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Article

Feasibility of Hunting Invasive Locusts and Studying its Economic, Social, and Environmental Effects (Approach: Preventing the Spraying of Locusts)

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Abstract: Locust is a pest that attacks human and animal food and endangers national security by threatening food security. Spraying is the easiest and fastest way to deal with them. But the easiest way is not always the best way. With chemical resistance, not only will permanent immunity from locust attacks not arise, but they will also become resistant to poisons. While we have to pay billions of dollars annually for this strategy, we will also cause water and soil pollution. Therefore, the research results of other researchers were used and modeled to measure the possibility of hunting invasive locusts to investigate the possibility and benefits of this action. So, this study was conducted in the field method. The obtained results indicate that it is possible to hunt invasive locusts. If traps are placed on time and in the right place, the possibility of preserving crops after the pest attack increases by 2.3 times more in protected fields than in unprotected fields. By hunting locusts, fields and even pastures are preserved, poisons are prevented from entering the food chain and ecosystem, part of the economic loss of farmers affected by the invasion of locusts will be compensated, and by providing animal feed through hunting locusts, water consumption will be reduced, soil erosion and energy consumption are saved.

Keywords: hunting invasive locusts; food security; entomophagy; pest; entry of toxins into the food chain

1. Introduction

Insects are one of the largest and most important groups of creatures, and some of them, including locusts, can affect human life[1]. Locusts are herbivores and have a varied diet[2] and in case of an outbreak in the population, they are known as a pest. Therefore, they have become a challenge for food security[4 ,3]. They are very isolated and often grow in warm and sunny ecosystems[6 ,5]. Consecutive droughts that have been accompanied by mild and wet winters provide the conditions for the outbreak of this insect, and the change in soil temperature will change the hatching time of the larvae of this insect7-][10. Population explosion occurs in some species of short-horned grasshoppers from the *Acrididae* family and turns Locusts into the worst plant pest.

After hatching, locusts are larvae, and cannot fly, mate, or lay eggs, but can jump. But after puberty, they will have the ability to fly, mate and reproduce. Vinylanisole, Phenol, Guaiacol, and Veratrol are the gases of the digestive system of locusts, which, as cohesion pheromones, turn them into social creatures to form large groups[11-13]. Increasing the tactile stimulation of the locusts' hind legs increases the serotonin level[14]. Under the influence of increased serotonin levels, their color changes, and they feed more. Their reproduction is accelerated and they show more collectivist behavior. After a few generations, their population overflows and they become one of the most important and destructive pests[15].

The invasion of locusts has occurred a lot throughout history and caused a lot of damage[16-18]. The management of pasture lands infested by locusts has been reported since 1974[4].]. A typical swarm of locusts can infect 150 square kilometers and fly 150 kilometers per day. The Rocky Mountain locust outbreak of 1875 was recorded in history. The length and width of that group were 180x2900 km, and the number of locusts in that invasion was estimated at 3.5 trillion[19]. Even the migration of desert locusts from Africa to the Caribbean Sea between 1987 and 1989 has been recorded[20-23].

Planting plants in distant pastures, removing land vegetation, concentrating damage in certain areas of pastures, creating deliberate and engineered fires, creating a green belt, and using D4-2 and carbaryl poisons have been common ways to deal with locusts24- ,15] [31. Locusts are affected by parasites, fungi, bacteria, and natural predators in different stages of their life cycle from the point of view of population and number[32-39 ,15]. Even a change in the locust's diet[40] or feeding on some plants such as Nerium oleander will control its population[41].

Mechanical mechanisms do not have enough power to deal with the massive invasion of locusts. In chemical countermeasures, lack of durability, creating resistance, high economic cost, and environmental harm are considered weak points[5]. In addition, the period of the poisons has been reported from 10 days to several months[43 ,42] and a study in America showed that 3 million hectares of pastures were controlled using 5 million liters of malathion for 25 million dollars[44].

Preventive biological control of the locust population is a scientific solution. But the allocation of funds by governments depends on their political inclinations, not on the scientific findings of scientists. Preventing the occurrence of a crisis using the concept of integrated pest management (IPM) is a strategy based on a correct understanding of the behavior and ecology of locusts[45].

The purpose of this research, which was conducted in the field, was to investigate the possibility of hunting invasive locusts and to study its economic, social, and environmental effects to find out what changes will occur in the yield of cultivated fields if they avoid spraying them and hunting locusts. In addition, to what extent can the damage caused by the invasion of locusts to agricultural land be compensated by hunting locusts? Also, the discussion about the comparison of the damage caused by the invasion of locusts versus the damage caused by the use of poisons used to destroy them is another goal of this research.

Therefore, according to the national forecasts and warnings of the Ministry of Agricultural Jihad and the General Directorate of Environmental Protection, regarding the invasion of invasive desert locusts from the deserts of the Arabian Peninsula, according to the weather patterns and maps, the necessary planning for observation and monitoring Based on this wave of locusts and the study of their behavior was carried out about the proposed hypothesis.

2. Materials and Methods

Materials

2 plots of land with relatively equal dimensions (each about 5000 square meters) with relatively similar dimensions (111x45 and 120x42) were selected in the agricultural lands of Nahand village (27.201035, 54.197782) from the functions of Kohij city located in Hormozgan province. 5 to 10 May 2019 to be evaluated and monitored in the field. The distance between the two fields was measured to be 1723 meters. Both fields were under alfalfa cultivation. The type of seed used in both plots was Nikshahri and its amount was 13.5 kg per 5000 square meters of land, the distance between the rows was 20 to 25 cm (each plot separately). Planting and harvesting in both fields were done by the mechanized method. Cultivation of the crop in both lands has been done using the classic rain irrigation method. An explanation is that both studied fields were in the second year of autumn alfalfa cultivation.

20 metal barrels each with a capacity of 220 liters, in addition to woven sacks made of plastic fibers for storing bakery flour with a capacity of 40 kg, as well as 20 lamps with a capacity of 100 watts and 450 meters of electric wire were used. Some of the iron used

to make the base of the lamp was also used as a holder for the lamps. Toussaint model 3260A mini milling machine was used to cut and change the shape of parts of metal barrels.

The 400-amp BOSS-Life Style welding machine was used to weld and connect the parts cut from metal barrels and create the desired compartments.

To measure the weight of the caught locusts, a standard MDS9800 model store digital scale with a capacity of 15 kg was used. This scale has a compact ABS plastic body with an iron sole, measuring 35x35x11 cm. It has an LCD, stainless steel-edged tray measuring 5x23x37 cm with a power supply/battery with an accuracy of 1 gram.

Methods

2 fields were monitored for 5 days. On one of the fields, 20 barrels, each equipped with a 200-watt filament lamp, were placed. The barrels were placed in 3 rows (2 side rows of 7 and the middle row of 6) with a distance of about 15 meters from each other (radius of about 7-8 meters) at a height of 1.5 meters from the ground. The lids of the metal barrels were cut and after changing their shape (from a flat shape to a concave conical shape) with a hole with a radius of 3.5 cm in the center, they have welded again in their original place. The lamps were installed at a distance of 50 to 60 cm above the holes of each barrel.

The lamps were lit only after sunset and during darkness (at night) for 8 hours and remained lit until sunrise. Every night when the lamps were on, the barrels were emptied 4 times, and this process continued for 5 nights.

No equipment was used on the second floor, and it was considered only as a witness in this research for testing and study.

3. Results

The normality of the data was tested by two methods of checking the curvature/skewness of the graph and also the Kolmogorov/Smirnov test. In both methods, the normality of the data was proved.

Table 1. The results of checking the normality of the data by checking the skewness/ kurtosis.

Descriptive Statistics							
	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
First Night	20	10269.70	1056.869	.386	.512	-1.079	.992
Second Night	20	10299.80	1082.727	.002	.512	-.964	.992
Third Night	20	10192.15	995.009	.623	.512	-.206	.992
Fourth Night	20	10558.30	1053.442	.160	.512	-1.244	.992
Fifth Night	20	10321.50	1124.876	-.040	.512	-1.307	.992
Valid N (listwise)	20						

Table 2. The results of checking the normality of the data based on the Kolmogorov/Smirnov test.

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
First Night	.174	20	.113	.934	20	.186
Second Night	.120	20	.200*	.944	20	.282
Third Night	.139	20	.200*	.944	20	.285
Fourth Night	.140	20	.200*	.937	20	.209
Fifth Night	.141	20	.200*	.934	20	.187

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

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Based on the observations and results obtained, the number of locusts counted on the control ground (without lamp) in a space of 1 square meter for 5 consecutive nights was 116 on average. In contrast, the number of locusts counted on the ground trapped with the lamp was an average of 85. Also, the average number of Locusts trapped in the trap was counted as 3648. Calculations show that the average number of locusts on the ground in the trapped field was 26.7% less than in the control field. Also, the average difference between the number of trapped locusts in the trap compared to the locusts on the control ground was calculated to be 3075.9%. In addition, the ratio of locusts inside the trap showed a 4234.1% increase in the number of locusts trapped on the ground.

Table 3. The number of locusts counted on 1 m^2 of the field.

	First Night	Second Night	Third Night	Fourth Night	Fifth Night	Average
On the floor without a lamp*	91	108	141	136	104	116
On the floor with a lamp**	67	92	78	85	103	85
Inside 1 trap	3650	3829	3531	3762	3648	3684

*- The number of locusts counted in the field without light traps (1 m^2) / (Out of the trap - on the floor)

**- The number of locusts counted in the field equipped with incandescent lamps (1 m^2) / (Out of the trap - on the floor)

The average weight of the locusts counted on 1 square meter of the control field was 302 grams. While the weight of locusts counted on the ground and trapped was calculated to be 212 grams on average. In addition, an average of 9819 grams of locusts were trapped. Comparing the weight of locusts on 1 square meter of the control plot with 1 square meter of the trapped field shows that 29.8% more locusts have accumulated on the control plot. This is while the average weight of locusts trapped in the trap was 3153.3% more than the control ground and 4535.8% more than the trapped ground.

Table 4. The weight of locusts on 1 m^2 of the farm.

	First Night	Second Night	Third Night	Fourth Night	Fifth Night	Average
On the floor without a lamp*	237	281	365	357	269	302
On the floor with a lamp*	165	219	196	221	258	212
Inside 1 trap*	9823	10261	9109	10270	9630	9819

It should be pointed out that the final product harvested from the field after the research period was 2635 kg. While the product harvested from the ground equipped with light traps after the research period was reported to be 6045 kg. This means that the amount of harvested crop from the trapped land was 2.3 times more than the control land despite the locust infestation. In other words, the yield of hay harvested from the trapped land was 229.4% more than the harvest from the control land. While both lands have been invaded by a single wave of a specific species of invasive locusts at the same time and in the same place.

4. Discussion

Due to the increasing need for people for food, the food supply has become a challenge, and maintaining food security is a necessity[46], in the absence of which national security is compromised. Therefore, any threat to food sources should be taken seriously.

On the other hand, fighting threats should not cause secondary problems. Although fighting against pests is a necessity, it should be known that poisons can produce other biological effects.

Many countries are affected by locusts. The largest number of invasions and damage can be seen in the continent of Africa and Asia, and the lands of European countries bordering the Mediterranean Sea are another destination for desert locusts.

Spraying locusts with poison may be able to destroy large masses of them, but it causes a small population of them to acquire biological resistance, and once again this small population grows, and a new threat emerges from them[47-50]. At the same time, due to biological resistance, the previous defense tools do not have the desired effect.

But the solution can be found elsewhere. The economic problems of the communities can be considered as a reason to promote them to hunt invasive locusts. In this way, the outbreak of locusts will be countered, employment will be created, and economic problems will be solved. It should also be remembered that not using chemical poisons saves money, and on the other hand, it avoids the entry of dangerous poisons into the environment and food chains and does not harm the environment.

Entomophagy is one of the United Nations Food and Agriculture Organization (FAO) recommendations to curb poverty and hunger[51-54]. Cultivation of edible insects is common for humans and in many countries, all kinds of worms, ants, locusts, dragonflies, cockroaches, tree beetles, rolling dung beetles, honey bees, wild yellow bees, silkworms, blue insect larvae, and many other insects such as They are eaten as a meal or appetizer. Due to their high nutritional value[55], locust is consumed as an appetizer or a full meal in restaurants in some countries[56]. India, Pakistan, and African countries facing food shortages have turned to cultivate various insects, including locusts[57] China, Korea, Japan, Thailand, Indonesia, Malaysia, Cambodia, Laos, Australia, Mexico, Arab countries, Africa, South America, etc. are among the consumers of this insectivore.

The construction of light and heavy livestock breeding centers (poultry or cattle breeding) is one of the ways to provide food, but the growth rate of birds and mammals cannot be compared with locusts[58]. Also, in addition to human nutrition, locusts can be used to feed fish, livestock, poultry, etc.[58-64 ,46]. Considering that most of the diet of farmed birds consists of corn and soy, we can consider locusts as the best alternative for these inputs due to their high protein[66 ,65].

Observing the feeding of geladas, wolves, and ravens on desert locusts in the Gwasa Plateau located in Ethiopia in 2009[67] showed how far locusts can enter the food chain of an ecosystem. Investigating the possibility of raising poultry in pastures infested by locusts in Huang Cheng pastures in China shows that birds feed well on locusts and this feeding increases the quantity and quality of their meat[68].

Table 5. Resources needed to produce 1kg of protein.

		The amount of water required to produce 1 kg of protein	The amount of feed needed to produce 1 kg of protein
1	Cow	1500*	20**
2	Pig	600*	6.7**
3	Chicken	360*	3.3**
4	locust	1*	1.7**

*- The contents are in liter (Li).

**- The contents are based on kilogram (kg).

Research shows that 46-56% of the dry weight of a locust is protein. The volume of fat is estimated at 31-35%, which is less than protein. Chitin in locust is 6-13% and the share of saturated and unsaturated fatty acids is 44% and 54%, respectively. The amount of cholesterol in a locust is about 286mg/100gr and it is higher than the cholesterol of red meat or chicken meat[70 ,69]. Locust meat also contains iodine, phosphorus, iron, thiamin, riboflavin, niacin, calcium, magnesium, selenium, and vitamin B[72 ,71]. Locust's carbohydrate level is very low, and that is why it is considered a suitable meal in some diets in Southeast Asian countries. Edible insects are a more suitable source of energy compared to soy, corn, lentils, meat, and legumes. The quality of grasshopper meat is improved by feeding on the leaves of nitrogenous plants[74 ,73 ,40].

Table 6. Nutritional value of locust meat (100gr).

1	Protein	3.14*
2	Fat	3.3*
3	Carbohydrate	2.2*
4	Calcium	5.27**
5	Iron	0.3**

*- The contents are based on gram(gr).

**- The contents are based on milliliters per gram (ml/gr).

5. Summary and Conclusion

One of the behavioral characteristics of locusts is their attraction to light, which can cause them to be trapped[75]. Research results in the Mauritanian desert showed that at night locusts are attracted to light and gather on tall plants[76]. Researchers of the Chinese Agricultural Engineering Association have found that locusts absorb visible light rays and show a positive phototactic effect[77]. On the other hand, the positive response of the visual system of locusts to 610 nm rays of orange light has been reported[79 ,78]. Also, reports indicate an increase in phototaxis at a temperature of 65°C[80].

After examining and analyzing the results obtained in the field phase of this research, it can be concluded that because there were more locusts on the control field compared to the trapped field, then the crop planted on the control field was more vulnerable to damage and the crop cultivated on the trapped land has been relatively more protected from the pest bite. This result can be checked by observing the results obtained from comparing the amount of hay harvested from each of the fields.

The reason for the lower average weight and number of locusts counted on the trapped ground is that the locusts were more attracted to the traps and were less close to the crop. This is proof that the traps have been able to keep the attention of the invading locusts away from the crop and trap them. This result can be proven by comparing the difference in the average weight and number of locusts trapped in the trap compared to the average weight and number of locusts on the field where the trap was placed and also on the control field.

The difference between the average weight and number of locusts in the traps with the average weight and number of locusts on the trapped field shows that this land was also attacked by locusts, but the traps prevented irreparable damage to the crop. Even the trapped farm attracted more locusts than normal due to the presence of incandescent lamps. But this did not cause the amount of damage caused by the pest to go out of control. On the contrary, due to the presence of traps, the damage was much less than the farm without traps.

Also, the difference between the weight and the number of locusts on the control field with the number of locusts in the traps, that is, although the locusts were present in the trapped field (the same as the control field), most of them were attracted to the traps and trapped. But there was no trap in the witness's farm, so they had more opportunity to be near the crop and damage it.

By comparing the statistics obtained from the weight and the number of locusts counted on 1 square meter of land in each of the farms, it was found that there were always fewer locusts on the ground equipped with light traps. At the same time, the weight and number of locusts in the traps show that the traps have been successful in attracting the locusts. By trapping the locusts, the traps prevent them from moving and prevent the spread of the pest. Also, the possibility of migration was taken away from them, and besides, the locusts were no longer able to lay eggs.

Due to the weight and the significant number of live and trapped locusts in the traps, the farmer could earn money by selling the locusts caught as a guarantee to the agricultural jihad departments. In addition, he claims the damage to his product through insurance.

It should be considered a necessity that creating diversity in food supply sources for communities helps food security. The difficulty of the food production process in farms, poultry farms, and animal husbandry are the reasons that will lead the world to use insects as much as possible in the not-too-distant future[58]. Hunting locusts is not impossible, and they can be hunted at a low cost and get an opportunity from the threat[81].

The following subjects are suggested to researchers:

- Study the methods of attracting locusts to traps and trapped lands during the day.
- Study on identifying the best time for trapping to prevent the formation of insurgent populations.
- Study on locating suitable lands for trapping and attracting locusts to livestock.
- Study on improving the performance and increasing the efficiency of traps.
- Study the extent of preventing the entry of toxins into the food chain in the case of hunting locusts.

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Financial resources: The price of 20 metal barrels was $150, a metal cutting machine (mini mill) was $75, a metal welding machine was $69, a scale was $146, and lamps, electric wires, and other equipment were $55. This research had a total cost of $495, which was 100% funded by the researcher, and no financial aid was received.

Additional items: All required details are available.

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References

.1 Samways, M.J., et al., *Solutions for humanity on how to conserve insects.* Biological Conservation, 2020. 242: p. 108427.
.2 Joern, A., *Feeding patterns in grasshoppers (Orthoptera: Acrididae): factors influencing diet specialization.* Oecologia, 1979. 3 :(3)8p. 325-347.
.3 Peng, W., et al., *A review of historical and recent locust outbreaks: Links to global warming, food security and mitigation strategies.* Environmental research, 2020. 191: p. 110046.
.4 Le Gall, M., R. Overson, and A. Cease, *A global review on locusts (Orthoptera: Acrididae) and their interactions with livestock grazing practices.* Frontiers in Ecology and Evolution, 2019. 7: p. 263.
.5 Moharana, S., et al., *A systematic review of behavioral aspects & management techniques to control locusts.* International Journal for Science and Advance Research in Technology, 2020. 6(7): p. 361-369.
.6 Symmons, P. and K. Cressman, *Desert locust guidelines: biology and behaviour.* FAO, Rome, 2001.
.7 Klein, I., et al., *Predicting suitable breeding areas for different locust species–A multi-scale approach accounting for environmental conditions and current land cover situation.* International Journal of Applied Earth Observation and Geoinformation, 2022. 107: p. 102672.
.8 Ellenburg, W.L., et al., *Detecting desert locust breeding grounds: A Satellite-Assisted modeling approach.* Remote Sensing, 2021. 13(7): p. 1276.
.9 Kimathi, E., et al., *Prediction of breeding regions for the desert locust Schistocerca gregaria in East Africa.* Scientific Reports, 2020. 1 :(1)0 p. 1-10.
.10 Cheke, R.A., et al., *Evidence for a causal relationship between the solar cycle and locust abundance.* Agronomy, 2020. 11(1): p. 69.
.11 Guo, X., et al., *4-Vinylanisole is an aggregation pheromone in locusts.* Nature, 2020. 584(7822): p.588-584 .
.12 Nakano, M., et al., *Chemical Ecology and Olfaction in Short-Horned Grasshoppers (Orthoptera: Acrididae).* Journal of Chemical Ecology, 2022. 48(2): p. 121-140.
.13 Tyśkiewicz, K., et al., *Characterization of bioactive compounds in the biomass of black locust, poplar and willow.* Trees, 2019. 33(5): p. 1235-1263.

.14 Pflüger, H.-J. and P. Bräunig, *One hundred years of phase polymorphism research in locusts.* Journal of Comparative Physiology A, 2021. 207(3): p. 321-326.
.15 Zhang, L., et al., *Locust and grasshopper management.* Annu. Rev. Entomol, 2019. 64(1): p. 15-34.
.16 Çiplak, B., *Locust and grasshopper outbreaks in the near east: Review under global warming context.* Agronomy, 2021. 11(1): p. 111.
.17 Bouteiller, X., et al., *The seeds of invasion: enhanced germination in invasive European populations of black locust (Robinia pseudoacacia L.) compared to native American populations.* Plant Biology, 2021. 23(6): p. 1006-1017.
.18 Meynard, C.N., et al., *On the relative role of climate change and management in the current desert locust outbreak in East Africa.* Global Change Biology, 2020. 26(7): p. 3753-3755.
.19 Lockwood, J.A. and L.D. Debrey, *A solution for the sudden and unexplained extinction of the Rocky Mountain grasshopper (Orthoptera: Acrididae).* Environmental Entomology, 1990. 19(5): p. 1194-1205.
.20 Rosenberg, J. and P.J. Burt, *Windborne displacements of desert locusts from Africa to the Caribbean and South America.* Aerobiologia, 1999. 15(3): p. 167-175.
.21 Lecoq, M. *Desert locust threat to agricultural development and food security and FAO/international role in its control*. 2003. Arab Society for Plant Protection.
.22 Skaf, R., G. Popov, and J. Roffey, *The Desert Locust: an international challenge.* Philosophical Transactions of the Royal Society of London. B, Biological Sciences, 1990. 328(1251): p. 525-538.
.23 Lecoq, M., *Recent progress in Desert and Migratory Locust management in Africa. Are preventative actions possible?* Journal of Orthoptera Research, 2001. 10(2): p. 277-291.
.24 Klein, I., N. Oppelt, and C. Kuenzer, *Application of remote sensing data for locust research and management—a review.* Insects, 2021. 12(3): p. 233.
.25 Word, M.L., et al., *Soil-targeted interventions could alleviate locust and grasshopper pest pressure in West Africa.* Science of the Total Environment, 2019. 663: p. 632-643.
.26 Mayfield-Mack, L.D., *Combating the green imps of Satan: Efforts of Nebraskans against the Rocky Mountain locust infestations of the 1870s*. 2012: University of Nebraska at Kearney.
.27 Ahmad, M.N., Z. Shao, and O. Altan, *Effect of locust invasion and mitigation using remote sensing techniques: a case study of North Sindh Pakistan.* Photogrammetric Engineering & Remote Sensing, 2022. 88(1): p. 47-53.
.28 Ojewumi, M.E., et al. *Phenomenological Model Development of Percentage Protein Present in Fermented African Locust Beans Seed*. in *Journal of Physics: Conference Series*. 2019. IOP Publishing.
.29 Wu, H. and N.G. Rozlomiy. *Research of Beauveria bassianao the field control of Locusta migratoria manilensis Meyen*. in *IOP Conference Series: Earth and Environmental Science*. 2021. IOP Publishing.
.30 Dakhel, W.H., S.T. Jaronski, and S. Schell, *Control of pest grasshoppers in North America.* Insects, 2020. 11(9): p. 566.
.31 Showier, A.T., *Desert locust control, public health, and environmental sustainability in North Africa*, in *The North African environment at risk*. 2019, Routledge. p. 217-240.
.32 Raji, I.A., et al., *Bird species use of Tapinanthus dodoneifolius mistletoes parasitising African locust bean trees Parkia biglobosa in Amurum Forest Reserve, Nigeria.* Journal of Ornithology, 2021. 162(4): p. 1129-1140.
.33 Chen, L., et al., *Complete genome of a unicellular parasite (Antonospora locustae) and transcriptional interactions with its host locust.* Microb Genom, 2020. 6.(9)
.34 Zhang, L. and M. Lecoq, *Nosema locustae (Protozoa, Microsporidia), a biological agent for Locust and Grasshopper control.* Agronomy, 2021. 11(4): p. 711.
.35 Kamga, S.F., et al., *The effect of climate variability in the efficacy of the entomopathogenic fungus Metarhizium acridum against the desert locust Schistocerca gregaria.* Scientific Reports, 2022. 12(1): p. 1-15.
.36 Jiang, Z.-Y., P. Ligoxygakis, and Y.-X. Xia, *HYD3, a conidial hydrophobin of the fungal entomopathogen Metarhizium acridum induces the immunity of its specialist host locust.* International Journal of Biological Macromolecules, 2020. 165: p. 1303-1311.
.37 Lavy, O., et al., *Locust bacterial symbionts: An update.* Insects, 2020. 11(10): p. 655.
.38 Lavy, O., et al., *The effect of density-dependent phase on the locust gut bacterial composition.* Frontiers in microbiology, 2019. 9: p. 3020.
.39 Nelson, K., E. Muge, and B. Wamalwa, *Cellulolytic Bacillus species isolated from the gut of the desert locust Schistocerca gregaria.* Scientific African, 2021. 11: p. e00665.
.40 Joern, A. and S.T. Behmer, *Impact of diet quality on demographic attributes in adult grasshoppers and the nitrogen limitation hypothesis.* Ecological Entomology, 1998. 23(2): p. 174-184.
.41 Üner, O., Ü. Geçgel, and T. Avcu, *Comparisons of activated carbons produced from sycamore balls, ripe black locust seed pods, and Nerium oleander fruits and also their H2 storage studies.* Carbon Letters, 2021. 31(1): p. 75-92.
.42 Ramanujam, B., et al ,*Management of insect pests by microorganisms.* Proceedings of the Indian National Science Academy, 2014. 80(2): p. 455-471.
.43 Maina, U., et al., *A review on the use of entomopathogenic fungi in the management of insect pests of field crops.* J. Entomol .Zool. Stud, 2018. 6(1): p. 27-32.
.44 Lockwood, J.A., R. Anderson-Sprecher, and S.P. Schell, *When less is more: optimization of reduced agent-area treatments (RAATs) for management of rangeland grasshoppers.* Crop Protection, 2002. 21(7): p. 551-562.
.45 Tashian, R.E., et al., *Carbonic anhydrase (CA)-related proteins (CA-RPs), and transmembrane proteins with CA or CA-RP domains.* The carbonic anhydrases, 2000: p. 105-120.

.46 Van Huis, A., *Insects as food and feed, a new emerging agricultural sector: a review.* Journal of Insects as Food and Feed, 2020. 6(1): p. 27-44.
.47 Yudaev, I., et al. *Methodology and Modeling of the Application of Electrophysical Methods for Locust Pest Control*. in *International Conference on Intelligent Computing & Optimization*. 202 .3Springer.
.48 Alekseev, A., et al., *Characterization and biological action of avermectin granules on the Moroccan Locust, Dociostaurus maroccanus (Orthoptera: Acrididae).* Journal of Economic Entomology, 2019. 112(6): p. 2663-2669.
.49 Githae, E.W. and E.K. Kuria, *Biological control of desert locust (Schistocerca gregaria Forskål).* CAB Rev. Perspect. Agric. Vet. Sci. Nutr. Nat. Resour, 2021. 16: p. 13.
.50 Zhu, B., et al., *MicroRNA-998–3p contributes to Cry1Ac-resistance by targeting ABCC2 in lepidopteran insects.* Insect biochemistry and molecular biology, 2020. 117: p. 103283.
.51 Hov, Ø., et al., *Desert locust populations, rainfall and climate change: insights from phenomenological models using gridded monthly data.*
.52 Hanboonsong, Y., T. Jamjanya, and P.B. Durst, *Six-legged livestock: edible insect farming, collection and marketing in Thailand.* RAP publication, 2013. 3: p. 8-21.
.53 Van Huis, A., et al., *Edible insects: future prospects for food and feed security*. 2013: Food and agriculture organization of the United Nations.
.54 Huis, A.v., et al., *Edible insects: future prospects for food and feed security*. FAO Forestry paper, 2013.(171)
.55 Toti, E., et al., *Entomophagy: A Narrative Review on Nutritional Value, Safety, Cultural Acceptance and A Focus on the Role of Food Neophobia in Italy.* European Journal of Investigation in Health, Psychology and Education, 2020. 10(2): p. 628-643.
.56 Srivastava, S., N. Babu, and H. Pandey, *Traditional insect bioprospecting–As human food and medicine.* 2009.
.57 Tratalos, J.A., et al., *Desert locust populations, rainfall and climate change: insights from phenomenological models using gridded monthly data.* Climate Research, 2010. 43(3): p. 229-239.
.58 Makkar, H.P., *Smart livestock feeding strategies for harvesting triple gain–the desired outcomes in planet, people and profit dimensions: a developing country perspective.* Animal Production Science, 2016. 56(3): p. 519-534.
.59 DeFoliart, G.R., *The human use of insects as food and as animal feed.* American Entomologist, 1989. 35(1): p. 22-36.
.60 Govorushko, S., *Global status of insects as food and feed source: A review.* Trends in Food Science & Technology, 2019. 91: p. 436-445.
.61 Dobermann, D., J. Swift, and L. Field, *Opportunities and hurdles of edible insects for food and feed.* Nutrition Bulletin, 2017. 42(4): p. 293-308.
.62 van Huis, A., *Prospects of insects as food and feed.* Organic Agriculture, 2021. 11(2): p. 301-308.
.63 Van Huis, A. and D.G. Oonincx, *The environmental sustainability of insects as food and feed. A review.* Agronomy for Sustainable Development, 2017. 37(5): p. 1-14.
.64 Van Huis, A., *Potential of insects as food and feed in assuring food security.* Annual review of entomology, 2013. 58: p. 563-583.
.65 Khan, S.H., *Recent advances in role of insects as alternative protein source in poultry nutrition.* Journal of Applied Animal Research, 2018. 46(1): p. 1144-1157.
.66 Khusro, M., N.R. Andrew, and A. Nicholas, *Insects as poultry feed: a scoping study for poultry production systems in Australia* . World's Poultry Science Journal, 2012. 68(3): p. 435-446.
.67 Fashing, P.J., N. Nguyen, and N.J. Fashing, *Behavior of geladas and other endemic wildlife during a desert locust outbreak at Guassa, Ethiopia: ecological and conservation implications*. Primates, 2010. 51(3): p. 193-197.
.68 Sun, T., et al., *Aspects of lipid oxidation of meat from free-range broilers consuming a diet containing grasshoppers on alpine steppe of the Tibetan Plateau.* Poultry Science, 2012. 91(1): p. 224-231.
.69 Adámková, A., et al., *Nutritional Potential of Selected Insect Species Reared on the Island of Sumatra.* International Journal of Environmental Research and Public Health, 2017. 14(5): p. 521.
.70 Makkar, H.P., et al., *State-of-the-art on use of insects as animal feed.* Animal feed science and technology, 2014. 197: p. 1-33.
.71 Altowairqi, A.A., A.M. Baghdadi, and N.T. Elsharawy, *Hydrocolloids is a new trend as meat preservative.* World Journal of Biology Pharmacy and Health Sciences, 2022. 9(3): p. 020-029.
.72 Salama, S.M ,*Nutrient composition and bioactive components of the migratory locust (Locusta migratoria)*, in *African Edible Insects As Alternative Source of Food, Oil, Protein and Bioactive Components*. 2020, Springer. p. 231-239.
.73 Ghosh, S., P. Haldar, and D.K. Mandal, *Suitable food plants for mass rearing of the short-horn grasshopper Oxya hyla hyla (Orthoptera: Acrididae).* European Journal of Entomology, 2014. 111.(3)
.74 Van Huis, A., et al., *Relationships between food quality and fitness in the desert locust ,Schistocerca gregaria, and its distribution over habitats on the Red Sea coastal plain of Sudan.* Entomologia Experimentalis et Applicata, 2008. 127(2): p. 144-156.
.75 Farrow, R., *A modified light-trap for obtaining large samples of night-flying locusts and grasshoppers.* Australian Journal of Entomology, 1974. 13(4): p. 357-360.
.76 Maeno, K.O., et al., *Adult Desert Locust Swarms, Schistocerca gregaria, Preferentially Roost in the Tallest Plants at Any Given Site in the Sahara Desert.* Agronomy, 2020. 10 :(12)p. 1923.
.77 Qihang, L., X. Zhe, and Z. Qiang, *Visual reaction effects induced and stimulated by different lights on phototactic bio-behaviors in Locusta migratoria manilensis.* International Journal of Agricultural and Biological Engineering, 2017. 1 :(4)0p. 173-181.
.78 Liu, Q., X. Hou, and Q. Zhou, *Influence of locusts visual reaction effect stimulated by orange light on response effect.* Journal of Biobased Materials and Bioenergy, 2017. 11(4): p. 264-270.
.79 Liu, Q., et al., *Regulation of visual sensitivity responses in locusts stimulated by different spectral lights.* Pakistan J. Zool, 2019. 51(6): p. 2245-2255.

doi:10.20944/preprints202302.0029.v1

.80 Liu, Q. and Q. Zhou, *Influence of light and heating temperature coupling effect onphototactic gain of locusts.* Transactions of the Chinese Society of Agricultural Engineering, 2011. 27(6): p. 110-116.
.81 Baghersad, V., A. Davari, and L. Sefidbari, *Policy-making based on entrepreneurship ecosystem and development of knowledge-based companies.* Karafan Quarterly Scientific Journal, 202117 .(Special Issue): p. 67-81.