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Development of an On-Field Autonomous Rodent Detection and Control System

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ABSTRACT

Background and Literature Context: Rodent infestation remains a major threat to agricultural productivity, causing severe crop damage and economic loss for farmers. Conventional control methods such as traps and chemical poisons require repeated human intervention and may create safety and environmental concerns, motivating the development of autonomous alternatives. **Methodology:** The study involved two phases. In the first phase, a 14-day baseline infestation assessment was conducted on three crop plots; potato, yam and cassava. Each crop plot contained eight ridges, eight bait positions and eight chew cards, while four motion-sensor cameras were mounted on four support poles, giving 12 cameras across the three experimental plots. Bait removal, chew-card marks and camera detections were recorded twice daily. In the second phase, the autonomous system, powered by a solar unit, was installed and evaluated on the potato plot because potato recorded the highest baseline infestation. The system integrated a Passive Infrared (PIR) motion sensor, relay module, timer and alarm unit to detect movement and trigger a sound alert. **Results and Discussion:** Potato recorded the highest baseline activity, with 925 percentage-points of cumulative daily infestation, 52 chew-card marks and 272 camera detections. After system deployment, the cumulative number of invaded-ridge observations declined from 104 during baseline to 18 post-deployments, representing an 82.69% reduction based on the reported counts. Three consecutive zero-infestation days were recorded at the end of the post-deployment period. **Conclusion and Recommendations:** The autonomous motion-triggered sound deterrent showed potential for reducing rodent activity under the field conditions evaluated. Longer-term trials with larger fields, quantitative control comparisons and improved camera-based rodent identification are recommended.

1. INTRODUCTION

Rodents, a major pest species, contribute to an estimated 5-10% of total food losses worldwide, with higher rates reported in regions with inadequate pest control measures, such as Sub-Saharan Africa and parts of Asia (Minter et al., 2019). These losses translate into reduced productivity and profitability for farmers and food processing industries, impacting food availability and quality on a broader scale. Traditional rodent control methods, such as traps and chemical poisons,

are limited by several factors, including effectiveness, safety, and environmental concerns (Hassanalian and Abdelkefi, 2017). Chemicals and poisons, though common, pose health risks to both humans and wildlife, while traps often require manual handling and regular monitoring, adding to labor costs. Autonomous systems provide a modern alternative by offering round-the-clock monitoring and detection without constant human intervention. The development of unmanned aerial vehicles



(UAVs), or drones, has transformed agricultural practices and could potentially revolutionize pest control in agriculture (Agbeyangi *et al.*, 2016). Drones equipped with thermal imaging and computer vision algorithms have already demonstrated the ability to autonomously detect and monitor wildlife, including pests, in various environments (Ward *et al.*, 2016).

Advancements in machine learning algorithms facilitate the detection and differentiation of pests, increasing system reliability and reducing false positives. Autonomous systems can be equipped with predictive navigation and pattern recognition capabilities, allowing them to target specific pest species, such as rodents, with greater precision (Babu *et al.*, 2017; Oyelami *et al.*, 2020). These systems' integration into pest management could result in substantial cost reductions by minimizing pesticide use, estimated at up to 20-30% in regions that adopt precision agriculture methods (Torroglosa-Garcia *et al.*, 2020).

Traditional rodent control methods, like chemical pesticides and traps, have limitations due to toxicity concerns, labour demands, and decreasing efficacy over time, especially as rodents adapt to these methods. In contrast, an autonomous rodent detection and control system powered by solar energy and sensor technologies presents a sustainable alternative, offering continuous monitoring and targeted responses without relying on harmful chemicals.

Therefore, this study aimed to develop and evaluate

an autonomous rodent detection and control system that combines motion sensing and sound-based deterrence and is powered by solar energy to reduce rodent infestation in agricultural crop fields.

2.0 MATERIALS AND METHODS

2.1 Experimental Design and Plot Establishment

Three designated experimental plots, each measuring 2 m × 2 m, were established within the study area. Each experimental plot represented one crop type: cassava, potato, or yam. Each plot contained eight ridges, with the respective crops planted on the ridges. For the baseline infestation assessment, one bait position was associated with each ridge, giving eight bait positions per crop plot. The planted crops served as the baits in this study, allowing observation of rodent interactions under field conditions.

Four support poles were securely fixed within each experimental plot to hold the motion-sensor cameras. One camera was mounted on each pole, giving four cameras per plot and 12 cameras across the three experimental plots. Each camera was mounted at a height of 1.5 m above ground level and positioned approximately 2 m from the monitored crop area to provide effective coverage within the operational range of the sensors.

Eight chew cards were installed near the crop ridges in each experimental plot, with one card associated with each ridge. Thus, 24 chew cards were used across the three experimental plots during the baseline assessment. The cards were inspected for bites, scratches and other physical signs of rodent

activity.

A Global Positioning System (GPS) device was first used to record the coordinates of the selected farmland area. This ensured accurate mapping of the test site and enabled consistent observation throughout the study period (Ahmed *et al.*, 2025). Figure 1 provides a schematic representation of the detection and control systems as set-up on the experimental plots.

2.2 Baseline Infestation Assessment.

The baseline infestation test was conducted for 14 consecutive days to evaluate rodent activity across cassava, potato and yam and to determine whether rodents were attracted to a specific crop.

Systematic daily inspections were conducted during the 14-day baseline assessment, with observations made twice daily, in the morning and late evening, to capture variations in rodent movement patterns.

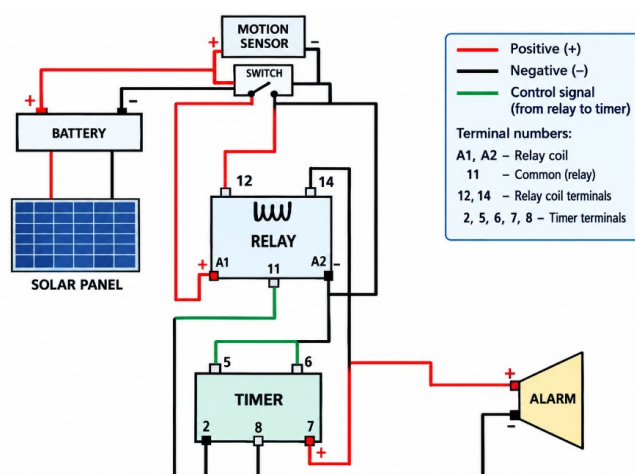


Fig. 1: Schematic arrangement of the detection and control systems as set-up on the experimental plots

During each inspection, disturbances around the planted ridges were observed; time-stamped motion-sensor camera detections were reviewed; chew cards were inspected for bites, scratches and other physical signs of activity; and environmental conditions such as rainfall or soil disturbance were recorded.

The infestation rate for each crop type was calculated from the number of invaded ridges relative to the total number of established ridges. Each crop plot contained eight ridges as shown in Figure 2 and the daily percentage infestation was calculated using Equation 1.

$$IR = \frac{N_{IR}}{N_R} \times 100 \quad (1)$$

where: IR = infestation rate (%); N_{IR} = number of invaded ridges; N_R = total number of established ridges (8 ridges per crop plot).

This formula provided a quantitative measure of infestation intensity and allowed for comparison between crops and monitoring periods.

2.3 Baseline Data Collection

Accurate data collection was maintained throughout the 14-day baseline testing period. For each observation, the number of uninjured and injured ridges, presence or absence of chew marks, motion-sensor camera detections, and evidence of new burrows or soil disturbances were recorded. Daily photographs were also taken as supplementary evidence. Data were collected on key parameters such as the number of invaded ridges, presence of chew marks, and motion sensor camera detections. These entries were recorded immediately after field observation to minimize recall errors.

In addition to written records, daily photographs were taken for each plot, focusing on planted ridges, chew cards, and any visible disturbances caused by rodents. These visual records served as supplementary evidence to validate the data obtained from sensor readings and physical observations.

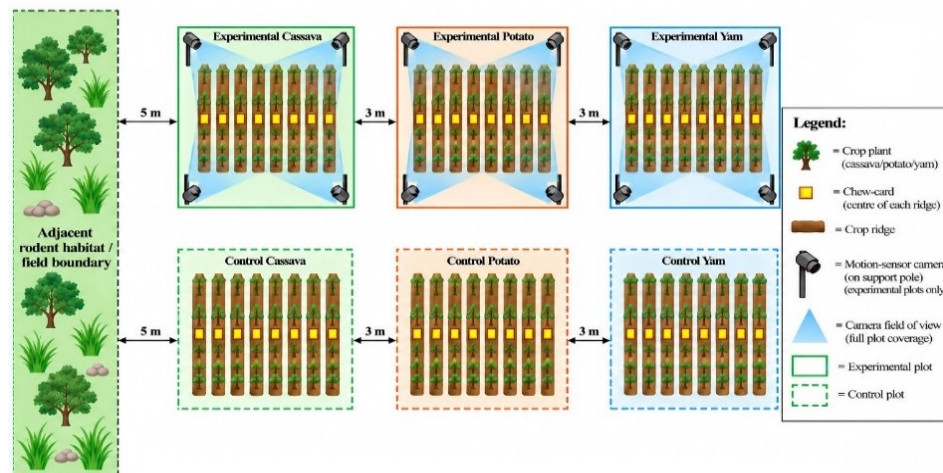


Fig. 2: 2D layout of one experimental plot showing eight ridges, eight chew-card positions and four camera support poles.

2.4 Data Analysis for Baseline Infestation Test

Data analysis was carried out using descriptive comparisons of invaded ridges, chew-card marks and motion-sensor camera detections across cassava, potato and yam. The indicators were compared to determine relative infestation intensity, crop preference, periods of peak activity and agreement between physical evidence and automated detections. Camera timestamps and daily inspection times were used to examine temporal activity patterns. The key variables included invaded ridges, chew-card marks and sensor-based detections.

2.5 System Deployment and Post-Deployment Data Collection

Following the 14-day baseline assessment, the autonomous detection and sound-deterrent system was deployed on the potato plot because potato recorded the highest baseline infestation. Post-deployment observations were conducted for 14 consecutive days using the same monitoring indicators: invaded ridges, chew-card marks and motion-sensor camera detections. Plates 1–4 show the timer, relay, motion sensor and sounder respectively as used in the autonomous system. Their inclusion documents the principal hardware components used for timing, switching, sound deterrence and motion detection.



Plate 1: Timer



Plate 2: Relay



Plate 3: Motion Sensor



Plate 4: Sounder

From the preliminary baseline assessment, the baseline infestation count (I_B) was determined using equation (2) by summing the daily numbers of invaded ridges recorded during the 14-day baseline period.

$$I_B = \sum_{d=1}^n I_{B,d} \quad (2)$$

where: I_B = baseline infestation count; d = day of observation; n = total number of observation days (14).

The post-deployment infestation count (I_A) represented residual rodent activity after system intervention and was calculated by summing the daily numbers of invaded ridges during the 14-day post-deployment period using equation 3.

$$I_A = \sum_{d=1}^n I_A \cdot d \quad (3)$$

where: I_A = post-deployment infestation count; d = day of observation; n = total number of observation days (14).

The absolute reduction in recorded infestation was then calculated as the difference between the baseline and post-deployment counts using equation 4.

$$R_I = I_B - I_A \quad (4)$$

where: R_I = absolute reduction in infestation count; I_B = baseline infestation count; I_A = post-deployment infestation count.

The efficiency of the autonomous system was calculated from the absolute reduction relative to the baseline infestation count using equation 5.

$$\varepsilon = \frac{R_I}{I_B} \times 100 \quad (5)$$

where: ε = efficiency of the autonomous system (%); R_I = absolute reduction in infestation count; I_B = baseline infestation count.

3.0 RESULTS AND DISCUSSION

3.1 Bait Removal Performance

The results of the number of ridges invaded by rodent per day and the percentage invaded per day are presented and summarized as in Figures 3 and 4. Potato recorded the highest number of invaded ridges throughout the observation period. The data showed an increase from 2 invaded ridges on day 1 to 8 invaded ridges on day 14. This represented a rise from 25 percent to 100 percent bait removal. Yam and cassava recorded lower levels of invasion. Their highest daily infestation rates were 62.5 percent and 50 percent respectively. The trend showed a progressive increase in potato infestation as days progressed. This indicated that rodents consistently preferred potato bait over the other crops, as recorded by Aulicky (2022) in temperate region is also recorded in tropical region. The pattern of attack confirmed that bait removal can reveal crop preference and infestation intensity before any intervention takes place.

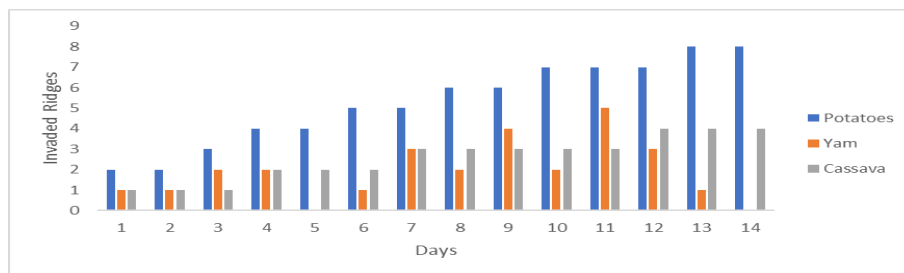


Fig. 3: Number of ridges invaded per day

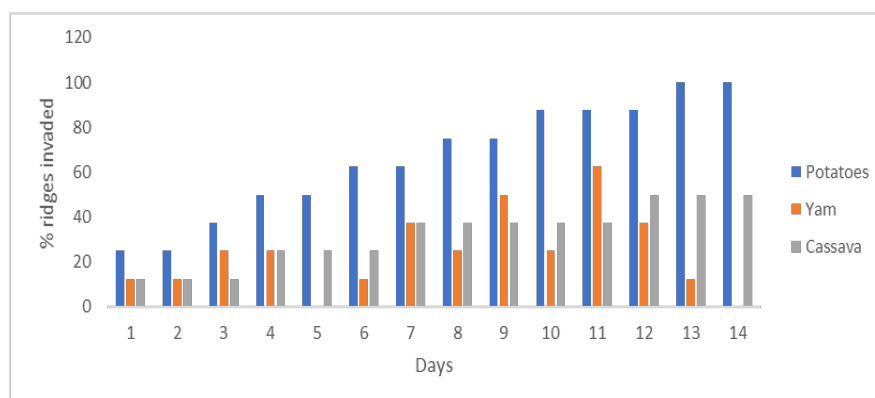


Fig. 4: Percentage ridges invaded per day

3.2 Chew Card Mark Assessment

Chew card marks served as a complementary method for validating physical feeding behaviour. Figure 5 showed that potato recorded the highest chew card marks across the fourteen days. Total chew marks for 14-day for potato were 52, while cassava recorded 37 chew marks. Yam had a significantly lower count of 12 marks. The daily pattern for potatoes showed repeated chewing activity with minimal variation from day to day. This confirmed a strong and consistent rodent attraction. Cassava recorded periods of moderate chewing activity. Yam remained the least targeted crop throughout the observation period just like it was affirmed in the review of Orek, (2024). The chew card evidence supported the bait removal results and further strengthened the conclusion that rodents were more attracted to potato than to the other two crops (Aulicky, 2022). The consistency between both indicators improved confidence in the validity of findings.

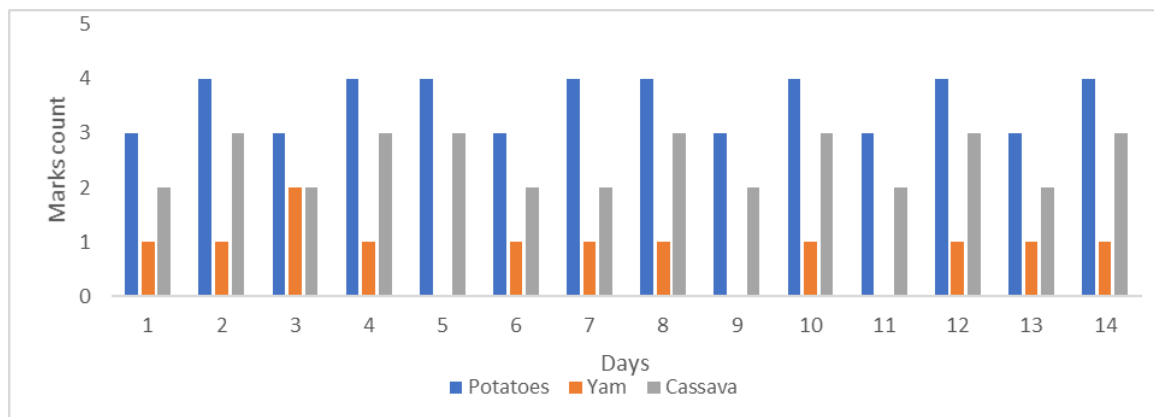


Fig. 5: Marks count on chew cards per day

3.3 Camera Detection Results

Automated data from motion-sensor cameras recorded the frequency of rodent movements within each crop area. The detection results presented in Figure 6 showed that potato had the highest total number of detections, with 272 recorded movements, while yam recorded 105 in total and cassava 162. The camera records provided time-stamped visual evidence of rodent activity and reduced observer bias. However, the submitted manuscript does not document systematic species-level identification of the rodents from the camera images. Therefore, no specific rodent species is assigned to the detections in this study. Future work should use higher-resolution cameras and image classification to identify the different rodent species responsible for crop damage.

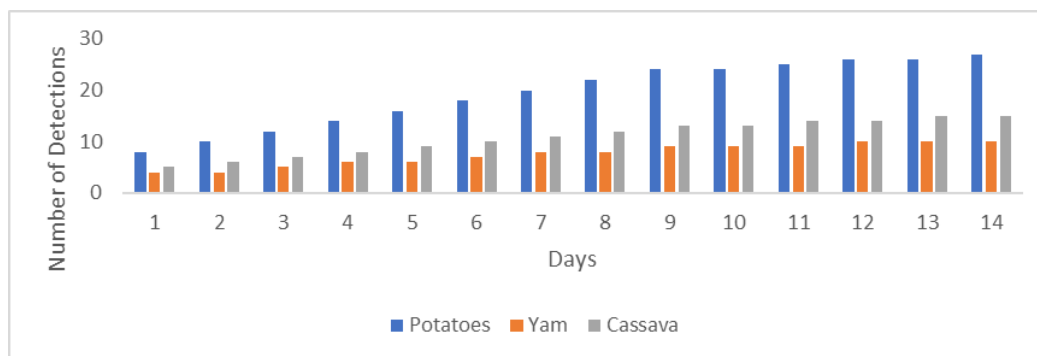


Fig. 6: Cumulative number of camera detections per day

3.4 Cumulative Interpretation of Rodent Preference

In Figure 7, potato recorded the highest value across all parameters with 925 percentage-points of cumulative daily infestation, 52 chew marks, and 272 camera detections. These results confirmed a very high preference level for potato. Cassava showed moderate total values. Yam had the least activity indicating lower preference and lower vulnerability. The

three independent indicators revealed a similar hierarchy of attraction. These outcomes confirmed that the potato plot experienced the highest infestation before any control measures were applied. The findings highlighted the urgent need for a control system. They also provided a strong reference point for performance evaluation during post deployment assessment.

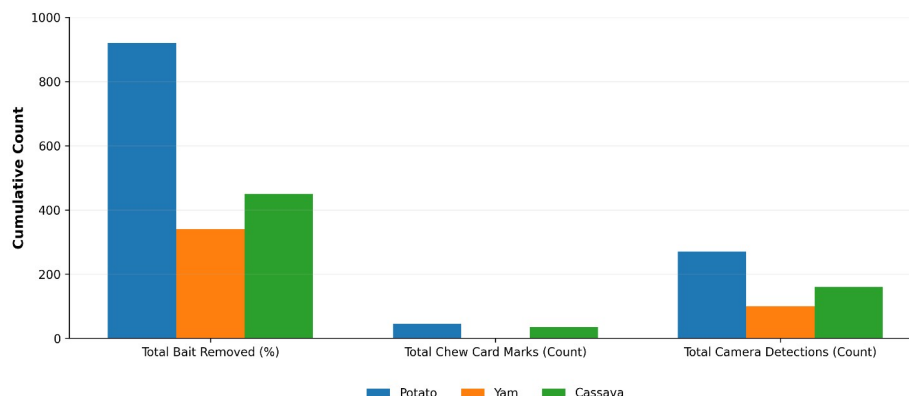


Fig. 7: Cumulative counts for bait removed card marks and camera detections

3.5 Comparative Analysis of Detection Indicators

The combined evidence shown above provides clarity on which crop faced the highest pressure and how the animals interacted with each detection method. By linking bait removal, chew card marks, and camera detections, the analysis supports the conclusion on crop vulnerability and identifies the most active periods of infestation.

3.6 Integration of Baseline Indicators

The cumulative results from bait removal, chew card markings, and camera detections reveal a clear ranking of infestation intensity across the three crops. Potato achieved the highest values of all parameters with 925 percentage-points of cumulative daily infestation, 52 chew card marks, and 272 camera detections. Yam recorded 337.5 percent bait removal, 12 chew card marks, and 105 camera

detections. Cassava recorded 450 percent bait removal, 37 chew card marks, and 162 detections. These results show a strong agreement across different monitoring methods. All indicators consistently point to potato as the most targeted crop (Aulicky, 2022). The convergence of results strengthens the reliability of the assessment since each method captures a different aspect of rodent interaction. Bait removal reflects feeding behavior. Chew card marks reflect exploratory gnawing. Camera recordings reflect active movement around the plots. The fact that all measurements show the same trend indicates real behavioral preference rather than random variability.

3.7 Cross-Parameter Correlation and Activity Patterns

Trends across the fourteen days show that potato plots experienced a steady rise in rodent activity

throughout the trial. All detection indicators increased at almost the same period, which suggests synchronized behavioral growth possibly due to improved resource familiarity as rodents repeatedly visited the same crop area. The steep increase in bait removal on potato ridges between Day 8 and Day 14 aligns with the rise in camera detections. This shows that the rodents not only fed more as days progressed but also visited more frequently.

Yam and cassava showed milder growth patterns and their detection curves remained clearly below potato values across all days. The moderate but rising activity in yam indicates conditional interest possibly influenced by food availability. Cassava results remained stable with gradual changes that implied lower attraction.

These correlations across parameters reveal that bait removal peaks coincide with the highest movement rates captured by cameras. Activity peaks are strongest during the last five days of monitoring which suggests that rodents established a strong routine around the potato plots, this is consistent with the findings Orek, 2024; Aulicky, 2022.

3.8 Crop Preference and Nest Proximity

The baseline results indicate that potatoes experienced greater recorded rodent activity than yam and cassava. Although this pattern suggests greater attraction or vulnerability of potato under the conditions of the study, the present design did not directly measure distance to burrows, nutritional preference, or other behavioral mechanisms.

Therefore, the observed crop ranking should not be interpreted as proof that rodents selected potatoes because of taste, texture or nutritional appeal.

This finding is significant for future rodent management plans. Protecting high-preference crops should be a strategic priority during active infestation periods. The combined indicators clearly confirm potato as the most vulnerable crop in the baseline assessment.

3.9 Moderating Role of Control Plots

The control plots were retained as reference conditions for the three crop types. However, quantitative control-plot observations were not reported in the submitted dataset; therefore, no formal treatment-versus-control statistical comparison is claimed. The observed post-deployment reduction is consequently interpreted as a before-versus-after change within the treated potato plot. Future experiments should report equivalent quantitative observations from the control plots to strengthen attribution of the treatment effect.

3.10 Post-Deployment System Performance (Potato Crop)

To evaluate the performance of the rodent monitoring and repellent system after its deployment on the potato plots, potato was selected for focused analysis because it recorded the highest infestation during the baseline phase. The results presented indicate changes in daily rodent intrusion, percentage infestation per ridge, and overall responsiveness of the animals to the installed technology. The findings

demonstrate how sensor-based alerts and sound deterrents helped reduce infestation levels (Lokesh *et al.*, 2025).

3.11 Post-Deployment Infestation Records and Reduced Activity

Table 1 presents the daily infestation results across eight potato ridges following the system deployment. The highest invasion recorded was three ridges on Days 1 and 2 which is considerably lower than the peak value of eight ridges during the baseline assessment. The percentage infestation started at 37.5 percent and continued to decline across the fourteen days. By Day 3 the number of invaded ridges reduced to two which corresponded to 25 percent infestation. From Day 6 onward the trend showed a steady drop with only one ridge affected daily at 12.5 percent infestation. The most significant improvement occurred from Day 12 to Day 14 when zero infestation was recorded for three consecutive days. Cumulative effects are shown in Table 2.

These data trends are shown in Figure 8 as the invaded-ridge count and in Figure 9 as the percentage infestation chart. The cumulative ridge-invasion count dropped from 104 during the baseline phase to 18 after deployment, representing an 82.69% reduction. The three consecutive zero-infestation days at the end of the post-deployment period provide additional evidence of reduced activity during the observation period.

Table 1: Post-Deployment Infestation Data for Potato (8 Ridges)

Day	Invaded Ridges	Percentage Infested (%)
1	3	37.5
2	3	37.5
3	2	25.0
4	2	25.0
5	2	25.0
6	1	12.5
7	1	12.5
8	1	12.5
9	1	12.5
10	1	12.5
11	1	12.5
12	0	0.0
13	0	0.0
14	18	0.0
Total (IA)	20	—

Table 2: Cumulative Infestation Evidence after 14 Days

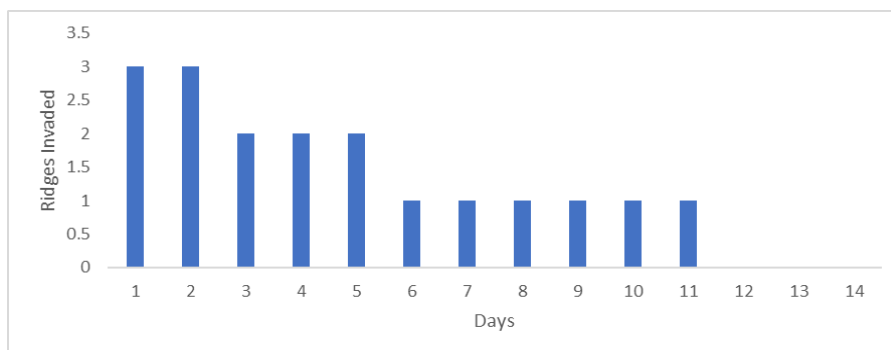
Crop Bait Type	Total Bait Removed (%)	Total Chew Card Marks (Count)	Total Camera Detections (Count)	Interpretation (Rodent Preference Level)
Potato	925	52	272	Very High Activity
Yam	337.5	12	105	Moderate Activity
Cassava	450	37	162	Lower Activity

3.12 Declining Trend and Behavioural Modification

The gradual decline in rodent activity suggests active modification of behaviour in response to the sound-based alerting and sensor detection system. The animals likely encountered the alerts upon entry which increased their hesitancy to return. Repeated exposures to deterrent signals may have conditioned them to avoid the monitored zones. This behavioral shift is supported by the fact that infestations never increased after the first two days. The stability of low intrusion levels from Day 6 through Day 11 shows that the system gained effectiveness quickly and maintained consistency.

The results also indicate that early installation intervention can prevent rodents from fully adapting to feeding on potato crops (Best *et al.*, 2022; Aulicky, 2022). Since rodents tend to return to profitable food sources once established, the early disruption that limited high infestation prevented reinforcement of the behaviour. Therefore, technology acted at a crucial time to reverse the baseline escalation trend.

A lack of major fluctuations during the post-deployment period further confirms that rodents did not develop avoidance strategies against the monitoring system itself. The deterrent approach therefore remains viable for ongoing application without immediate decline in effectiveness.

**Fig. 8:** Number of invaded ridges per day

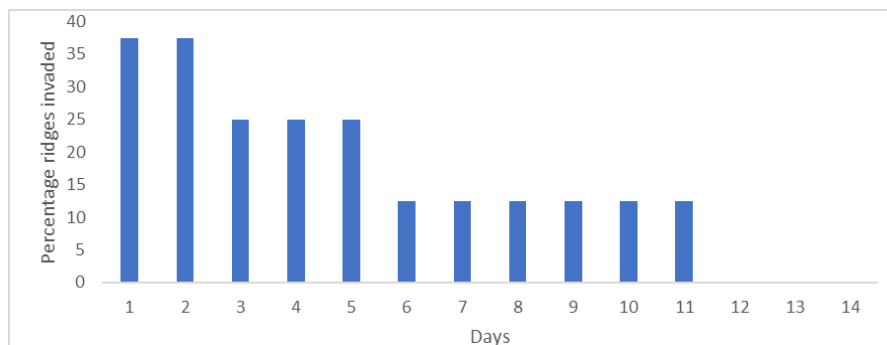


Fig. 9: Percentage ridges invaded

3.13 Effectiveness of Sensor and Sound Alerting System

The improvement observed in the infestation rate can be strongly linked to the features of the installed system. The sensor module detected motion and triggered a responsive sound alert intended to scare rodents away from the ridges. This mirrors similar Internet of Things (IoT)-based deterrent architectures reported in the literature, where motion, sound, and heat sensors positioned around a field perimeter feed a central processing unit that triggers a deterrent response and alerts the farmer (Mantasha et al. 2023). Comparable ultrasonic repeller systems using PIR sensors have been developed to operate effectively even in darkness, with transmission ranges reported up to 50 m.

These alerts created an unfavourable environment with unpredictable noise that rodents typically interpret as presence of predators or human activity, consistent with reports that short-term deterrents can be effective but that animals may habituate unvarying stimuli over time a point worth acknowledging as a limitation of long-term sustainability in your own conclusion.

The occurrence of zero-infested days is an important result because no invaded ridge was recorded on Days 12–14 after system deployment. However, the data demonstrate reduced recorded infestation rather than proving complete abandonment of the wider farm environment or a specific behavioral mechanism. The result supports the interpretation that rodent activity within the monitored potato plot was reduced during the post-deployment period.

Overall, these findings support the potential of sensor-and-sound alerting systems as non-chemical alternatives for reducing rodent activity under field conditions. The present study, however, does not establish long-term effectiveness; future work should evaluate habituation and performance over longer monitoring periods.

3.14 Efficiency Evaluation of the Autonomous System

The efficiency assessment is based on a comparison between baseline infestation before system deployment and post-deployment infestation on the potato plots. Potato served as the primary test crop due to its high susceptibility and highest recorded rodent activity during the baseline phase, consistent

with reports that rodent damage in agriculture extends across nearly all major crop types, including vegetables and root crops, both in the field and in storage (Witmer & Moulton, 2022).

The baseline infestation count (IB) obtained during the 14-day initial assessment was 104 ridge invasions. After installation of the sensor-activated sound repellent system, the post-deployment infestation count (IA) was 18 ridge invasions over the same duration of monitoring. Based on Equation 5 presented in the methodology, the calculated efficiency of the system was 82.69%.

The calculated 82.69% reduction indicates substantial decline in recorded rodent activity after system deployment. The three consecutive zero-infestation days at the end of the monitoring period further indicate reduced activity during the post-deployment assessment. These results should be interpreted within the limitations of the study duration, field scale and absence of a quantitative control-plot comparison.

The efficiency result proves that the combination of motion sensing and sound deterrence provided a reliable and effective control strategy. The system successfully mitigated feeding pressure and protected the potato crops from severe damage. These findings confirm that the autonomous design used in this project has strong capability to detect rodent intrusion early and deter sustained activity. Therefore, the technology shows promise for practical agricultural use, particularly in rural regions facing persistent rodent challenges.

4.0 CONCLUSION AND RECOMMENDATIONS

The study demonstrated the potential of an autonomous rodent detection and control system for reducing rodent activity under agricultural field conditions. The 14-day baseline assessment using bait removal, chew-card marks and motion-sensor camera detections showed that potato recorded the highest level of activity among potato, yam and cassava. The developed system integrated a PIR motion sensor, relay module, timer, electronic siren and solar power supply to provide automatic detection and sound-based deterrence without requiring continuous human intervention. Cumulative invaded-ridge observations declined from 104 during the baseline assessment to 18 during the 14-day post-deployment assessment, giving a calculated efficiency of 82.69%. Three consecutive zero-infestation days were recorded at the end of the post-deployment period. These findings support the potential of motion-triggered sound deterrence as a non-chemical approach for reducing rodent activity. Nevertheless, the short monitoring period, limited field scale, absence of a reported quantitative control-plot comparison and lack of systematic species-level camera identification limit the generalization of the findings. Future studies should use larger fields and longer monitoring periods, including formal treatment-control comparisons, evaluate performance across seasons and crop types, and incorporate improved camera systems or image-classification methods for rodent species identification.

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