsula in May and October 2018 which resulted into favourable conditions for three generation breeding and numerous swarms started to leave those area in early 2019 in order to cause outbreak (FAO, 2020) [44].

3. Biology of desert locust

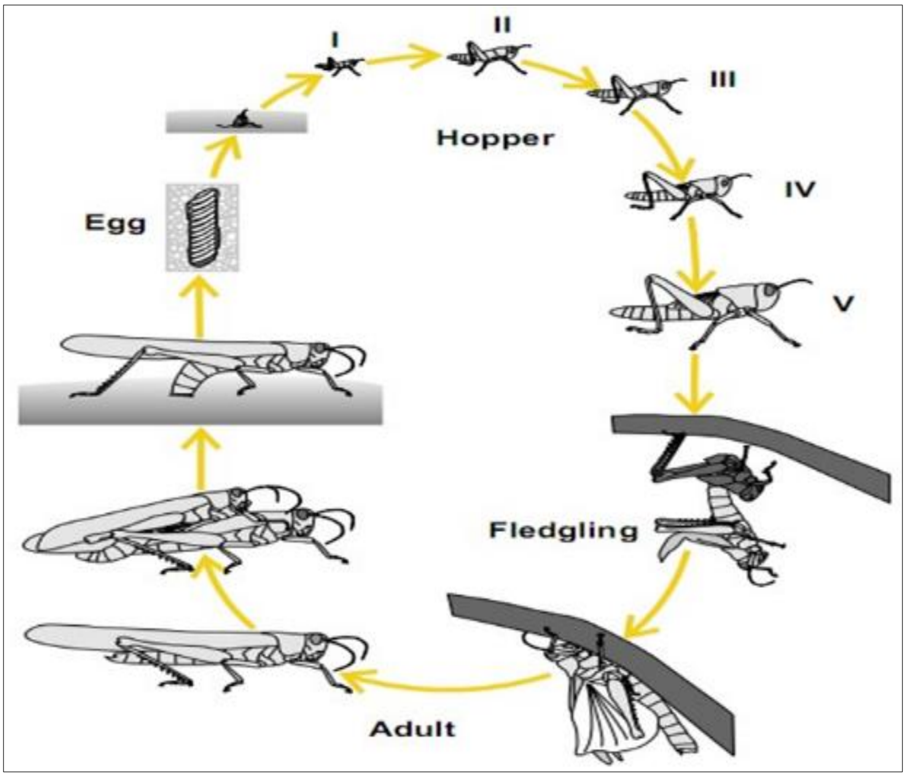
3.1 Life cycle

Mating: Mackean and Ian (2011) [29] mentioned that during mating the male locust mounts the back of the female, applies the tip of his adomen to hers and passes sperms into her reproductive tract. The sperms are stored in a sperm sac in the female's abdomen, and as the eggs pass down the oviduct during laying, the sperms are released and so fertilize the eggs.

Eggs: Roffy and Magouer (2003) [30] indicated that after mating, the female lays her eggs in warm, moist sand following a rainy spell. It pushes her abdomen down into the sand, extending the membranes between the segments, and burrowing to a depth of 50 or 60 mm. In this burrow, 50 to 100 eggs are laid and mixed with a frothy fluid, which hardens slightly and may help to maintain an air supply round the eggs. Egg needs to absorb approximately their own weight of water to complete their development.

Nymph: This stage starts with hatching an egg into a nymph called hopper. S. gregaria hopper develops in about 30 to 40 days which undergoes five to six stages (Cresman, 2016) [2]. In these stages, solitarious hoppers shed their skin for five to six times and five times in gregarious hoppers which is called as moulting and the stages between moulting is called as instar. The first instars after hatching are white colored and get changed into black within 1 to 2 hours (Stedman, 1990) [31]. Furthermore, with change in instars color its body structure and size also get changed so finally in fifth instar, it is bright yellow with black colored pattern but it varies with temperature.

Adult: Fledgling develops into an immature adult which later develops into a mature adult. The wings of fledgling get hardened in ten days and it changes into an immature adult. The young adult (fledgling), under optimal condition develops into an adult in 3 to 8 weeks but if the condition is unfavourable (like cool, no sufficient rain) then they remain in larval stages for six months or more (Stedman, 1990) [31]. The colour of an immature adult varies from light to dark pink colour according to weather and becomes sexually mature in a few weeks or months. The beginning of maturation is indicated by the disappearance of pink color from hind tibia and the mature adult colour changes to yellow in which male adults are brighter yellow coloured than female. Moreover, in the adult stage the weight increases gradually however size doesn't increase (Cymons and Cresman, 2001) [2]. The immature solitarius adult is pale grey whose colour on maturation changes to pale yellow. Similarly, immature gregarious is bright pink coloured which on maturation changes to bright yellow.



***Source*:** (Symmons and Cressman, 2001)

Fig 1: Shows Desert Locust life cycle

4. Management methods of desert locust

4.1 Traditional methods

Farmers, before the availability of new and advanced technology, have developed a variety of physical and cultural methods to protect their crops from the locusts. These methods are practiced especially when the infestation or hopper bands are small. Some of them are killing or trampling the bands, ploughing or burning the egg infested field & trapping the hoppers in pits or trenches and killing them (Sharma A. 2014) [32]. When a huge swarm of locusts are about to land in cultivated areas, the best way is to chase them away. Local people use fire, clouds of smoke and loud sounds to repel them from descending in the field.

Gordon *et al. (*2014) [33] Reported that tympanal movement and electrophysiological response of locust is between 4 and 8 kHz. They have the ability to distinguish between low frequencies (conspecific) and high frequencies (like predatory echolocating bats) (Robert, 1989) [47]. Acoustic and electronic devices that pulses ultrasounds can be used to deter large swarms of desert locusts (Ibrahim *et al*, 2015) [35]. Also, people use nets to protect small nurseries and kitchen gardens. Medicated nets, which are sprayed with garlic or neem oil are also effective to repel different insects including locusts and grasshoppers (Kuar, 2017) [36]. However, these traditional methods work well when the swarms and crop areas are small.

4.2 Mechanical control

Methods such as digging trenches for hoppers to fall into, beating hoppers with branches, burning and tillige are sometimes used as a last resort to try to protect crops. In some societies people believe on a magician man that he can drive away swarm of locust from their crops (Kalaffa Alla, 2004) [37]. Cresman (2016) [8] Said that mechanical control may prevent some crop damage if the locust infestation is light, but they have little effect on the overall population in the region and can fail to protect crops when there are locusts continuously invading the fields. Locust eggs in the ground are sometimes dug or ploughed up but this is a laborious work and it is difficult to find many of the locust egg beds witout very good information on previous swarm laying sites.

4.3 Botanical methods
Botanicals mainly include plant derived products. They are broad spectrum pesticides, safe to the environment & non-target animals, less toxic, cheap & easily available. Resistance by pests against them is very slow and less common (Raghavendra 2016) [38]. Most widely used botanical products include pyrethrum, rotenone, neem and essential oils. Others include ryania, nicotine, sabadilla, garlic oil, capsicum oleoresin which are used in limited (low volume) regional use (Hernandez *et al*, 2006) [39].

4.4 Chemical control
Previously, organochlorines like Dieldrin were widely used to control the locusts as barrier spraying (Rachardi and Focart, 1999) [40]. But after the ban of dieldrin in 1995, current locust operations use chemical insecticides of classes organophosphates, carbamates, pyrethroids, phenyl pyrazole and benzoylurea (Dobson, 2001) [41]. These include broad spectrum insecticides (Arthurs, 2008) [42]. Pesticide Referee Group (PRG), an independent advising body of FAO, recommends different pesticides especially for locust control. According to PRG, neurotoxic insecticides should be only used as a last resort whereas Metarhizium acridum (Driver & Milner) comes in first priority and insect growth regulators in second. The hoppers (young instars) are more susceptible to pesticides than the adults (Rachid, 2010) [43]. So spraying operation should be

5. Conclusion
The outbreak of Desert locust leads to food insecurity and starvation. The invasion of desert locust in addition with the effect of corona virus and the political instability of Ethiopia is the cause for current food insecurity. In Ethiopia Desert locust outbreak occurs when there is long dry season followed by short rainy time before the entrance of summer. This climatic variability can be used as pre-preparation to control Desert locus before its outbreak. But area specific control is not successful method to control Desert locust. Because it can invade many areas in short time crossing countries as the movement is in a windward direction. As these trans boundary pests appear in millions of numbers all the concerned authorities should be well pre-prepared to reduce the damage. Traditional methods can be used but only when the swarms are very few in number. For controlling thousands or millions in swarms, we need to shift from traditional cultures to modern approaches. So the Ethiopian government should incorporate new policies that encourage the cooperative control of Desert locust with neighboring countries.

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