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Effectiveness of Traditional Approaches in the Management of Desert Locusts (*Schistocerca gregaria* Forskål in Arid Areas of Isiolo and Laikipia (Kenya)

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ABSTRACT

Keywords

Desert locust, Kenya, Physical methods, cultural methods, Traditional locust control

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The Horn of Africa has witnessed an upsurge in desert locust invasions (*Schistocerca gregaria* Forskål). Curiously, the first-line of management is often based on traditional methods. We assessed the effectiveness the traditional methods of desert locust control in two rural arid areas in Kenya between 2019 and 2020 using a questionnaire survey. Large swarms of desert locusts were observed during the migratory, feeding, and developmental stages during the driest months. Most of the identified stages were adults and 3rd nymphal instars. The past desert locust preventive strategies among the respondents were early planting, high seed rates, early warning strategies, and information interchange. The physical/mechanical control strategies used by the respondents during the outbreaks included digging up eggs, handpicking, smoking, and baiting. The cultural desert locust control strategies used by the respondents were noise from beating drums, metallic containers, and motorbike hooting. These methods had low effectiveness in controlling desert locust populations. Traditional methods of locust control should not rely solely on desert locust management. There is a need to integrate these traditional methods with new methods for desert locust control only when the swarms are low.

Introduction

Desert locusts (*Schistocerca gregaria*) are part of approximately 20 species of short-horned grasshoppers belonging to the Acrididae family (Hassan & Aslam, 2024). Invasion by desert locusts occurs mainly in the drier areas of Africa North of the equator, Arabian Peninsula, Middle East, West Africa, Southwest Asia, and Horn of Africa (Dong *et al.,* 2023; Qayyum *et al.,* 2024). Desert locusts have invaded an estimated area of 29-35 million km2 where they can migrate over successive generations (Chen *et al.,* 2020; Retkute *et al.,* 2023; Anum *et al.,* 2024). Their distribution is correlated with climatic conditions where high rainfall leads to increased vegetation biomass, promoting their sustenance (Peng *et al.,* 2020; Youngblood *et al.,* 2023; Tang *et al.,* 2023). Environmental cues are also responsible for changes in behavioral modifications, leading to the formation of adult swarms (Tang *et al.,* 2023; Hassan & Aslam, 2024). Sustained suitable conditions in their migratory path lasting up to two years, usually lead to an exponential rise in their population before eventually descending ravenously in previously uninfested areas (Wang *et al.,* 2023; Çiplak & Uluar, 2024). Desert locusts can occur as solitary at low densities (Günzel *et al.,* 2023) or as gregarious phases when their numbers and densities increase (Foquet *et al.,* 2022; Babar, 2023).

To control the desert locust menace, the local, national, regional, and international components often work in a coordinated approach to achieve global action plans for desert locust meta-population management (Retkute *et al.,* 2021; Rajak & Yadav, 2023). The control strategy target where gregarisation occurs, through monitoring or employing infrastructure to control gregarising and gregarious desert locust populations (Matthews, 2021; Retkute *et al.,* 2021). Desert swarms are often monitored when the numbers are low, but control programs are evoked when the swarms grow substantially large, start migration, and spread (Lecoq, 2001; Showler *et al.,* 2021). However, this seems to sum up the simplistic solution put together on a large scale and the coordinated approach in the management of desert locust invasions, which precludes local occurrences in various regions.

In most countries, desert locusts often invade remote locations when there is little or no preparedness or large-scale coordinated efforts to control these pests (Showler *et al.,* 2022). In such cases, the first line in managing the invasion involves suites of traditional methods before resorting to chemical methods (Sharma, 2014; Arshad *et al.,* 2022a). Most of these traditional management methods, alone or in combination with chemical control, are often more effective against small, mainly solitarous, desert locust infestations (Shahzad *et al.,* 2024). However, for large swarms of gregarious desert locusts, chemical methods must always be used even when traditional methods have been put in place to ensure effective control.

Traditional approaches to control or prevent desert locusts have been used since the pioneering work of Uvarov to control bands and small swarms before large swarm outbreaks (Sharma, 2014). When properly applied, these preventative strategies are useful for minimizing the duration, frequency, and intensity of the gregarious desert locust upsurge. The three phases of desert locust management were outbreak prevention, upsurge prevention, and upsurge elimination. This has led to several approaches in traditional methods of desert locust control, which can be subdivided into preventive, mechanical/physical, and cultural approaches (Lecoq, 2005; Van Huis, 1992; Lecoq, 2001). Unfortunately, many of these programs have not been clearly defined and identified in many regions with desert locust invasions. Therefore, the current study aimed to identify the status and effectiveness of traditional approaches in the management of desert locust swarms Kenya.

Materials and Methods

Research Design

This study used a descriptive research design to establish the cultural methods of control and management of desert locusts.

Study Area

The sample collection sites for the study were the Isiolo and Laikipia counties (Figure 1). The sites were identified as egg-laying sites in the arid parts of Kenya past Kenyan government-monitoring agencies. These counties also suffered large swarms of deserts migrating from other Horns of African countries such as Somalia, Ethiopia, Djibouti, and Eritrea.

Target population and sample size

The target population comprised 687 households in two agro-ecological zones. The sample size for households was calculated based on Fisher's statistical formula for sample size (Charan & Biswas, 2013):

$$\text{Sample size} = \frac{Z_{1-\alpha/2}{}^{2}(p)(1-p)}{d^2}$$

$Z_{1-\alpha/2}$ = is the standard normal variate, (at 5% type 1 error) and is 1.96.

p = 0.5 (the estimated % of respondents reporting desert locust invasion 90%)

q (1-p) = 0.5 (the estimated % of respondents not reporting desert locust invasion 10%)

d = Absolute error or precision (0.05)

Thus, Therefore, the sample size of respondents was 138. Equal numbers of samples were collected from each agroecological zone. That is, 69 each were from Isiolo and Laikipia.

Sampling Design

Proportional stratified random sampling was used to select the study sample. The sampling areas were stratified into two counties. The sample for local residents per county was determined using proportionate sampling, which allows for picking an element proportional to its weight. Residents were selected through systematic sampling at specific intervals (k = N/n, where k = systematic sampling interval, N = Population size and n = sample size) until the required sample size was obtained from the target population.

Research Instruments, Validity and Reliability

Data were collected using questionnaires. The questionnaire contained information on the sociodemographic characteristics of the respondents, incidences of desert locust invasion, and desert locust prevention and management strategies. The validity of the instrument was ascertained through expert judgment (Demirpence & Putnam, 2020), where a prior discussion of items in the questionnaire was conducted with other researchers in the same field. Suggestions were incorporated into the final instrument. Reliability was evaluated using Cronbach's alpha (Amirrudin *et al.,* 2021). Data for the Cronbach's alpha test were collected during piloting from respondents not selected for the current study. The data were declared reliable when Cronbach's alpha coefficient was above 0.60 (Alkhadim, 2022).

Observation and photography was used to capture the incidences of desert locust in Isiolo and Laikipia counties during the study period. The photographs were taken using Canon Powershot G7X Mark II Digital Camera.

Methods of Data Collection

A cross-sectional survey was conducted among households living in the sampled areas of Isiolo Laikipia Counties. The regions of the selected districts had experienced frequent and heavy infestation of desert locusts. This study was performed using researcher-administered questionnaires. Administration of the questionnaires were through face to face in the local language. Informed consent was sought from the respondents verbally. The verbal consent was used because most of the respondents were not literate and relied on vernacular languages to communicate prompting the researcher to use a translator for verbal consent from the respondents. The University of Eldoret Ethical Approval Committee approved the consent for this study. The verbal consent was obtained using a voice recorder.

Data Analysis

Differences in the socio-economic profiles of the respondents was analyzed using chi-square. Significance was declared at $P < 0.05$. The respondents were provided with a Likert Scale where 1. SD = Strongly Disagree; 2. D = Disagree; 3. N = Neutral; 4. A=Agree; and 5. SA = Strongly Agree, and were requested to rate their level of agreement with statements that were related to the effectiveness of traditional methods of controlling locust. Mean weighted rank were then computed to determine the effectiveness of the methods.

Ethical Considerations

This study incorporated the principles of responsible research (Resnik & Shamoo, 2017) including informed consent, honesty, objectivity, confidentiality, respect for subjects, and intellectual property rights. This study was approved by the University of Eldoret Ethical Approval Committee (UoE/RES/Approval/PBS/054). Permits to conduct this research were sourced from the National Commission for Science, Technology, and Innovation (NACOSTI).

Results and Discussion

Questionnaire Return Rate

The data contained responses from households in the selected regions of Isiolo Laikipia Counties. A total of 138 self-administered questionnaires were distributed, of which 122 were returned, resulting in an 88.4% return rate. The return rate from Isiolo was 64 out of 69(92.7%), while in Laikipia, it was 58 out of 69(84.0%).

The researcher analyzed all returned questionnaires, as they were found to have appropriate response rates. A questionnaire return rate of over 70% is adequate to validate any survey-based study (Fosnacht *et al.,* 2017). Hence, a return rate of 87.7% is deemed sufficient (Lund, 2023). The lower return rate from Isiolo was due to high levels of sudden insecurity compared with Laikipia.

Socio-economic Status of the Respondents

The socioeconomic characteristics of respondents in the two sampled locations are listed in Table 1. There were varied responses concerning the social aspects of the respondents (age, gender and level of education). There were no significant differences in age distribution between the respondents in the Isiolo and Laikipia populations (χ^2 = 4.989, df = 3, P = 0.173). However, there was a significant age distribution among the respondents within the Isiolo (χ^2 = 159.518, df = 3, P < 0.001) and Laikipia (χ^2 = 143.890, df = 3, P < 0.001) regions. The majority of the respondents were aged 51-65 years followed by those aged above 65 years, while there were few respondents below 35 years. A significant gender disparity was observed between respondents in Isiolo and Laikipia (χ^2 = 10.073, df = 2, P = 0.0026). Most of the household head respondents in Isiolo were female, whereas those in Laikipia were male. There were no significant differences in the level of education among the respondents in Isiolo and Laikipia (χ^2 = 2.152, df = 4, P = 0.0821). The majority of the respondents from both regions had no formal education, followed by those with primary and secondary levels of education. The tertiary education level was generally low for both sets of respondents (<12%).

In terms of demographic attributes, the study found no significant differences in household size among the respondents in Isiolo and Laikipia (χ^2 = 1.911, df = 3, P = 0.201). The household size for most respondents ranged from three to five, followed by six to ten household members. Monthly household income did not differ significantly between Isiolo and Laikipia (χ^2 = 1.442, df = 3, P = 0.301). In terms of the economic well-being of the respondents, the household monthly income for the majority of the respondents at both sites was less than 50 USD, followed by 50 to 100 USD. Most of the respondents at both sites were pastoralists, followed by casual laborers with a smaller number engaging in business.

Incidences of desert locust invasion

The incidence of desert locust invasion in Isiolo and Laikipia counties in 2019 is shown in Figure 2. One of the residents described this outbreak as the largest to have occurred in the region over the 40 years that he had stayed there. Large swarms of desert locusts were observed in migratory, feeding, and developmental stage modes. The captured incidences showed damage to trees and crops during their occurrence.

The frequency of locust attacks, as recalled by the respondents, is shown in Figure 3. Based on the figure, the locust problem occurred mostly in April, with sporadic numbers reported in March, February, and August.

Information on the coloration and stage of desert locust for most of the respondents in Isiolo and Laikipia Counties are shown in Figure 4. Most of the identified locusts were adults and 3rd nymphal instars of desert locusts.

Desert locust prevention and management strategies

The desert locust preventive strategies used by respondents in the past during outbreaks are provided in Table 2. The most common methods used were early planting, high seed rates, early warning strategies, and information interchange. However, differences in the use of all the preventive strategies were similar between Isiolo and Laikipia counties (P > 0.05).

The physical and mechanical control strategies used by the respondents during the outbreaks are listed in Table 3. The most common methods of physical/mechanical control include digging eggs, handpicking, smoke, and baiting. Only digging up of eggs was different between the two regions.

The cultural desert locust control strategies used by respondents during the outbreaks are shown in Table 4. The component method of cultural control of desert locusts was beating drums, noise, and metal beating, while in some regions motorbike hooting.

Table 5 shows that the rating for traditional methods of desert control. The preventive strategies against the desert locust scored a rating of 2.14 ± 1.47 out of 5.00 and 2.13 ± 0.97 out of 5.00 in Isiolo and Laikipia Counties respectively. This indicates low effectiveness of the preventive strategies in controlling desert locust. Similarly, the Likert scores of physical/mechanical control methods were 1.74 ± 0.48 out of 5.00 and 1.76 ± 0.58 out of 5.00 for Isiolo and Laikipia respectively suggesting lower effectiveness of these strategies. The rating of cultural methods of control (mean of 2.08) also indicate less effectiveness of the strategies in controlling desert locusts in the two regions. From the overall traditional methods, the mean rating of 1.99 indicate low effectiveness of the traditional strategies in controlling desert locusts.

The desert locust invasion that occurred in 2019 across the two study counties was unprecedented and larger in magnitude than previously witnessed. In fact, it has been reported that the magnitude of desert locust incidence witnessed in the region is larger in magnitude than those in the last 70 years (Kimathi *et al.,* 2020), when large swarm migration southward ravaged any vegetation. Early reported accounts of desert locust invasion and destruction of vegetation in these regions date back to the 1940s (Waloff, 1946; Gunn, 1948), when 25 million were affected (Landmann *et al.,* 2023). We observed that in the path of desert locust migration, there was a large destruction of crops, pasture, and any green vegetation in their pathway.

Desert locusts were observed in larger swarms after unusually heavy rains following a prolonged drought that occurred in March, April, and August. The large desert locust swarm coincides with the locust breeding reported between 2019 and 2020 in Eritrea, Somalia, and Yemen, which was attributed to unusually heavy rainfall after prolonged drought (UNEP, 2020). It has been reported that when there are heavy rains after a long period of drought, the soil becomes moist and supports a large quantity of lush vegetation, which is the perfect condition for the rapid breeding of desert locusts (Wang *et al.,* 2021; Dong *et al.,* 2023). The locusts begin to produce rapidly and become even more crowded together, leading to a lack of food, causing migration in search of food (Usman *et al.,* 2022). Although it is widely believed that the same scenario is present in Northern Kenya, a large incidence of desert locust is believed to have come from elsewhere, especially along the dry horn of Africa, where reports of large swarms of desert locusts were reported earlier than in Kenya (Dong *et al.,* 2023). Therefore, it is possible that this breeding led to southward migrations of the desert locust, Kenya causing the extraordinary swarms witnessed more than 70 years ago. This could account for the high incidence of adults and 3rd nymphal instars, which are prolific feeders and can travel long distances. A consensus was that management of the desert locust was a priority. In this study covering Isiolo and Laikipia Counties, desert locust invasions were most likely to be reported in April, which coincided with the driest month in the region (Ayugi *et al.,* 2020). In the past, outbreaks of desert locusts in the region have occurred mainly in drier months (Kimathi *et al.,* 2020; Landmann *et al.,* 2023) which has also been the trend reported at the global scale (Retkute *et al.,* 2023; Retkute *et al.,* 2021). Locusts commonly occur in stages 5 or 3, which are adult gregarious locusts that cause most menace when they occur. In the study regions of Isiolo and Laikipia, it was evidenced that they had experienced low incidences of desert locust invasion, which was easy to prevent in the past. The locals used several traditional methods to prevent the occurrence of desert locusts, mainly early planting, high seed rates, early warning strategies, and information interchange. Some of these methods have been applied in China (Dong *et al.,* 2023), Pakistan (Showler *et al.,* 2022), and Nepal (Shrestha *et al.,* 2021). A preventative control strategy helps minimize the intensity of desert locust menaces but may fail to control its population. These preventive measures are used because of the lack of adequate monitoring programs and resources for early detection and prevention of outbreaks. Except for early warning strategies that were observed to be poorly executed due to a lack of trained personnel, the methods applied in the current study to prevent desert locust menace appear to differ from Uvarov's preventive control strategy (Sharma, 2014) as they seem incapable of preventing outbreaks of swarms of locusts. A good prevention strategy for desert locusts must include the analysis of rainfall patterns, breeding behavior, and breeding areas (Showler, 2019), which was not applied in the current study.

When prevention fails and there is already an outbreak or invasion by a desert locust, complete eradication is not advisable, not tenable, or simply difficult to achieve. In the present study, the mechanical/physical characteristics during the outbreaks included digging up eggs, handpicking, smoking baiting, and trapping. These methods are widely used in India (Moharana *et al.,* 2020), Nepal (Adhikari, 2020; Pandey *et al.,* 2021), China (Farhan & Kanwal, 2023), and resource-limited African countries such as Somalia (Kimathi *et al.,* 2020), Ethiopia (Ayana, 2023), Eritrea (Brader *et al.,* 2006), Sudan (Emana, 2023), Djibouti, and South Sudan (Showler & Lecoq, 2021). These methods are also consistent with those applicable in West African countries, such as Senegal, Niger, and Nigeria (Ceccato *et al.,* 2007; Vallebona *et al.,* 2008). These methods are useful when there is no alternative, or when they are the only available methods.

Table.1 Socio-economic characteristics of the respondents

Variable	Response category	Isiolo (n = 58)		Laikipia (n = 64)	
		Frequency	Percent	Frequency	Percent
Age (years)	18-35	3	5.2	5	7.8
	36-50	11	19.0	10	15.6
	51-65	32	55.2	30	46.9
	Above 65	12	20.7	19	29.7
Gender	Male	20	34.5	40	62.5
	Female	38	65.5	24	37.5
Level of education	No formal education	24	41.4	28	48.3
	Primary	22	37.9	17	29.3
	Secondary	9	15.5	13	22.4
	Tertiary	3	5.2	6	10.3
Household size	<3	20	34.5	16	25.0
	3-5	22	37.9	28	43.8
	6-10	9	15.5	12	18.8
	11-20	7	12.1	8	12.5
Household income (US$)	<50	28	48.3	31	48.4
	50-100	17	29.3	19	29.7
	101-200	11	19.0	10	15.6
	201-500	2	3.4	4	6.3
Occupation	None	11	19.0	13	20.3
	Salaried employment	7	12.1	9	14.1
	Casual labour	8	13.8	6	9.4
	Self employed	5	8.6	5	7.8
	Pastoralist	24	41.4	25	39.1
	Business	3	5.2	6	9.4

Table.2 Desert locust preventive strategies used by the farmers in the past during outbreaks

	Isiolo		Laikipia		Statistical test	
Preventive strategies	Freq.	Percent	Freq.	Percent	χ^2	*P*-value
Early planting	4	6.3	9	15.3	1.641	0.200
High seed rate	5	7.8	9	15.3	0.887	0.346
Destruction of breeding grounds	3	4.7	6	10.2	0.786	0.375
Flooding	4	6.3	3	5.1	0.275	0.600
Timely harvesting	3	4.7	7	11.9	1.344	0.246
Early warning	9	14.1	5	8.5	1.178	0.182
Monitoring	4	6.3	3	5.1	0.275	0.600
Information interchange	2	3.1	7	11.9	2.498	0.114

Figure.1 Map showing the location of the study areas

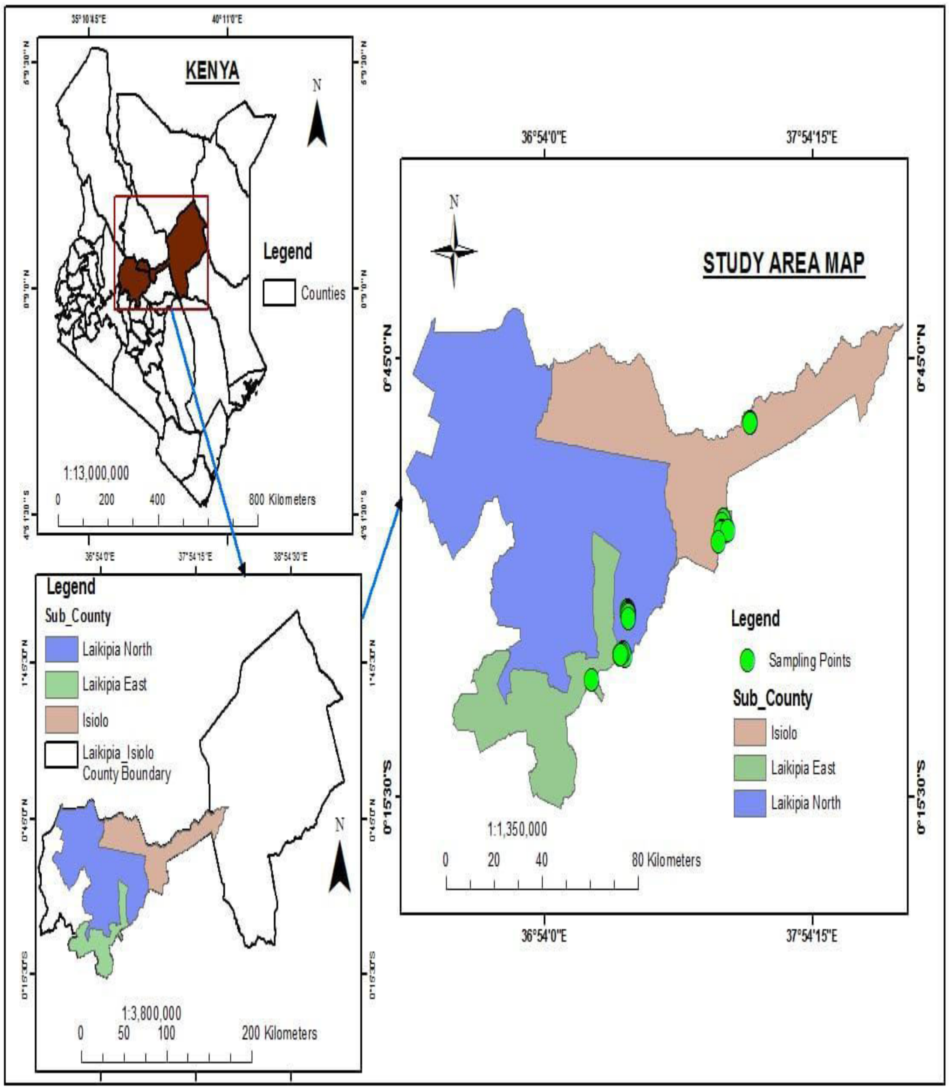


Table.3 Desert locust physical/mechanical control strategies used by the farmers during outbreaks

Physical/mechanical control methods	Isiolo		Laikipia		Statistical test	
	Freq.	Percent	Freq	Percent	χ^2	P-value
Digging up eggs	16	25.0	8	13.6	4.382	0.036*
Application of ash	3	4.7	2	3.4	0.325	0.569
Handpicking	14	21.9	8	13.6	2.788	0.095
Shaking plants	3	4.7	2	3.4	0.325	0.569
Smoke	8	12.5	7	11.9	0.230	0.631
Trapping	5	7.8	8	13.6	0.481	0.488
Baiting	10	15.6	6	10.2	0.652	0.199

Table.4 Cultural desert locust control strategies used by the farmers during outbreaks

	Isiolo		**Laikipia**		**Statistical test**	
Cultural control methods	Freq.	Percent	Freq.	Percent	Chi-square	*P*-value
Beating drums	13	20.3	9	15.3	1.436	0.231
Shouting	15	23.4	12	20.3	0.893	0.345
Metal beating	13	20.3	5	8.5	5.158	0.023
Whistling	6	9.4	3	5.1	1.425	0.233
Motorbike hooting	6	9.4	7	11.9	0.011	0.916

Table.5 Rating of effectiveness of traditional methods of controlling locusts

Statement	**Mean ± Std. Dev**	**Mean ± Std. Dev**
	Isiolo	Laikipia
Preventive strategies		
Early planting	2.21 ± 0.28	2.23 ± 0.12
High seed rate	1.43 ± 1.15	1.42 ± 1.17
Destruction of breeding grounds	2.45 ± 1.04	2.41 ± 0.69
Flooding	2.26 ± 5.26	2.23 ± 2.29
Timely harvesting	1.22 ± 0.61	1.25 ± 1.69
Early warning strategies	2.41 ± 0.38	2.42 ± 0.45
Monitoring	1.84 ± 1.47	1.80 ± 0.92
Information interchange	3.28 ± 1.56	3.25 ± 0.43
Average	**2.14 ± 1.47**	**2.13 ± 0.97**
Physical/mechanical control methods		
Digging up eggs	1.45 ± 0.19	1.45 ± 0.18
Application of ash	1.12 ± 0.42	1.22 ± 0.79
Handpicking eggs/nymphs/locust	2.37 ± 0.17	2.39 ± 0.47
Shaking plants	1.23 ± 0.91	1.25 ± 1.00
Smoke	1.89 ± 0.22	1.89 ± 0.22
Trapping	2.35 ± 0.35	2.31 ± 0.28
Baiting	2.12 ± 1.11	1.80 ± 1.13
Average	**1.74 ± 0.48**	**1.76 ± 0.58**
Cultural control methods		
Beating drums	2.12 ± 0.16	2.11 ± 0.11
Shouting	2.05 ± 0.51	2.06± 2.31
Metal beating	2.26 ± 2.24	2.28 ± 0.77
Whistling	1.55 ± 0.73	1.56 ± 0.52
Motorbike hooting	2.43 ± 0.13	2.45 ± 0.43
Average	**2.08 ± 0.75**	**2.08 ± 0.82**
Overall total	**1.99 ± 0.64**	**1.99 ± 0.79**

Figure.2 Pictures showing incidences of desert locust in Isiolo and Laikipia counties during the study period.

The pictures indicate: a) Swarms of desert locust migrating b) adult swarms attacking and devouring a tree, c) nymphal instar feeding on a local tree, d) display of an adult locusts, e) 4th Nymphal instar on maize plantation and f) swarms of 3rd nymphal instar attacking a farm.

Figure.3 Months during which there was massive problem with desert locust in Isiolo and Lakipia Counties

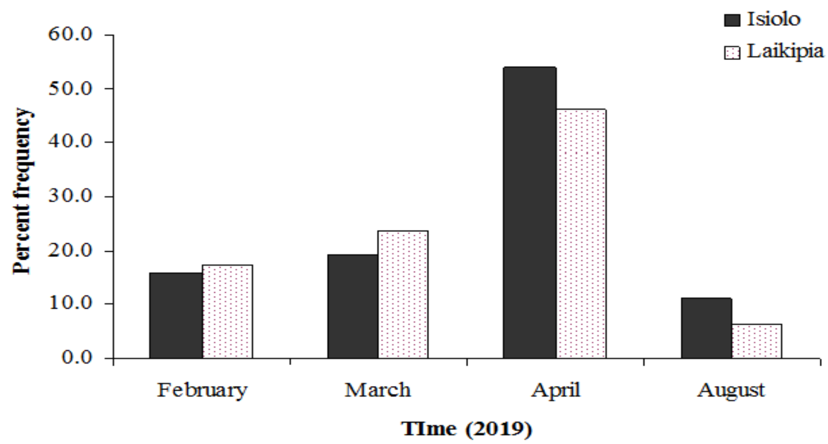
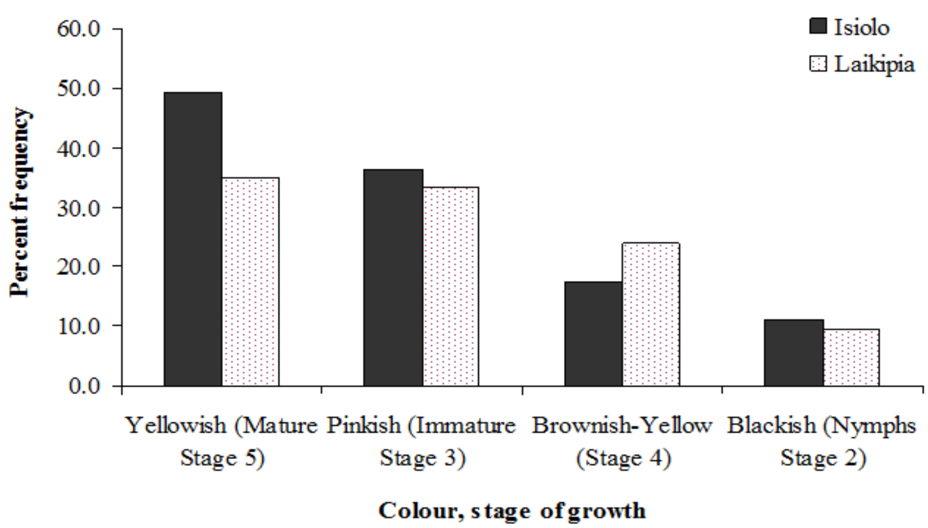


Figure.4 Colouration and stage of desert locust for most of the farmers in Isiolo and Lakipia Counties



In some instances, these mechanical/physical methods rely on the developmental stage of the desert locust, such as eggs, nymphs, or adults. When breeding grounds with large quantities of eggs are identified, these methods become very successful. However, they are less useful for controlling migratory locusts.

The cultural desert locust control strategies used by the respondents during outbreaks were noise-based, such as beating drums and metals and shouting, while in some regions, motorbike hooting was used. Many communities use cultural attachment to chase away locusts before they attack crops (Magor *et al.,* 2008). Many communities that have cultural attachments to noise believe that noise will scare away locusts and prevent them from damaging crops; hence, the use of noise has found a lot of attachment in West African countries (Brader *et al.,* 2006; Shrestha *et al.,* 2021), Uganda (Barasa *et al.,* 2023), and in Middle East countries such as Yemen and Iraq (Farhan & Kanwal, 2023). Noise can be generated through several methods; however, the most widely reported noise comes from drums and has been used in India (Narayanamma & Krishnaiah, 2020), Pakistan (Arshad *et al.,* 2022b), Indonesia (Lecoq, 1998), and some parts of the Middle East (Showler, 2019; Pandey *et al.,* 2021; Ahmad & Hussain, 2024). In many religions in Asia and Africa, beating drums were believed to drive away evil spirits and cast demons, of which locust is considered a demon that needs to be cast away (Sharma, 2014).

There was a low rating of preventive strategies and control of physical/mechanical and cultural control methods in the effective management of desert locust outbreaks and spread. These methods were used effectively in the past and in cases where there was a low density of desert locusts, and were applicable where desert locust outbreaks are from the same region where preventive or control actions are being applied. It was difficult to determine the effectiveness of these traditional preventive/control methods because of the lack of sufficient data, but the current methods applied in the study areas appeared to be ineffective when dealing with large outbreaks of migratory desert locusts. Perhaps, these methods should be applied as the first line of defence when there are no other alternatives or when the outbreak is still low.

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Author contributions

PM (Conceptualization [lead], Formal analysis [lead], Investigation [lead], Visualization [lead], Writing—original draft [lead], Writing—review & editing [equal]), LM (Investigation [supporting], Writing—original draft [supporting]), PSM, (Conceptualization [supporting], Writing—review & editing [supporting]) PM, LM, and PSM have approved the publication of this article. All authors agree to be accountable for all aspects of this study.

Data availability statement

The authors confirm that the data that support the findings of this study are openly available in [Uganda Martyrs University Institutional Repository] at [http://hdl.handle.net/20.500.12280/3160], reference number [Agro-ecology and Food Systems [2]].

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Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare that there are no relevant financial or non-financial competing interests.

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