ULTRASONIC DEVICE POWERED BY RENEWABLE ENERGY FOR PROTECTING POTATO CROPS AGAINST THE COLORADO POTATO BEETLE (LEPTINOTARSA DECEMLINEATA)

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Abstract:

The Colorado potato beetle (Leptinotarsa decemlineata) is one of the most destructive pests of potato crops and has developed resistance to numerous insecticides. This study aimed to develop and evaluate a portable ultrasonic device powered by solar energy and a rechargeable battery to suppress beetle activity in *potato fields. The device emitted ultrasonic waves in the 20-40 kHz frequency range, targeting the beetles' sensitivity to sound vibrations. Field trials showed that continuous ultrasonic exposure reduced mating activity by 65-70%, nearly halted reproduction within 14 days, and decreased leaf damage by 35%. As a result, potato yield increased by approximately 32,5% compared to untreated plots. These findings indicate that ultrasonic technology can serve as an eco-friendly and sustainable method of pest management in potato cultivation.*

Keywords: *Colorado potato beetle, potato protection, ultrasonic device, renewable energy, integrated pest management.*

Introduction

Potato (*Solanum tuberosum L.*) is one of the world's most important staple food crops, providing significant nutritional and economic value. However, its cultivation is severely threatened by the Colorado potato beetle (*Leptinotarsa decemlineata* Say, 1824), a highly destructive pest that damages foliage and can reduce yields by up to 100% in untreated fields. Native to North America, the beetle has spread widely across Europe and Asia, adapting to diverse climates and becoming a global agricultural concern.

Chemical insecticides have traditionally been the main strategy for controlling this pest. Nevertheless, repeated and widespread application of insecticides has resulted in resistance development in beetle populations, leading to reduced efficacy of many commonly used compounds. Moreover, excessive reliance on chemicals poses serious environmental risks, including soil and water contamination, non-target organism toxicity, and negative impacts on human health. These limitations highlight the urgent need for alternative, sustainable pest control methods.

In recent years, physical and ecological technologies have gained attention as environmentally friendly solutions. Among these, the use of ultrasonic waves represents a promising approach for pest management. Ultrasonic vibrations can disrupt insect feeding behavior, orientation, and reproduction, thereby reducing pest populations without chemical inputs. However, practical field-based applications of ultrasonic devices remain limited, especially in open-field potato cultivation systems.

To reduce dependency on chemical inputs, alternative approaches such as physical, biological, and electro-physical methods are being explored. Among them, ultrasonic technology has attracted attention for its potential to disrupt insect behavior without introducing chemical residues into the environment. Ultrasonic waves within the range of 20-40 kHz have been reported to affect the locomotor and reproductive activities of insects, making them promising tools for pest control.

This study focuses on the development and field testing of a renewable-energy-powered ultrasonic device designed to suppress the activity of the Colorado potato beetle in potato fields.

Materials and Methods

Study site and experimental design. Field experiments were conducted during the summer of 2025 in Shahrisabz district, Qashqadaryo region, Uzbekistan. A total area of 288 m² of potato (*Solanum tuberosum* L.) field was divided into two equal plots of 144 m² each: one experimental plot with ultrasonic treatment and one untreated control plot. Both plots were planted with potatoes under identical agronomic conditions, including planting density, irrigation, and fertilization.

Ultrasonic device. The experimental treatment involved a solar-powered ultrasonic device specifically designed for pest control in open-field conditions. The system consisted of:

Solar panel: 20 W capacity, producing 18 V output and 1.16 A current.

Inverter (DOXIN model): Converted 12 V DC to 220 V AC with a maximum capacity of 300 W.

Rechargeable battery: 12 V, 27 A·h, providing power during night-time operations.

The ultrasonic generator was programmed to emit sound waves in the 20-40 kHz frequency range, which corresponds to the sensitivity threshold of the Colorado potato beetle (*Leptinotarsa decemlineata*). The device was installed between potato rows, operating for 8 hours per day throughout the experimental period.

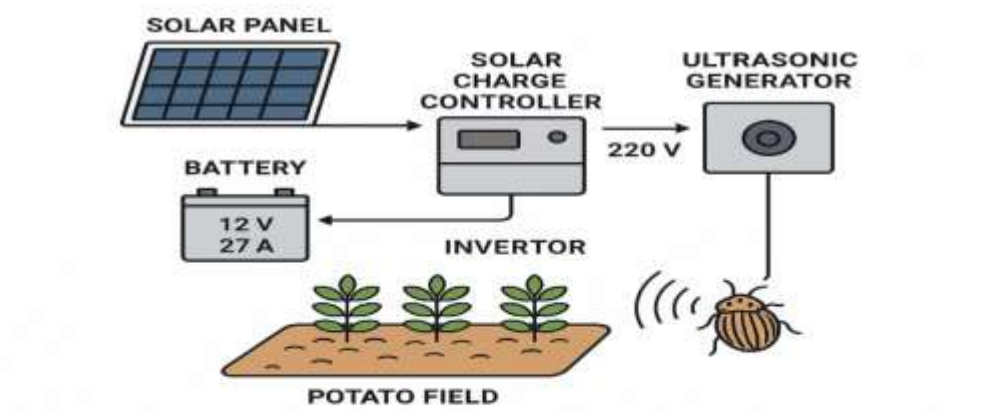

Figure 1. Connection diagram of the ultrasonic device

Beet activity was monitored by counting adult insects and larvae on randomly selected plants within each plot. Observations were conducted every 3-4 days. Parameters assessed included:

Feeding damage (percentage of leaves affected).

Number of adult beetles and larvae per plant.

Reproductive activity (presence of egg clusters and mating behavior).

At harvest, tuber yield was recorded separately for the experimental and control plots. The total weight of marketable tubers was measured and compared to evaluate the impact of ultrasonic treatment on crop productivity.

Differences in beetle activity, leaf damage, and yield between treated and control plots were analyzed descriptively. Reduction percentages in pest activity and yield increases were calculated to assess the efficiency of the ultrasonic system.

This dual power supply (solar + battery) allowed the device to emit ultrasonic waves continuously, both day and night. The ultrasonic frequency was maintained within the 20-40 kHz range. Emitters were installed between potato rows and operated for approximately 8 hours daily.

Figure 2. Installation of the solar-powered ultrasonic device in a potato field

Results and Discussion

The application of ultrasonic waves significantly influenced the behavior and reproductive activity of the Colorado potato beetle. Continuous exposure reduced mating activity by **65–70%** and nearly stopped reproduction after 14 days. In addition, the number of damaged leaves decreased by **35%**, demonstrating the suppressive effect of ultrasound on pest feeding behavior.

Yield measurements highlighted the practical benefits of this technology. The ultrasonic-treated 144 m² plot yielded **228 kg of potato tubers**, compared to only **172 kg** harvested from the control plot of equal size. This corresponds to a **24,5% increase in yield** (Table 1).

These results clearly show that ultrasonic technology can reduce pest pressure and enhance crop productivity. They also support previous studies on insect sensitivity to acoustic and mechanical stimuli, reinforcing the potential of ultrasound as a non-chemical alternative for pest control.

Table 1. Effect of ultrasonic treatment (20-40 kHz) on Colorado potato beetle activity and potato yield.

Indicator	Control (No ultrasonic)	Ultrasonic treatment (20-40 kHz)	Effect (%)
Mating activity reduction	–	65–70%	–
Damaged leaves reduction	–	35%	–
Beetle reproduction after 14 days	Active	Nearly stopped	–
Potato yield from 144 m² (kg)	172	228	+24,5%

Figure 3. The harvested potatoes were categorized into large, medium, and small size groups

The practical significance of this research lies in its demonstration that solar-powered ultrasonic devices can provide a sustainable and autonomous solution for pest management in potato fields. By integrating renewable energy with non-chemical pest control, the system eliminates the need for synthetic insecticides, thereby reducing environmental pollution and safeguarding human health.

From an agronomic perspective, the observed 24,5% increase in yield under ultrasonic treatment highlights the potential of this technology to improve farm profitability, particularly for smallholder farmers in regions with high pest pressure. The low operational cost and renewable energy supply make the system suitable for large-scale agricultural applications, even in remote areas with limited access to electricity.

Moreover, this approach aligns with global efforts to promote environmentally friendly and climate-smart agricultural practices. The use of ultrasonic technology contributes to sustainable crop protection strategies by reducing pesticide dependency, preserving biodiversity, and supporting the long-term resilience of agroecosystems.

Future adoption of such devices could play a key role in integrated pest management (IPM) programs, offering farmers an innovative, cost-effective, and eco-friendly alternative that ensures both productivity and sustainability in food production systems.

Conclusion

The present study demonstrated that the use of ultrasonic waves in the frequency range of 20-40 kHz significantly reduced the activity and reproductive capacity of the Colorado potato beetle (*Leptinotarsa decemlineata*), one of the most destructive pests of potato crops. Field experiments confirmed that continuous ultrasonic exposure decreased mating activity by 65–70%, nearly inhibited reproduction after 14 days, and reduced feeding damage on potato foliage by 35%. Importantly, the yield from the treated plot increased by approximately 24,5% compared to the control, highlighting the agronomic benefits of this eco-friendly technology.

These results confirm that ultrasonic treatment can serve as an effective and environmentally safe alternative to chemical insecticides. Unlike synthetic chemicals, ultrasound leaves no harmful residues in soil, water, or agricultural products and does not contribute to pesticide resistance in pest populations. This positions ultrasonic technology as a sustainable and innovative tool for integrated pest management systems.

Furthermore, the integration of renewable energy sources, such as solar panels and battery storage, ensures that the system can function autonomously under field conditions. This increases the feasibility of adopting the technology in rural areas with limited access to conventional power supply.

However, additional research is required to optimize the parameters of ultrasonic devices, including frequency ranges, power levels, and installation density within crop fields. Large-scale trials under different agro-climatic conditions will provide more comprehensive data on the long-term effectiveness and economic viability of the method.

These findings highlight the potential of ultrasonic technology as an environmentally friendly and sustainable pest management strategy for potato cultivation. Unlike chemical insecticides, ultrasonic methods minimize ecological risks and can be integrated into broader integrated pest management (IPM) programs. Further large-scale trials are recommended to optimize operating parameters and assess the long-term efficiency and economic feasibility of this device.

In conclusion, the study not only demonstrates the potential of ultrasonic waves as a non-chemical control strategy against *L. decemlineata* but also provides practical insights for developing sustainable, environmentally friendly technologies that can contribute to global food security and reduce dependence on chemical pesticides in modern agriculture.

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