

## Review Article

# The Indirect Threats of Desert Locust Infestation on Honeybees in Ethiopia

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This review focuses on the potential effects of a desert locust infestation on Ethiopian honeybees. Data on the country's infestation, locust activity, honeybee foraging behavior, pesticide kinds, and application rates were collected and analyzed in connection to honeybee life and performance. Desert locust has damaged a considerable number of plants of various kinds, possibly causing pollen and nectar loss. As a result, honeybees are likely to produce less brood, less honey, suffer from poor health, and abscond. Besides, studies suggested that the use of pesticides to control the locust could directly harm honeybees. The pesticide was used for 21 days in a row to cover a huge region infected with locusts, which could have had a severe effect on honeybees. The probability of an influence is also indicated by the overlap of pesticide administration with honeybee foraging seasons and hours. Furthermore, forager bees leave their hive 1 to 13 times per day, spending about 3 hours outside each time, indicating higher chemical exposure. Malathion is one of the pesticides that could harm honeybees, while there is no comprehensive list of the chemicals used on the internet or anywhere else. Finally, the current desert locust invasion and eradication operation in Ethiopia may have caused substantial damage to honeybees as a result of bee forage loss and pesticide hazard, emphasizing the need for future precautions. Because this is speculative work based on evidence, detailed survey research is recommended to determine the actual impact imposed on honeybees.

## 1. Introduction

Beekeeping (*Apis mellifera*) has been practiced in Ethiopia since 3500 to 3000 BC [1] times, and it has played an important role in socioeconomic issues such as churches, holidays, weddings, and other events. Ethiopia is the first and tenth honey-producing country in Africa and the world, respectively [2], which is ascribed to the suitability of the country for honeybees. Ethiopia's suitability for beekeeping is measured by the abundance of diverse varieties of plants [3]. Honey is produced in almost all parts of Ethiopia, with distinctive types of honey coming from different regions.

Honeybees play a significant part in the livelihood of rural households and are considered an economically

important insect. Honey, beeswax, and bee colony sales are vital sources of income for rural households, which are utilized for a variety of expenses such as children's school fees and taxes. Due to its nature of low perishability, honey sales can be scheduled at any time during the year when it is needed [4]. Because beekeeping requires less initial capital, empowering poor households in general, and women in particular, is easier than with other livestock [5].

Despite the long history of beekeeping, productivity of the sector is suboptimal which is ascribed to numerous factors such as the use of traditional technology, low management practices, prevalence of pests, and indiscriminate use of agrochemicals. Traditional beekeeping characterized by the use of traditional hives (made of locally

available materials such as mud, clay, log, bark, bamboo, and others) and poor management (no supplementary feeding and less protection from enemies) of the bees accounts for more than 90% of beekeeping in the country. The prevalence of honeybee pests such as ants, spiders, birds, lizards, bee beetles, and wax moths is commonly reported by small-scale beekeepers as a major challenge to productivity. Repeated attacks by these intruders will lead the bees to abandon their beehives and move to other places. Currently, indiscriminate application of herbicides and pesticides to food crops is becoming the leading challenge to honey production in most parts of Ethiopia [6, 7], and several herbicides are used to control weeds of food crops without considering the bad effects on honeybees and their forage [8]. Agrochemicals are responsible to weaken a colony, kill the bees, and pollute the products through residues.

The desert locust (*Schistocerca gregaria*) belongs to the class insecta and is one of a dozen grasshopper families. This desert locust belongs to the Acrididae family, which includes most short-horned grasshoppers. Although the desert locust looks like any other grasshopper, it is larger and aggressively voracious. The desert locust passes through three developmental phases, namely egg, nymph, and adult. The female locust lays eggs, and the eggs hatch into wingless larvae or nymphs called hoppers. This hopper moults five to six times, increasing in size with each moulting stage it passes through. Wings develop as hoppers undergo their sixth moult. Wingless hoppers are called instars, and winged hoppers are called fledglings [9].

The desert locust is well-known for one distinct behavior that distinguishes it from other grasshoppers: it adapts its life habits to the environment it inhabits and the available resources [10]. In reaction to swarm density and environmental conditions, they can change their body color and shape. Concentration, multiplication, and grangerization are three processes that cause significant behavioral changes in desert locusts.

The desert locust can have swarms that number up to 10 billion, and these swarm move and feed in a highly organized way. The desert locust is a major threat to agricultural production [11] as it is a voracious consumer of every green plant, including leaves, fruits, shoots, flowers, barks, found on its way [12]. A plague of desert locusts, the most destructive of all locust species, could easily affect 20% of the world's land, threatening the livelihoods of one tenth of the world's people and seriously jeopardizing food security [13].

The impact of the locust may not only be limited to severe damage of food crops but the control operation may also result in unintended effects, as for example, toxicity to the honeybees by the pesticides applied to kill the desert locust. As a result, honeybees are likely to be harmed twice: once from a lack of food (pollen and nectar) and again from chemical toxicity. Given the difficulties of testing these impacts, collecting evidence to demonstrate their effects has been chosen as an alternative for the time being. As a result, the goal of this work was to compile relevant data that suggest the likelihood of negative impacts of the desert locust invasion on Ethiopian honeybees.

## 2. Methodology

This research is entirely based on a review of scientific papers and reports from international and national organizations. We aimed to compile relevant information that could indicate the possibility of a significant adverse effect of the desert locust on honeybees. Therefore, we examined evidence that is thought to suggest a trend of negative impacts. As a result, the scale of locust invasion, suitability of infested areas for honeybees, recurrence of desert locust in Ethiopia, honeybee behaviors (foraging time, frequency, and population size), and pesticide application intensity (total land treated) are all evaluated, discussed, and interpreted.

## 3. Results and Discussion

*3.1. Desert Locust Infested Areas.* In 2019/2020, Ethiopia was infested by desert locusts that have migrated from Yemen and settled in the Afar lowland. Swarms begun to migrate from the Afar region's lowland to the semihighland Amhara regional state. While, another swarm migrated from Somaliland to the Dire Dawa city administration. Despite the fact that North East Ethiopia was the first to be confronted with the problem, the desert locust infested practically all Ethiopia's regional states, causing varying degrees of damage. Among the regional states of the country, Tigray, Amhara, Afar, Oromia, Somalia, and SNNP regional states faced severe damage where large areas have been considerably invaded, leading to significant loss of feed and food crops (Figure 1). There was a significant reduction in pasture availability of 50 percent or more in Somali (61 percent), Afar (59 percent), Oromia (31 percent), Dire Dawa (35 percent), SNNP Region (22 percent), and Amhara (28 percent) during the outbreak of the desert locust in 2020, compared to the normal situation prior to the invasion of the locusts [14].

Following the first round of infestation, new areas were invaded, which was exacerbated by favorable conditions such as rain, wind direction, and locust speed. For example, swarms of desert locusts from Kenya infested new areas in Ethiopia as a result of a change in wind direction. The rains helped the swarms in North East Ethiopia laying eggs, which could pose a threat to Somalia, Eritrea, and Eastern Ethiopia if they hatch. Due to the pest's tendency to travel longer distances and consume enormous quantities of plants, larger areas were readily invaded and harmed by the desert locust. The locust, assisted by the wind, can travel up to 150 kilometers, indicating how quickly it can cause damage to crops and pastures over a wider area [13].

*3.2. Availability of Resources.* For a number of reasons, Ethiopia is generally regarded as a good place to keep honeybees. Larger altitudinal differences, ranging from -116 meters below sea level to 4542 meters above sea level, resulted in a wide diversity of climate conditions. Besides, the rainfall varies from about 750 mm/year in Tigray and Amhara Regional States to over 1,000 mm/year in parts of Oromia Regional State [15]. As a result of the suitable

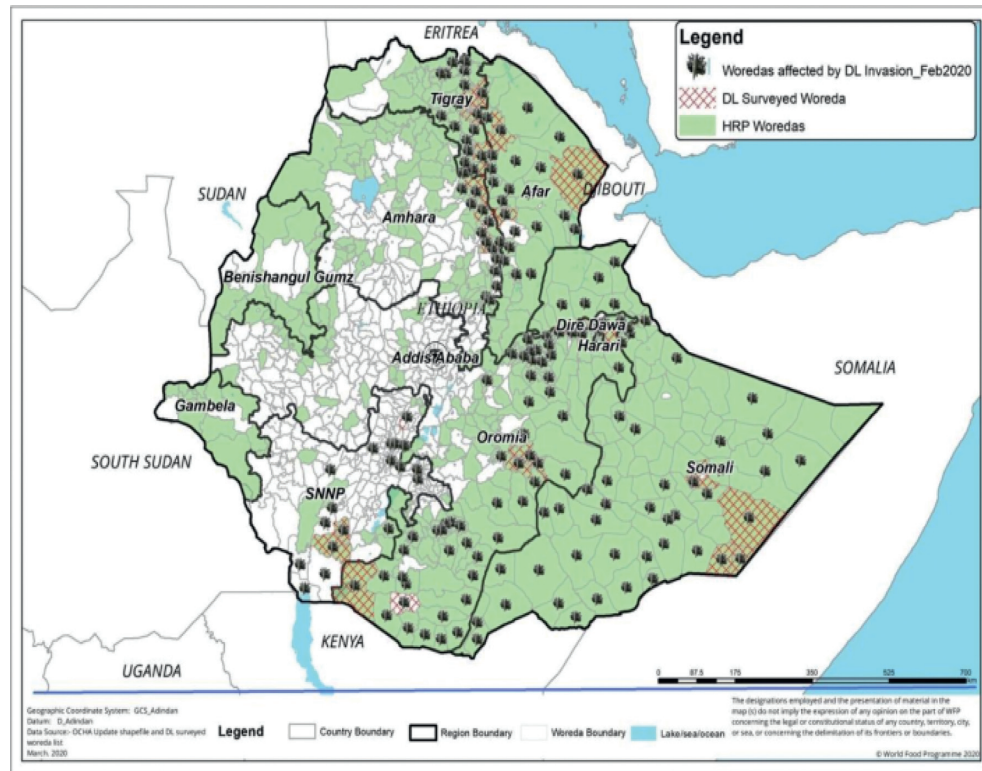


FIGURE 1: Map of affected areas in Ethiopia (source: [14]).

climate and weather conditions, a high plant biodiversity exists in the country. Trees, shrubs, bushes, and other types of plants are found either in forests, parks, homesteads, and other places. Besides, several crop species of cereals, legumes, vegetables, fruits, tubers, and oil seed are cultivated across the country with different degree of intensity. Moreover, specific studies at Afar [16], Amahara [17], and Tigray [18] indicate that there is abundant melliferous flora blooming during different seasons in Ethiopia. The large availability of resources and different honeybee races makes Ethiopia ideal for honeybee keeping [18, 19]. Consequently, honeybee keeping is carried out in almost all geographic locations of Ethiopia including both moist and dry areas [16, 20]. We can expect numerous honeybee colonies in desert-infested areas of Ethiopia. Actually, the Oromia region has over 50% of all bee colonies while Amhara and SNNPR together account for a further 36%.

**3.3. Recurrence of Desert Locust in Ethiopia.** The severity of a single occurrence, as well as the frequency with which it occurs, determines the severity of a problem. In Ethiopia, the annual probability of locust infestation is estimated to be between 30 and 40% [21]. If not on a yearly basis, periodic occurrence over a short period of time appears to be unavoidable. Ethiopia was plagued by desert locust in June of 2020, which is the biggest outbreak in twenty-five years [13]. Due to the possibility of favorable conditions associated to recurrent tropical storms and tropical depressions, there is a high risk of cyclical infestation for the next few years [22]. As a result, the number of swarms of desert locusts generated by

sequential generations rapidly grows within 1-2 months, and they begin to congregate and become gregarious. The presence of immature swarms in several parts of Ethiopia until March 2021 confirms the aforesaid predictions [23]. Furthermore, given to the prevailing appropriate moisture, FAO predicted hatching and band formation in Ethiopia until mid-June 2021 [24]. If the pest appears on a regular basis, the impact on honeybees cannot be expected to be minimal.

#### 3.4. How Could Honeybees Be Adversely Affected by the Locust?

**3.4.1. Loss of Honeybee Forage Sources.** Desert locusts, which are common in East Africa in general and Ethiopia in particular, may have an impact on honeybees indirectly by consuming shared resources. Honeybees collect pollen and nectar from a wide range of wild and cultivated plants and can easily learn how to exploit various and novel sources [25]. Honeybees would not be able to exist or operate at their best without these supplies. Pollen is largely employed as a protein source for the replacement generation brood and adults. Honeybees, on the other hand, use nectar as a source of energy, especially during foraging flights.

Honeybees transform excess nectar into honey for future use when there is more than enough for daily consumption. In honeybees, insufficient pollen is linked to decreased brood production [26–28], poor health [29, 30], a larger percentage of precocious foragers [27], and absconding [31]. Similarly, nectar insufficiency can lead to disease susceptibility, the inability to collect food, and the inability to secrete wax for

TABLE 1: Pesticide treated areas since August 2019 up to May 2021.

Fiscal year	Months	Treated areas (ha)	References
2019	June	—	4 July 2019, no 489
2019	July	—	2 July 2019, no 490
2019	August	11	3 September 2019, no 491
2019	September	4,636	3 October 2019, no 492
2019	October	4,064	4 November 2019, no 493
2019	November	10,822	4 December 2019, no 494
2019	December	8,410	6 January 2020, no 495
2020	January	22,550	3 February 2020, no 496
2020	February	50,350	5 March 2020, no 497
2020	March	51,633	4 April 2020, no 498
2020	April	99,948	4 May 2020, no 499
2020	May	57,058	4 June 2020, no 500
2020	June	79,574	3 August 2020 no 502
2020	July	44,883	3 August 2020 no 502
2020	August	54,703	2 September 2020, no 503
2020	September	57,457	5 October 2020, no 504
2020	October	335,453	2 November 2020, no 505
2020	November	160,580	3 December 2020, no 506
2020	December	210,673	4 January 2021, no 507
2021	January	166,158	4 February 2021, no 508
2021	February	73,838	3 March 2021, no 509
2021	March	15,066	3 May 2021, no 511
2021	April	14,370	3 May 2021, no 511
Total		1,522,237	

Source: [24].

comb construction and honey preparation, [32], 2020 [33]. Bees will die in a matter of days if they do not have access to food or a surplus of carbohydrates. As a result, the loss of flowers causes a food shortage for honeybees, with negative consequences for the colony. Supplementary feeding could be used to help alleviate food crisis but may result expensive in the long term.

**3.4.2. Pesticide Hazard.** Since there is no way of early warning on locust spread and invasion, reactions to these sudden events are various but can be grouped as mechanical disturbance (banging on cans and pans, blowing whistles, and honking motorcycle horns) or chemical application (spraying pesticides from vehicles and aerial application by using helicopters). Of all the methods, pesticide application was found to be effective regardless of the dire consequences. Agricultural pesticides are major contributors to honeybees and other pollinators decline worldwide [34] including Ethiopia [6].

Pesticides affect all developmental stages and casts of honeybees. Honeybees are exposed to agrochemicals through spray and residues in pollen and nectar [35]. Mortality, delayed brood development, and reduced adult longevity are the consequences of pesticides to honeybee

colonies [36]. Some chemicals (for example 2, 4-D) can kill 95% of the exposed adult bees [37]. Similarly, exposure of future queen bees to pesticides during developmental stage results in reduced capped queen cells and queen emergence [38]. The problem during the developmental phase extends to adult hood performance expressed in terms of reduced egg laying rate and reduced capacity to attract attendant worker bees [39]. Lower sperm viability is caused by pesticides exposure during developmental stage in drones [40]. Presence of disease [41, 42], cocktails of pesticides [43], and developmental stages are factors that exacerbate pesticide impact on honeybees. Furthermore, exposure to chemicals increases the susceptibility of bees to disease [44]. The ultimate result of these adverse effects on the honeybee community is a decrease in the number of honeybee colonies, as well as reduced performance of the survivor's ones.

Impact of pesticide application to control locusts (like the present situation) may be greater than the customary manual application method to crop lands due to wider area coverage and application method of the former. Unlike the use of pesticide to control crop pests, which is applied to specific acre of land (containing the crop only), the use of pesticide to control locusts is applied wherever the pest exists. Unfortunately, locusts are found on every green plant including grasses, crops, trees, shrubs, and even on residence homes. Spraying on surfaces increases the probability of exposure of the bees to the pesticides. Besides, aerial application is assumed to be dangerous compared to land-based application methods.

The probability of bee exposure to pesticide determines the level associated to the risk. The exposure to pesticides depends on crop-related factors (overlap between the presence of bees in the crop area and the flowering of the crop or weeds, overlap between bee activity on the flowering crop and pesticide application, or the presence of extra floral nectaries, insects producing honeydew, or drinking water in the crop area), bee biology factor (period, duration and range of foraging, nest location, and nectar and pollen consumption), and pesticides use and application practice (types and rate of use) [45]. These facts lead to hypothesize a higher probability of bee exposure to pesticides when these are applied to control the desert locust in Ethiopia. Evidences of our hypothesis are explained below.

Desert locusts infested Ethiopia towards the end of June 2019 and following months [24] with great loss to crops and pastures. Ethiopia has been battling the locusts since the infestation. About 1.5 million hectare of land has been treated since its prevalence in the country except the first two months. This means 72,487 ha of land has been treated monthly for 21 successive months (Table 1). In other words, no month was pesticide-free for almost two years, confirming the overlap between flowering times and pesticide application. Most of the honeybee floras of the country are in bloom from September-November [46] followed by second shorter season in April-May. Honeybees are actively foraging during these periods because pollen and nectars are linked to flowering stage of plants; therefore, they certainly got into contact with sprayed pesticides for a long period of time.

Furthermore, honeybees are diurnal insects that forage during the day time, which is concurrent to spray time, particularly aerial application which is impossible during the night. Africanized honeybees are reported to be active during the whole day with early morning and late evening being the two peak periods [47]. A forager bee move out of hive 1 to 13.5 time per day [33]. In general, a honeybee is reported to be outside the hive for 0.95–3.0 h per day for multiple purposes but commonly for pollen and nectar collection. The probability of bees to be sprayed by pesticides is 100% if the bee or the hive is found within the range of the spray [35]. This may be damaging a large number of honeybee individuals, foragers in particular.

Other than forager bees, house bees are also affected by pesticides through infected pollen and nectar. Forager bees collect and deposit nectar and pollen from pesticide-treated fields into the hives, therefore spreading toxic substances to bees in the hives and to hive products, a threat also for consumers [48]. Bees are not repelled by pesticides and thus collect contaminated pollen and nectar [49]. Scientific reports indicated that a single worker honeybee may cause disruption to the casts in the hive with possible death of large numbers bees [50].

Exhaustive list of applied pesticides to control desert locusts is not available from reports online. However, Malathion, Diazinon, and other environmentally friendly pesticides are used to control the pest in Ethiopia {Formatting Citation}. However, scientific reports indicated that Malathion is among toxic chemicals for honeybees [51, 52]. Malathion reduces the life of worker bees by 80% under higher concentration [52]. Genetic variation to Malathion sensitivity is reported by [53] implying that some groups of honeybees might have been affected more than others. No research finding is reported regarding the effect of diazinon on honeybees.

#### 4. Conclusion and Recommendation

The long-lasting desert locust invasion in Ethiopia is expected to have a detrimental influence on honeybee colonies, honey yield, and quality, due to the loss of honeybee resources (pollen and nectar) and chemical spray hazards. Pesticide poisoning could be avoided by keeping the colony in the hive through internal feeding during intensive pesticide application periods or by moving hives away from pesticide application sites. Supplemental nutrition should be provided to honeybees so that the colony can survive the dearth period when locusts destroy the surrounding flora. Furthermore, we would suggest raising awareness about the need of using predominantly mechanical techniques and safe insecticides while eradicating the desert locust.

#### Data Availability

The data that support the findings of this study are available from the corresponding author, Bihonegn, upon reasonable request.

#### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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