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Original Article

Designing a Solar-Powered Ultra-Sonic Pest Repellent Device for Agricultural Fields in India

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Abstract *- Agricultural productivity and activity are primarily impacted by pest control efforts taken by farmers. Pest infestations may lead to the destruction of significantly valuable produce. Since the Second World War, particularly the early 1940s, chemical pesticides have been seen as the solution to this problem, and while being effective, the long-term side effects are quite severe. Use of chemical pesticides over a prolonged period of time causes various problems, including soil degradation and groundwater contamination, with a prominent example being the Malwa region in Punjab, India. The paper introduces a Solar-Powered Pest Repellent Device that works on the principles of ultrasound. Several harmful pests present in an agricultural setting are known to be vulnerable to high-frequency sound frequencies between the range of 38-42 kHz. The current research provides a tangible design for this device. The capabilities of this device expand to several frontiers, including pest control in grain storage facilities, agricultural fields, etc.*

Keywords *- Application of Ultrasound, Pesticides, Agriculture.*

1. Introduction

Chemical pesticides have reigned over the agricultural pest repellent industry with a marketwide revenue of more than $102.9 billion in 2023[1]. Farmers in underdeveloped and developing countries face regular financial problems, leading to the use of cheaper chemical pesticides. These pesticides harm the land to a marvelous effect[2], which eventually leads to soil degradation and groundwater contamination, eventually causing the land's inability to grow healthy crops.

Table 1. Estimated produce loss due to pest infestations

State / Region	Crop	Primary Pest Cause	Estimated Loss (%)
Punjab[3]	Wheat, Paddy	Termites, aphids, bollworms	12–15%
Madhya Pradesh[4]	Soybeans, Wheat	Stem borers, semi-looper, termites	10–14%
Bihar[5]	Maize, Paddy	Stem borers, cutworms, hairy caterpillars	15–20%
Karnataka (Kodagu)[6]	Coffee	White stem borer	~10–15% (by plant count)
Andhra Pradesh (NTR)[7]	Mango	Fruit flies, sooty mold	~50% export loss
Uttar Pradesh	Sugarcane	Black bug, pyrilla	High damage (est. 10–15%)
Maharashtra (Nashik)[8]	Onion	Storage pests	~50% post-harvest loss
Tamil Nadu[9]	Paddy, Sorghum, Maize, Bajra	Storage insects	~2–4% during storage

The data in Table 1 clearly show how pests are widely responsible for both during and post-harvest losses.

Chemical pesticides have been used by farmers since the Green Revolution to increase crop quality and protect farmlands from unwanted pests and vermin. The usage of organophosphates, carbamates, and other types of pesticides causes soil degradation and groundwater contamination in the long term while benefiting crop production in the short run[15]. These pesticides cause soil toxicity and will eventually render the land they are used on infertile and barren. One example of an acute level of groundwater contamination is the Malwa region of Punjab, encompassing 12 districts, including major ones like Bathinda, Moga, and Mansa. The Malwa region accounts for less than 15% of Punjab's population, but it accounts for 75% of the pesticides used in Punjab[16].

Ultrasound frequencies are defined as frequencies of sound waves that lie above the human hearing range of 20 kHz. Most pests found in an agricultural setting are proven to be vulnerable and repelled by ultrasound waves of a frequency within the range of 38- 44 kHz[17].

The concept of repelling pests using ultrasound frequencies was first explored and patented by Charles W. Frick[18]. Frick focused on repelling rodents by producing sound of a frequency above 20 kHz, laying the groundwork for non-invasive pest control. According to another study conducted by one of the author, based on the understanding that many species, particularly nocturnal ones like moths, have evolved to detect and evade the ultrasonic echolocation cries of their primary predators, such as bats.

The underlying principle is that high-frequency sound waves can induce a state of auditory stress in many pests, disrupting their natural behaviours like feeding, breeding, and communicating. For certain insects, these frequencies can mimic the presence of a predator, triggering an instinctual flight response that drives them away from the protected area. Research by Nakano et al. highlights this deep-seated evolutionary relationship between prey-predator ultrasound interactions, providing a strong biological basis for the use of such technology in pest control.

However, more recent and focused scientific studies have begun to validate the technology when properly implemented. Researchers are now identifying specific frequency ranges that are effective against particular agricultural pests. For instance, studies have shown that frequencies in the 30-50 kHz range can be particularly disruptive to insects like aphids, bollworms, and various types of borers, which are the primary culprits for crop loss in regions like Punjab and Madhya Pradesh (as indicated in Table 1.0). This modern research confirms that the key to successful ultrasonic pest control lies not in a generic device, but in a well-engineered system capable of producing a powerful, targeted, and sustained ultrasonic output directly in the agricultural environment. This paper builds upon this renewed scientific validation, addressing the previous failures by designing a robust, field-ready device specifically for the agricultural context.

This research aims to introduce a Solar-Powered Pest Repellent Sound Device. This device is theoretically capable of substituting chemical pesticides. This product is focused on catering to farmers with financial constraints, which leads to them using cheaper versions of chemical pesticides. In Bathinda, popular chemical pesticides include chlorpyrifos, confidor, and fipronil insecticide; these chemically damage the land due to their excessive toxicity.

Although past research and inventions show the usage of ultrasonic frequencies to repel rodents, they use a lower frequency of operation. The current study involves the development of a device that operates at high frequencies from 38-42kHz, which targets a wider range of pests rather than just rodents. The wavelength is also set so that the impact on external biorganisms remains minimal. This also does not kill pests; it just repels them as these pests get irritated by these sounds. Wherever "vulnerable" is mentioned in this paper, it refers to irritability.

This device involves the use of ultrasonic cleaning apparatus, like the Ultrasonic cleaning transducer, which has not been explored before as a potential output of sound waves for previous repellents.

The device is built for agricultural needs, and this paper also discusses the most efficient way to place these repellents on a field to maximize range and cost efficiency. However, it can also be utilized in crop storage facilities.

2. Materials Used

2.1. 20-watt Solar Panels

Solar panels are used to convert incident solar energy, promoting increased independence and sustainability, especially in rural and semi-urban farming areas where grid electricity supply is unavailable or limited. Through the use of renewable solar power, the system is independent of the grid, which reduces the price of electricity for farmers while promoting sustainable environmental practices and pest control activities.

This increases the reliability of storage while at the same time placing the system in agreement with green energy and long-term economic sustainability goals for economically disadvantaged farming communities.

2.2. ESP32

ESP32 was chosen as the operating microcontroller-based development board after careful consideration of 3 other alternatives- Arduino UNO, Raspberry Pi (RPi 4), and ESP8266.Arduino UNO is not capable enough to produce ultrasound of such high frequency; its PWM capabilities only allow the production of sound with a frequency of around 1 kHz [13]. Therefore, it was not seen as a suitable choice for this device.

Raspberry Pi (RPi 4) poses a cost concern; it is not a viable choice for making the sound repellent affordable for farmers. Although it has all the required features and more, it is technically sound. It is capable of creating decisive high-frequency sound waves even more so than ESP32, but this level of accuracy and clarity is not required to cause the desired effect.

ESP8266 has limited PWM capabilities due to its 8 channels compared to ESP32's 16 PWM channels [14]. PWM channels are the modules that drive the generation of accurate and precise ultrasound frequencies. It also requires a higher input voltage, which decreases the energy efficiency of the device.

ESP 32 was the most cost-effective and technically capable of long-term ultrasound generation; it requires a comparatively lower input voltage while also having adequate PWM capabilities with 16 channels [10].

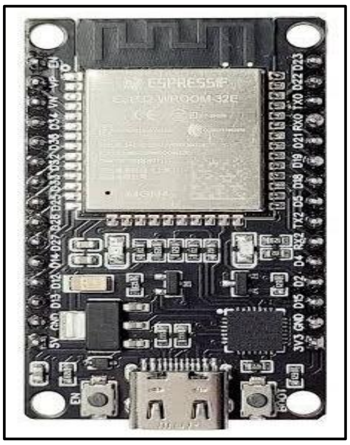


Fig. 1 ESP 32 Node MCU

2.3. Relay- 1 Channel Relay Module 24V High and Low Level Trigger Relay Module

The relay module was used to operate the ultrasonic transducer in regular time intervals using the ESP32. It was also used to manage the incandescent bulbs and heating beds.

2.4. 40 KHz 60W Adjustable Ultrasonic Cleaning Transducer

This Ultrasonic cleaning transducer is usually used for cleaning jewelry and metal parts. It produces frequencies between 38kHz and 42kHz, requiring 60 watts of power. This provides a range of frequencies required at a very high amplitude, increasing the range for a medium power range. This transducer was chosen after considering several other amplification methods and speakers. This provides a range of 10m, which gives a considerable covered area of around 100π. This range is adequate for covering the entire storage facility.

Fig. 2 Ultrasonic Cleaning Transducer 40kHz

RITRONICS HT-342 was also tried as an amplification module used to intensify ultrasound waves. This was done after testing the device with the 8Ω Trumpet speaker, and the result showed that the 8Ω trumpet was too weak to produce ultrasound waves of such intensity.

Due to the product failure of the RITRONICS HT-342 Dual Driver Piezo Tweeter, shifting to a new approach was essential. Instead of using one strong speaker, several smaller ultrasonic transducers were used, which yielded a better effect in terms of cost efficiency and the intensity of sound produced, but their production design was not suitable for the field, and their range was very small.

The 8Ω trumpet is capable of amplifying ultrasound frequencies up to 45 kHz, which covers the range of frequencies needed for the device. After testing for sound pressure using a Vernier Calliper sound pressure sensor, the speaker was not able to amplify sound to a considerable level after 15 kHz. Therefore, it was not a good choice for the final project.

RITRONICS HT-342 is a heavy-duty speaker with the potential to amplify sound frequencies up to 80 kHz. It has a high maximum power of 300 watts compared to 2 watts of the 8 8-ohm trumpet. This was the perfect choice for cost-effectiveness as it helped increase the range of the product to cover the vast areas of an agricultural field. However, after field testing, the device was deemed not usable due to its power inefficiencies, as it requires over 300 watts of power.

2.5. 220V 40KHz 100W Ultrasonic Cleaning Circuit Board Generator Parts

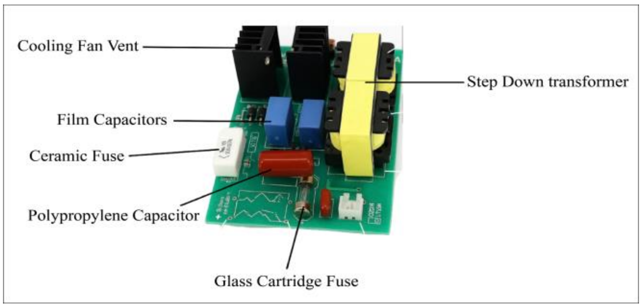


Fig. 3 Labelled diagram of Ultrasonic Cleaning Circuit Board Generator

The choice of the 220V 40kHz 100W Ultrasonic Cleaning Circuit Board Generator is guided by a thorough evaluation of its compatibility, efficiency, and economic benefits. It uses a frequency of 40 kHz, which is within the predetermined frequency range (38–44 kHz) that has been discovered to deter common agricultural pests through the use of high-frequency sound waves. This particular frequency effectively induces auditory stress in pests without harming crops or the environment.

The 100W power rating delivers a strong and consistent ultrasonic output, which is necessary for the device to have a sufficient intensity over a wide area. Furthermore, the generator is made for continuous use, and thus it is suitable for long-term use in open farm operations.

The need for a single 220V input allows for easy interfacing with grid power and solar-power inverters as well, thus enhancing the device's scalability and off-grid applicability for resource-constrained farmers. The board's ruggedness, compact nature, and comparatively light weight also complement its applicability to mounting in a portable, field-deployable enclosure.

In general, this generator was chosen because it possesses the optimal combination of maximum performance, efficiency, and expense, complementary to the inherent aims of this device: promoting sustainable pest control and making it accessible for small and medium-scale agricultural producers.

2.6. 12 Volt Battery
A 12-volt battery was used to power the ESP 32.

2.7. Channel Relay Module 24V High and Low Level Trigger Relay Module
The relay module was used to operate the ultrasonic transducer in regular time intervals using the ESP32.

2.8. Solar Panels
Solar panels were used to maintain power efficiency. Open fields do not have any obstructions that may impact the efficiency of the solar panels. This allows for ample power to be collected by using solar panels. This makes the device sustainable in terms of energy usage and reduces running costs as it will not use any electricity from the grid, which the farmer may have to pay for.

3. Discussion
3.1. Product Design
The device primarily has 2 very unique components, the Cleaning Transducer and the Cleaning Circuit Board. These components are usually used together in devices that are made to clean jewelry through vibrations made by ultrasound.

The same principle has been used for this device, using the vibrations to repel pests. The transducer is connected to an ESP32 so that it can produce vibrations in bursts within 2-minute durations. The relay gives the Transducer the ability to be programmed. It also has a casing made of waterproof material, which makes it suitable for outdoor use.

The device essentially works on Ultrasonic Cleaning modules. These are electrical components that are technically designed to clean jewelry and metals. But, these have great capabilities in terms of producing and emitting ultrasound.

The block circuit diagram in Figure 4 shows the Ultrasonic Cleaning Circuit Board connecting to the ultrasonic transducer and the 24-volt relay. The 24-volt relay is connected with the ESP 32 and the transducer to act as a bridge between the signals from ESP 32 and the ultrasonic transducer[11]. The Ultrasonic Cleaning Circuit Board is connected to a 220-volt mains supply, and the ESP 32 is connected to a 12-volt battery.

This setup is able to produce better results than previous devices as it has the capability of producing sound waves at a very high frequency of 38- 42kHz due to the usage of an ultrasonic cleaning apparatus. This is the reason why this device is applicable to a variety of common pests and thus more effective against pest infestations.

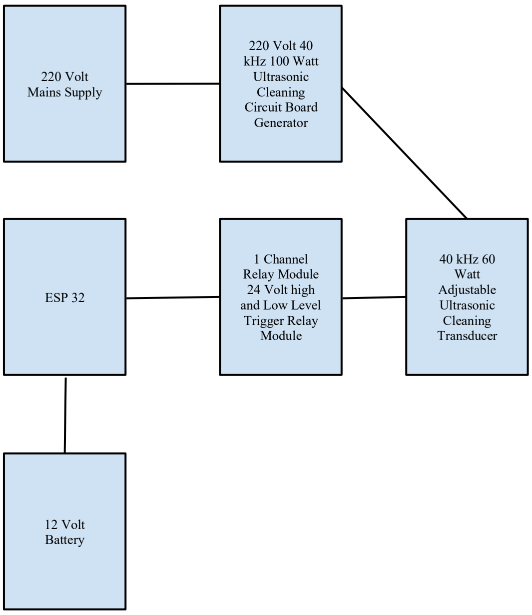


Fig. 4 (a) Block circuit diagram of the electronic components.

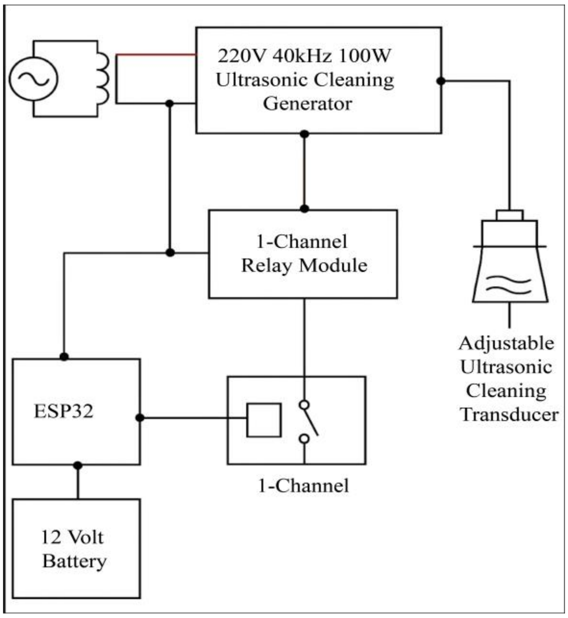
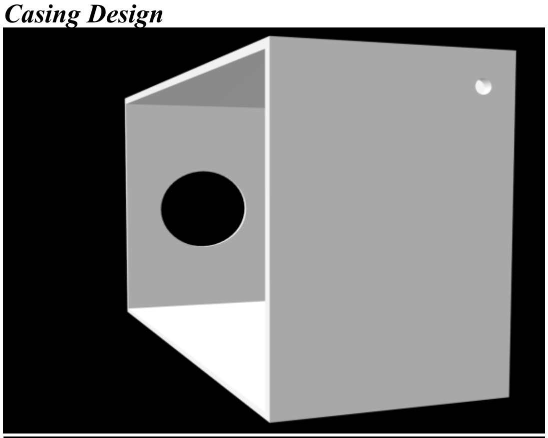


Fig. 4(b) Circuit diagram with component symbols

3.2. Casing Design



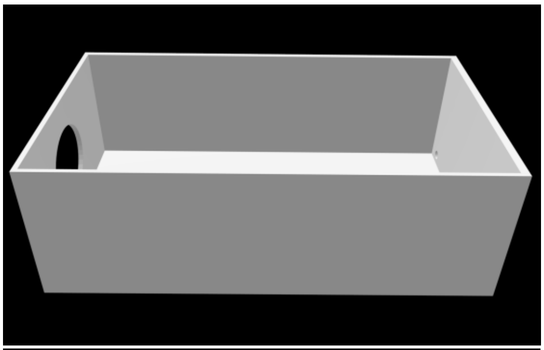


Fig. 5 (a)and 5(b) Show the Casing Design

The outside casing of the device was created with Computer-Aided Design (CAD) technology to make it accurate, reliable and efficient in its operation. The design consists of a rectangular housing specifically designed to encase the electronic components securely in a manner that facilitates sufficient air flow and user convenience in practical applications.

The enclosure contains two precisely positioned cut-outs: the power cord entry and the ultrasonic transducer exit. The cut-outs are optimized in dimensions and shape to give a proper fit, preventing movement and reducing environmental exposure such as dust or moisture intrusion. The exit of the transducer is located on the broader side panel, directionally oriented to maximize the forward transmission of ultrasonic waves into the agricultural field. The entry point of the power cord is located on the adjacent side for easy connection to the power source or solar-powered inverter.

The box itself is deliberately tapered in design to be more structurally supportive and use less material, as seen in the rear and top-view drawings. The open top or front panel also makes it simple to perform maintenance or replace the internal circuit board and wires. The casing material is imagined to be weatherproof but lightweight, preferably HDPE or coated aluminium sheet, to allow for outdoor portability and ruggedness[12]. The ultimate casing design not only provides mechanical safeguarding but also improves the functional capabilities of the device by enabling directional sound dispersion, convenient accessibility for working, and longevity in various environmental conditions.

3.3. Real Life Application and Testing

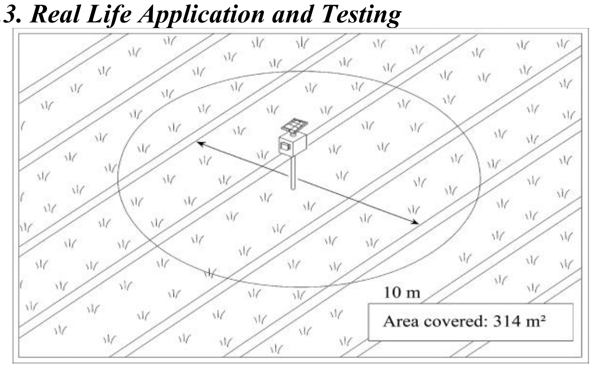


Fig. 6 Diagram showcasing the area covered in an agricultural field context

To ensure optimal field application and operational efficiency, the ultrasonic pest repellent device is designed to be mounted on a pole that elevates it approximately 1.5 meters above ground level. This height allows the transducer to emit ultrasonic waves over a wide area without obstruction from surrounding crops or uneven terrain.

Each device utilizes a high-efficiency ultrasonic transducer capable of covering a circular area with a radius of approximately 10 meters. This translates to a total coverage area of 314 square meters per device, based on the standard formula for the area of a circle ($A = \pi r^2$). This spatial distribution is ideal for medium-sized farmland plots, ensuring that a minimal number of units can effectively service larger areas through strategic placement[19].

The accompanying visual representation includes a real-world application image and a schematic bird's-eye view to illustrate the zone of influence. The schematic demonstrates how the ultrasonic emissions radiate symmetrically in all directions, making it easy to plan field layouts for maximum coverage. The actual field deployment image shows the device securely installed among crops, with a solar panel mounted atop the pole to provide sustainable, off-grid power.

By leveraging an elevated mounting system and maximizing the effective acoustic radius, this device ensures that ultrasonic deterrents reach pests such as insects or rodents over a wide area, without interfering with the growth, irrigation, or harvesting processes. As the frequency generated by the device is not discernible by human hearing, a vernier sound sensor was used to test the audio output. This clearly showed that the device was working, as it showed a frequency of 40kHz being generated at a high intensity.

3.4. Limitations and Future Scope

The primary concern is the impact on non-target and beneficial organisms, which is an area that requires dedicated study. Our agricultural ecosystems are complex webs of life. While the frequency range was chosen to be outside human and livestock hearing, its effect on beneficial insects, such as pollinators like bees and butterflies, or soil-enriching microorganisms, remains uninvestigated. A truly sustainable solution must not deter the allies of the farmer, along with the pests.

Furthermore, the operational effectiveness of the device is subject to environmental variables. The current 314 metre coverage is an ideal calculation. In a real-world field, factors such as dense crop foliage, uneven terrain, high humidity, and strong winds could absorb, deflect, or scatter the sound waves, creating acoustic "shadows" where pests could remain unaffected. The device's performance will not be a perfect circle, as the schematic suggests, but will vary with the specific conditions of each field.

The limitations identified pave the way for several avenues of future research and development. The ultimate goal is to evolve this standalone device into a smarter, more integrated system.

Looking ahead, a network of these devices forming an intelligent, interconnected pest management system could be explored. Instead of a homogeneous device, it could be turned into a hive of pest repellents to increase zonal efficiency. By leveraging IoT (Internet of Things) technology, multiple repellent units and a central server could communicate with each other. This would allow for the creation of a "sonic fence" around an entire farm. Farmers could then monitor the status of each device, receive alerts, and potentially even view pest activity data through a simple mobile application.

To address the concern of harming beneficial organisms, future research could focus on pest-specific frequency targeting. This would involve laboratory and field studies to identify the precise ultrasonic frequencies that are most irritating to key pests like termites, aphids, and bollworms, while simultaneously identifying frequencies that are benign to local pollinators. This could lead to a 'tunable' device that can be calibrated for the specific pest profile of a farm.

Finally, there is scope to enhance the physical robustness and energy efficiency of the device. This includes long-term field testing of different casing materials to ensure durability against extreme weather and exploring next-generation solar cells and more efficient battery storage to guarantee uninterrupted, year-round operation, even during monsoon seasons or in regions with variable sunlight. By addressing these areas, we can move closer to our goal of providing a truly sustainable, effective, and accessible alternative to chemical pesticides for farmers in India and beyond.

4. Conclusion

Dependence on chemical pesticides in modern agricultural practice has had devastating and long-term consequences on the environment, particularly in regions like the Malwa belt of Punjab. There, pesticide overuse has led to unprecedented levels of soil degradation and groundwater contamination, which has been linked with high cancer rates among indigenous people. This research suggests a sustainable and innovative solution in the shape of a Solar-Powered Pest Repellent Device utilizing ultrasonic technology. By employing high-frequency sound waves, referred to as sound waves above 25 kHz that repel pests, the device presents an unobtrusive and environmentally friendly solution to long-standing agricultural issues.

Shifting from chemical pesticides is not only a technological shift but a necessary transformation of farming practices. Short-term gains in productivity since the green revolution have the potential to mask attention to the long-term health of the soil and the environment at large. This instrument seeks to rekindle that balance by providing farmers, particularly those operating in economically impoverished settings, a low-cost, low-input option that does away with environmental damage while effectively protecting crops from unwanted pests.

The current study highlights the possibility of merging sustainable technology and IoT with conventional agriculture to make scale affordable, feasible, and practical. The green revolution focused on efficiency and increasing the amount of crops produced because that was the only thing that mattered back then. The world had seen food shortages like never before during the two World Wars. Increasing production is not all that is needed; sustaining the amount of agricultural production is just as important, and finding alternatives to chemical pesticides is one of the first steps towards this new and more refined goal for the agricultural community. The use of ultrasound as a means to control pests is scientifically proven, and utilizing its application to operate based on renewable energy in the form of solar power introduces another layer to the environmental awareness that current agricultural practitioners need to embrace.

References

[1] Infosys, Agri-chem Industry Outlook 2024. [Online]. Available: www.infosys.com/iki/research/agrochem-industry-market-outlook.html

[2] Center for Biological Diversity, Pesticides and Soil Health. [Online]. Available: www.biologicaldiversity.org/campaigns/pesticides-and-soil-health

[3] Government of India, Ministry of Agriculture & Farmers Welfare, Agricultural Statistics at a Glance 2022, Directorate of Economics and Statistics, 2022. [Online]. Available: https://desagri.gov.in/wp-content/uploads/2023/05/Agricultural-Statistics-at-a-Glance-2022.pdf

[4] Indian Council of Agricultural Research, Pest Surveillance and Management Strategies in India, ICAR-NCIPM Report, 2022. [Online]. Available: https://nriipm.res.in/NCIPMPDFs/AnnualReport/AnnualReport2021_.pdf

[5] Tamoghna Saha, Nithya Chandran, and B. C. Annul, *Major Insect Pests of Vegetable Crops in Bihar and Their Management*, Sustainable Agriculture, 1st ed., Apple Academic Press, pp. 1-35, 2020. [Google Scholar] [Publisher Link]

[6] Coffee Board of India, "White Stem Borer Infestation and Control Measures," *Coffee Research Institute Annual Bulletin*, 2021.

[7] The Hindu Business Line, Fruit Fly Menace Hits Mango Exports from Andhra, The Hindu, 2021. [Online]. Available: https://www.thehindubusinessline.com/economy/agri-business/

[8] Times of India, 50% of Onions Wasted in Storage Due to Pests in Maharashtra, 2022. [Online]. Available: www.timesofindia.indiatimes.com

[9] Study on Post-Harvest Losses and Storage Practices in India, National Bank for Agriculture and Rural Development. [Online]. Available: www.nabard.org

[10] Nonkululeko Landy Mdeni et al., "Analytical Evaluation of Carbamate and Organophosphate Pesticides in Human and Environmental Matrices: A Review," *Molecules*, vol. 27, no. 3, pp. 1-21, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[11] Neeraj Godara, "A Review Study of Chemical Contamination in Groundwater of Punjab (Malwa Region)," *International Journal of Applied Research*, vol. 1, no. 12, pp. 278-281, 2015. [Google Scholar] [Publisher Link]

[12] Ryo Nakano, Akio Ito, and Susumu Tokumaru., "Sustainable Pest Control Inspired by Prey–Predator Ultrasound Interactions," *Proceedings of National Academic Science U.S.A.*, vol. 119, no. 43, pp. 1-9, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] Tomson Electronics, Arduino Uno Specification. [Online]. Available: www.tomsonelectronics.com/blogs/news/arduino-uno-specification

[14] John, NodeMCU ESP8266 Specifications, Overview and Setting Up, Make-It.ca, 2022. [Online]. Available: www.make-it.ca/nodemcu-details-specifications

[15] Hübschmann, ESP32 for IoT: A Complete Guide, Nabto, 2024. [Online]. Available: www.nabto.com/guide-to-iot-esp-32

[16] S. Monk, Programming the ESP32: Getting Started with the ESP32 Development Board, McGraw Hill, 2020.

[17] J.R. Davis, *Aluminum and Aluminum Alloys*, ASM International, 1993. [Google Scholar] [Publisher Link]

[18] Dale Ensminger, and Leonard J. Bond, *Ultrasonics: Fundamentals, Technologies, and Applications*, CRC Press, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[19] Food and Agriculture Organization of the United Nations, Guidelines on Irrigation and Drainage Management, FAO, 2020. [Online]. Available: https://www.fao.org/home/en