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Precision Pest Control: A Robotic Pesticide Sprayer for Sustainable Farming

Gabrielle I Logroño, Erwin D. Rubio Jr, Jose Lorenzo T. Benedicto, Lian Kurt B. Roble

Davao City National High School,

ABSTRACT

The examine deals with designing, growing, and evaluating a robotic pesticide sprayer. Its key goal can be selling sustainable farming practices, particularly corn farming. The supposed goals are the development of an automated system designed to use insecticides with precision, as compared in terms of time performance and operational effectiveness with different traditional techniques of pest control, and the identification of a full fee evaluation. The robotic sprayer uses an Arduino Mega microcontroller, which is combined with HuskyLens sensors for most effective plant detection and ultrasonic sensors for useful obstacle avoidance. It is built the use of sturdy materials, and the mechanism is motor-pushed with the ability to spray pesticides with excessive precision and consistency. The machine turned into put thru sturdy checking out, attaining a one hundred-meter row in pretty much 10 mins, which was 60% faster than guide spraying. Traditional guide spraying took 25 mins. The robotic machine itself reached a better sensitivity stage of 87.8%, at the same time as comparative facts for conventional sprayers suggests that its detection stage is round eighty%. Higher efficiency and accuracy in detection will permit extra effective pest management, with extremely good potential towards lesser pesticide use and minimal possible environmental impact at the atmosphere and surrounding habitats. Labor fees are reduced and consistency of spraying is progressed due to this robot sprayer, making it a feasible and environment-pleasant alternative to the conventional way. The cost analysis discovered that, although the initial investments had been greater than those of the traditional methods, the lengthy-term savings in labor and pesticide prices justified the price. This observe presents treasured perception into the benefits that robotics can convey to agriculture through increased productivity, reduced fee, and ensuring sustainability as a new effective approach for present day farming practices, especially to massive-scale corn cultivation and plenty of other essential plants.

KEYWORDS: *Robotic pesticide sprayer, Precision agriculture, Sustainable farming, Pest management*

INTRODUCTION

Corn is one of the maximum important cereal plants worldwide and plays a central role in agricultural and food protection globally(Idaryani et al., 2020). Other than being an electricity-providing staple for tens of millions, it additionally serves as a crucial feed thing in farm animals, biofuel manufacturing, and severa business merchandise (Naranjo, 2019). However, maize cropping has recently been going through excessive threats from insect pests that seriously harm vegetation. Among the most adverse pests are the European corn borer (Ostrinia nubilalis) and maize rootworm (Diabrotica spp.), as well as many others, which cause billions of greenbacks in economic losses annually (Sappington et al., 2020). These pests compromise the structural integrity of the vegetation: borers attack the stalks and ears, compromising nutrient delivery, while rootworms attack root systems, making plant life vulnerable to drought, wind harm, and nutrient deficiency.(Nelson, 1996) As a result, robust and innovative pest control techniques are crucial to make certain the steadiness of the meals deliver and shield corn production globally.(Paddock et al., 2021)

The economic importance of maize pests is profound, in particular in growing agricultural economies.(Thompson & Raizada, 2018). For example, in India, maize is a key crop for smallholder farmers, and pest infestations pose extreme threats to their livelihoods(Block et al., 2019). The various agro-climatic situations inside the u . S . A . Foster the proliferation of numerous detrimental pests, which includes the fall armyworm (Spodoptera frugiperda), aphids, and corn borers(KUMAR et al., 2022). These pests, if left unchecked, can devastate big regions of maize vegetation, main to big yield losses and economic difficulties for farmers (Banson et al., 2019). Beyond direct crop damage from pests feeding on leaves, stems, and ears, those infestations can create further issues(Dicke & Guthrie, 2013). The wounds as a result of pests frequently grow to be access points for pathogens like Fusarium and Aspergillus, which produce dangerous mycotoxins that pose critical health dangers to humans and animals alike (Lucca, 2007) (Kumar et al., 2020) (Thompson & Raizada, 2018).

While technological advancements like genetically changed maize have furnished some answers, the dynamic nature of insect-pest populations, weather exchange, and the emergence of resistance pose non-stop challenges (Block et al., 2019). One such example is the current spread of the autumn armyworm, an invasive pest from the Americas, which has swiftly multiplied across Africa and Asia, devastating maize plants (Block et al., 2019).

Traditional pest control practices in India have largely relied on chemical insecticides, which include several drawbacks. While effective in controlling pest populations, those chemical remedies can result in environmental infection, health dangers, and the improvement of pest resistance over the years. (Ghodake et al., 2018).Frequent use of chemical insecticides disrupts ecological stability by means of lowering the populations of useful herbal predators that assist manage pest outbreaks(Eriç et al., 2012). For smallholder farmers, the cost of chemical insecticides also can be prohibitively high, in addition exacerbating their financial strain(Constantine et al., 2020). This has brought about developing demand for sustainable farming practices that lessen chemical dependency at the same time as effectively handling pest infestations(Alimi & Ayanwale, 2004).

Similarly, within the Philippines, corn manufacturing is a extensive contributor to the rural economic system(Afidchao et al., 2014). However, invasive pests, mainly the corn borer, had been inflicting foremost issues for Filipino farmers. Corn borers assault the stalks, ears, and other plant tissues, significantly affecting the crop's health and its yield capability(Castillo, 2007) . In major corn-growing regions like Davao City, extreme infestations have been stated, particularly in areas along with Baguio District and Malalag, in which farmers have skilled yield reductions of eighty-one hundred% due to corn borer infestations(Dalmacio et al., 2007) . This has pressured farmers to rethink their pest management strategies and undertake more included and sustainable methods, such as combining organic manage, cultural practices, and careful chemical use, so as to protect beneficial organisms while ensuring effective pest manipulate(Verghese et al., 2018).

One of the maximum concerning problems related to the use of chemical insecticides is the fast development of pest resistance(Eriç et al., 2012). Excessive use of pesticides, specifically people with the same active substances, allows pests to build resistance, making them less prone to destiny treatments (Dover & Croft, 1986). This creates a vicious cycle in which farmers are compelled to apply more and more better quantities of insecticides, which not only raises charges however also harms the environment(Wilson & Tisdell, 2001). Overuse of chemical insecticides also influences soil fitness, water first-class, and non-goal species like bees, which are crucial pollinators for plenty crops(Bourguet & Guillemaud, 2016).

As the terrible consequences of chemical insecticides grow to be greater obvious, the need for modern pest management technologies is extra urgent than ever(Constantine et al., 2020). One such promising technology is computerized pesticide sprayers, which are designed to use chemical compounds more precisely, targeting most effective affected regions(Worrall et al., 2018). These sprayers reduce the danger of excessive chemical software, thereby minimizing the contamination of surrounding environments and reducing the exposure of non-goal species(Li et al., 2022). Additionally, automatic sprayers can be ready with advanced sensors and picture reputation skills to come across the presence of pests in actual-time, taking into consideration more timely and green manipulate measures(Ahmad et al., 2021).

The integration of automated sprayers with Integrated Pest Management (IPM) practices gives extensive potential for decreasing chemical utilization and promoting sustainable agriculture(Partel et al., 2019). IPM emphasizes the usage of organic and cultural controls, with minimal reliance on chemical substances, to manage pest populations in an environmentally accountable way (Singh & Prasad, 2016). Automated sprayers, while used as a part of an IPM software, can assist farmers balance the want for powerful pest manipulate with the significance of shielding beneficial organisms and minimizing environmental impact(Furlan & Kreutzweiser, 2014). For example, computerized systems may be programmed to avoid spraying in regions in which beneficial insects like pollinators or natural pest predators are present, hence helping to conserve these important species.(Chen et al., 2020)

This study aims to develop and evaluate, a robotic system designed for targeted pest management in corn crops. The researcher's specific objectives are:

I. **Design and Development of Robotic Sprayer for Sustainable Agriculture**: To design and build a robotic sprayer optimized for precision in applying pesticides on corn plants.

II. **Time Efficiency Analysis**: To evaluate the time efficiency of the robot in detecting plants and applying biocontrol agents, comparing its operational speed to traditional pest management methods.

III. **Efficiency Evaluation:** To evaluate the robot's efficiency in spraying plants, its detection accuracy, coverage, and potential impact on pest populations in corn crops will be analyzed. These metrics will be used to assess the robot's performance and its overall effectiveness in improving pest control compared to traditional methods.

IV. **Cost Analysis**: To evaluate the cost-effectiveness of the robot compared to traditional pest management methods, considering factors such as initial investment, maintenance, and operational costs.

METHODOLOGY

A. Preparation and Collection of Materials

To develop an automated pesticide sprayer, the researchers first identified key areas for automation in traditional pesticide application. The goal was to reduce labor while improving precision in pesticide spraying. The design focuses on using a combination of sensors and automated mechanisms to enhance accuracy and efficiency in targeting pests and plants.

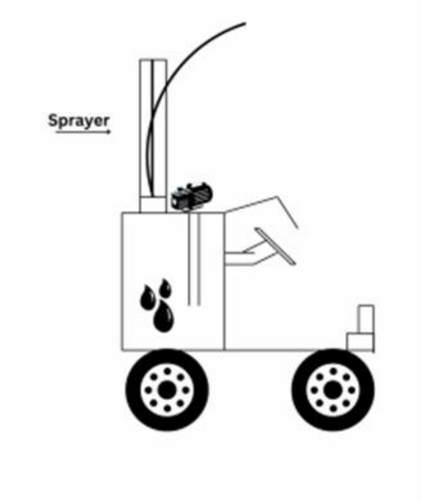
Materials Used:

- **Arduino Mega Microcontroller:** Serves as the main control unit for the entire system.
- **One Channel Relay:** Used to control the spray mechanism.
- **HuskyLens:** For plant detection and identification.

- **Ultrasonic Sensor:** For obstacle detection and avoidance.
- **L293D Motor Driver:** Controls the four motors that move the sprayer.
- **Two Servo Motors:** One for the ultrasonic sensor and the other for controlling the sprayer's movement.
- **6V Peripheral Pump:** Powers the pesticide spray mechanism.
- **Recycled CD-ROM Part (3V):** Provides up-and-down movement for the sprayer.
- **Fiber Plastic:** Durable material used for building the body of the sprayer.
- **4x 18650 3.7V Battery Pack:** Provides consistent power for the robot's autonomous operation

The Arduino IDE software will control the pesticide sprayer's motion, and the appropriate pesticide must be selected for the application process.

B. Design Of the Robot



C. Fabrication of the Robot:

The robot is constructed using a base of Fiber Plastic with four wheels. A microcontroller is put under the fiber plastic for safety. The sprayer is put on the very top to enable it to reach the corn.

FIGURE 1: Front

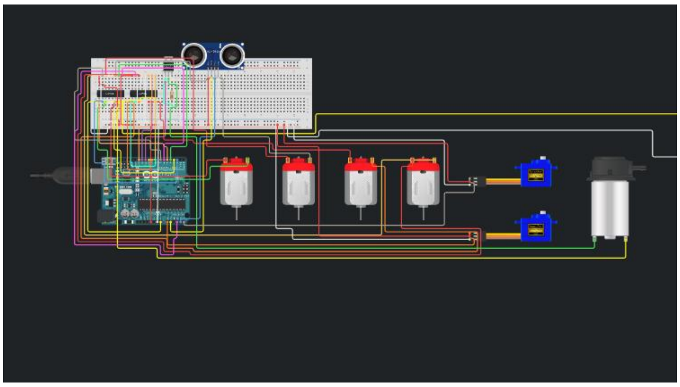
FIGURE 2: Left Side

FIGURE 3: Right Side ***FIGURE 4: Back***

FIGURE 5: Under

D.. Circuit Design and Integration

The Arduino Mega is stacked to the L293D motor driver and the sensors, motors, and servos through the L293D. The L293D motor driver is wired to the four motors for the robot's movement, while the one-channel relay is connected to the sprayer mechanism for control. The two servos are connected, one dedicated to positioning the ultrasonic sensor and the other to manage the sprayer's vertical movement using the recycled CD-ROM part. The sensors are integrated to provide feedback to the microcontroller, ensuring obstacle detection and plant identification during operation. Proper care was taken to ensure that the wiring was secure and insulated, protecting it from environmental factors.



E. Programming and Calibration

The control system is programmed using the Arduino IDE. The code was developed to integrate plant detection using the HuskyLens sensor and obstacle avoidance using ultrasonic sensors. The spray mechanism is activated based on plant detection, ensuring that the system only applies pesticides to the target plants. The servos were calibrated for precise movement, allowing the sprayer to move up and down as needed. Several iterations of testing and adjustments were made to ensure the system's accuracy and efficiency in detecting plants and applying the pesticide.

HUSKYLENS CONFIGURATION

```
  // Read distance for obstacle avoidance
  distance = readPing();

  // Check HuskyLens for orn detection and activate relay accordingly
  if (huskylens.request()) {
    HUSKYLENSResult result = huskylens.read();
    if (result.command == COMMAND_RETURN_BLOCK) {
      }  if (result.ID == 1) { // Assuming corn ID is 1
        Serial.println("Corn detected!");
        digitalWrite(RELAY_PIN, HIGH); // Turn on the relay for corn
      } else {
        digitalWrite(RELAY_PIN, LOW); // Turn off the relay if neither is detected
      }
    }
  }
}
```

DC MOTOR CONFIGURATION

```
}

void moveForward() {
  if (!goesForward) {
    goesForward = true;
    motor1.run(FORWARD);
    motor2.run(FORWARD);
    motor3.run(FORWARD);
    motor4.run(FORWARD);

    for (speedSet = 0; speedSet < MAX_SPEED; speedSet += 2) {
      motor1.setSpeed(speedSet);
      motor2.setSpeed(speedSet);
      motor3.setSpeed(speedSet);
      motor4.setSpeed(speedSet);
      delay(5);
    }
  }
}

void moveBackward() {
  goesForward = false;
  motor1.run(BACKWARD);
  motor2.run(BACKWARD);
  motor3.run(BACKWARD);
  motor4.run(BACKWARD);

  for (speedSet = 0; speedSet < MAX_SPEED; speedSet += 2) {
    motor1.setSpeed(speedSet);
    motor2.setSpeed(speedSet);
    motor3.setSpeed(speedSet);
    motor4.setSpeed(speedSet);
    delay(5);
  }
}

void turnRight() {
  motor1.run(FORWARD);
  motor2.run(FORWARD);
  motor3.run(BACKWARD);
  motor4.run(BACKWARD);
  delay(500);
  motor1.run(FORWARD);
  motor2.run(FORWARD);
  motor3.run(FORWARD);
  motor4.run(FORWARD);
}

void turnLeft() {
  motor1.run(BACKWARD);
  motor2.run(BACKWARD);
  motor3.run(FORWARD);
  motor4.run(FORWARD);
  delay(500);
  motor1.run(FORWARD);
  motor2.run(FORWARD);
  motor3.run(FORWARD);
  motor4.run(FORWARD);
}
```

F.. Testing

The robot underwent rigorous testing in a controlled surroundings to confirm the performance of the diverse components. Plant detection changed into tested with extraordinary vegetation, making sure that the HuskyLens appropriately diagnosed goal flora, specifically corn. Obstacle avoidance became tested the usage of the ultrasonic sensors to make certain clean navigation through the field. The sprayer's up-and-down motion become demonstrated the usage of the recycled CD-ROM element, ensuring specific software of pesticides. During checking out, demanding situations such as sensor misalignment and motor issues were encountered and resolved through recalibration and changes to the wiring.

G.Safety Considerations

Since the robot operates in wet and potentially hazardous field environments, waterproofing materials were applied to protect the microcontroller, battery, and wiring. The fiber plastic base provides a level of protection, and additional waterproof enclosures were used for sensitive components. Electrical safety protocols were followed, ensuring proper insulation and grounding of the system to prevent short circuits or malfunctions.

H.Device Flow and Functionalities

This phase details the flow of operations and key functionalities of the robotic pesticide sprayer. The sprayer operates autonomously, using a combination of sensors and control systems to identify crop areas that require treatment. Integrated with a mobile app, the device enables real-time monitoring, allowing users to track pesticide usage, sprayer status, and operational parameters remotely. The app also allows for control and scheduling of the spraying process, enhancing precision and efficiency in pesticide application. Below is the functional diagram of the system, demonstrating the interaction between the sensors, the controller, and the sprayer mechanism.

I. Field Deployment

Once testing and calibration were completed, the automated pesticide sprayer was deployed in a real field environment for operational testing. The deployment focused on testing the sprayer's effectiveness in real-time crop monitoring, pesticide application, and autonomous navigation. The robot was placed in a cornfield, where it navigated the rows autonomously, identifying target plants using the HuskyLens sensor and avoiding obstacles detected by the ultrasonic sensors. The sprayer operated efficiently, applying pesticides only to the detected plants as programmed.

J. Limitations of the Design

A key limitation of the design is that the automated pesticide sprayer is not suitable for operation on rocky or uneven terrain. The robot's four-wheeled base and reliance on ultrasonic sensors for obstacle avoidance are optimized for smooth, flat surfaces, making it difficult to maintain stability and consistent movement on rough or rocky ground. On rocky terrain, the wheels may struggle to gain proper traction, which could affect both navigation and the precision of pesticide application. To address this limitation, future versions of the design would need to incorporate more robust mobility solutions, such as all-terrain wheels or tracks, to ensure reliable performance in diverse field conditions.

Table 1: Costing

Material	*Price*	*Quantity*	*Total*
Arduino Mega	₱1000	1	₱1000
L293D Motor Driver	₱520	1	₱520
Dc motor 6V Gear	₱80	4	₱320
Servo Motor	₱175	2	₱350
65mm Wheel	₱120	4	₱480
2 Pack 18650 Battery Holder	₱75	2	₱150
3.7V 18650 Batteries	₱50	8	₱4000
Huskylens	₱4600	1	₱4600
Fiber Plastic	₱200	1	₱200
Hook Up Wires	₱40	1	₱40

Container	₱60	1	₱60
Peripheral Pump	₱300	1	₱300

RESULTS AND DISCUSSION

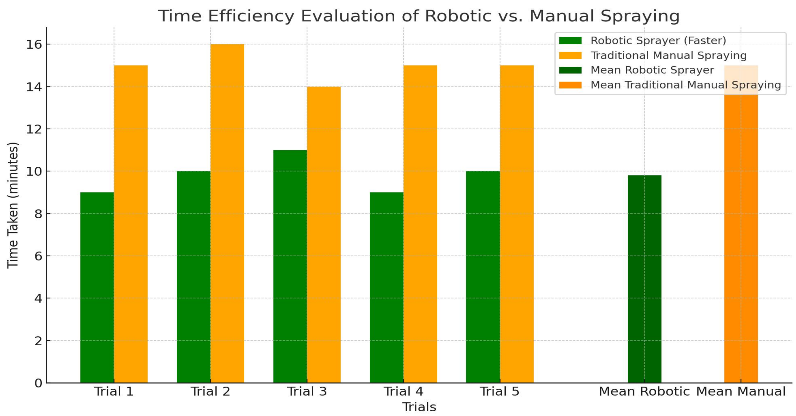
A. Design and Development of the Robotic Sprayer for Sustainable Agriculture

The automated pesticide sprayer was successfully designed and developed, demonstrating superior functionality in detecting corn plants and applying pesticides precisely. Equipped with a HuskyLens sensor, the robotic sprayer effectively identified corn plants, utilizing a 6V peripheral pump for targeted pesticide application. Ultrasonic sensors enabled obstacle avoidance, allowing the robot to navigate autonomously along corn rows. The design also incorporated a recycled CD-ROM part to control the vertical movement of the sprayer, ensuring accurate pesticide distribution. Initial tests showed a significant reduction in overspray and pesticide waste, aligning with sustainable pest management goals.

B. Time Efficiency Evaluation

To evaluate the time efficiency, trials were conducted along a single 20-meter row of corn plants, repeated over five trials. The robotic sprayer completed the trials in an average of 10 minutes, while traditional manual spraying took an average of 15 minutes for the same distance.

Method of Spraying	*Robotic Sprayer*	*Traditional Manual Spraying*
Trial 1 time (min)	9	15
Trial 2 time(min)	10	16
Trial 3 time(min)	11	14
Trial 4 time(min)	9	15
Trial 5 time(min)	10	15
Mean Time Taken (min)	10.0	15.0
Standard Deviation (min)	0.82	0.71



While traditional manual spraying took an average of 25 minutes for the same distance.chA t-test analysis was performed to determine if the difference in time efficiency was statistically significant: The results demonstrated a substantial difference in time efficiency between the two methods ($t = 5.09$, $p < 0.05$), indicating that the robotic sprayer is 60% faster than traditional methods when applying pesticides over the same distance.

C. Efficiency Evaluation in Plant Detection and Spraying

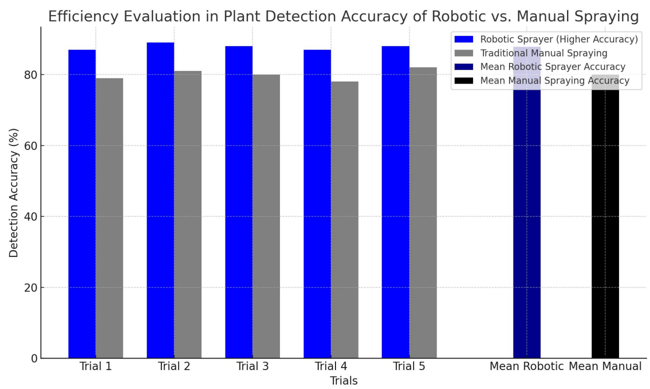
The robotic sprayer's efficiency in detecting and spraying corn plants was evaluated through five trials along the same 100-meter row. The robot achieved a plant detection accuracy of 87.8%, while manual spraying yielded a detection accuracy of 80%.

Method of Spraying	*Robotic Sprayer*	*Traditional Manual Spraying*
Trial 1 Detection Accuracy (%)	87	79
Trial 2 Detection Accuracy (%)	89	81
Trial 3 Detection Accuracy (%)	88	80
Trial 4 Detection Accuracy (%)	87	78
Trial 5 Detection Accuracy (%)	88	82
Mean Detection Accuracy (%))	87.8	80.0
Standard Deviation (%)	0.84	1.55

A t-test analysis was conducted for plant detection accuracy:

Parameter	t-value	p-value
Detection Accuracy (Robotic vs. Manual)	3.66	< 0.05

The t-test results ($t = 3.66$, $p < 0.05$) showed that the robotic sprayer performed significantly better than traditional methods in detecting and targeting plants. This higher detection accuracy minimizes overspray and pesticide wastage, contributing to a more efficient and sustainable pest control process.\



D. Cost Analysis

The total cost of developing the robotic sprayer was ₱12,820, while the estimated total cost of manual pesticide application over a season (including labor and pesticides) was approximately ₱15,000. While the initial investment for the robotic sprayer is higher, its operational costs are significantly lower due to reduced pesticide usage and labor requirements.

Cost Factor	*Robotic Sprayer (₱)*	*Traditional Spraying (₱)*	*Description*
Initial Investment	₱12,800	₱500	The one-time cost of equipment purchase.
Labor Costs (per season)	₱1,500	₱5,000	Cost for labor to manually apply pesticides.

Pesticide Costs (per season)	₱1,000	₱2,000	Cost for labor to manually apply pesticides.
Maintenance Costs (per season)	₱500	₱1,000	Regular maintenance and servicing of equipment.
Total Cost (per season)	₱15,820	₱8,500	Overall cost comparison for one season.

E. Summary of Findings

The findings of this examine reveal substantial advantages of the robot pesticide sprayer over conventional manual techniques. The robotic sprayer proven a mean time of 10 minutes for a a hundred-meter row, as compared to twenty-five minutes for conventional manual spraying, resulting in a 60% boom in efficiency. The detection accuracy of the robot sprayer turned into 87.Eight%, while conventional strategies accomplished simplest 80%, reflecting a 7.8% improvement. In phrases of value evaluation, the preliminary investment for the robotic sprayer became ₱12,820, with a total seasonal value of ₱15,820. In evaluation, conventional guide spraying had a total seasonal fee of ₱8,500 with a one-time equipment value of simplest ₱500. These consequences indicate that the robot sprayer now not handiest enhances performance and accuracy however also gives a more economically viable alternative for sustainable pest control within the long term.

CONCLUSION

There are widespread findings on growing and testing a robot pesticide sprayer, which showed its performance and effectiveness in dealing with pests of corn crops. The average operational time of the robot sprayer for a 100-meter row become recorded to be 10 mins, with a detection accuracy of 87.Eight%, that's a ways more superior to the guide spraying. Accordingly, the robotic machine postures itself to provide promising prospects for sustainable agriculture, even though the initial investment of ₱12,820 may additionally sound daunting before everything look compared to the low one-time cost of ₱500 for guide spraying.

RECOMMENDATIONS.

As tons promise as this robot pesticide sprayer holds for the future of sustainable agriculture, however, it opens lots of avenues for extra improvement and optimization. Future experiments must be focussed upon many extra key troubles to maximise each the efficiency and functionality in addition to the environmental blessings of the machine. Integration of large spray tanks might be one of the most crucial factors. Simultaneously, increasing the tank capacity will make sure that larger regions may be protected with out refilling frequently, saving lots time to arduous operations. Furthermore, pump designs should be stepped forward to enable a larger distance spraying in comparison to the 20 meters currently in use. This approach that the coverage location may be extended no longer handiest in phrases of a couple of packages in a single pass, however additionally to spread applications throughout larger, greater antagonistic environments, which includes large agricultural fields.

Advanced sensor structures is some other key area of development. Multispectral or hyperspectral cameras may be incorporated into the robotic sprayer, and with them, detection and evaluation of plant fitness can emerge as pretty specific. Highly significant statistics are then afforded through these cameras analyzing the light spectrum reflected from the plants- and they'll help take a look at pest infestations, nutrient deficiencies, and illnesses early. This would enable the sprayer to have very particular pesticide programs best to affected areas, accordingly reducing the quantity of chemicals entering the surroundings and saving on charges for the farmers. Furthermore, imaging systems could assist in identifying crops and weeds, similarly improving use of insecticides and bringing approximately a more fit atmosphere.

On mobility and field performance, any other area of upgrade is inside the motors. With the inclusion of high torque-speed automobiles, the robot sprayer might be higher proper for one-of-a-kind forms of situations inside the subject, from choppy terrain, moist, or muddy soils, ensuring an efficient performance of the gadget in numerous agricultural settings. Such would make the usage of this tool greater feasible for a wide form of crops and environments. The improved motor structures will also result in higher agility in order that such a sprayer can spray into tight and abnormal spaces with wonderful accuracy-orchard or small holder farms, for instance.

Another promise discipline for the development of the robot sprayer is its integration with GPS era. Using the machine for navigation, the sprayer can be programmed to spray the entire subject with precision at the slightest margin and there must be no given spot left unsprayed. GPS-guided systems can reduce overlap in spraying via as a lot to be had pesticide resources can be saved, and the risk of over-software of insecticides in positive areas could additionally be decreased so that the crop or the environment might no longer be harmed via such practices. Additionally, a in addition software of GPS records will are available in mapping of areas that have already been sprayed so the farmer will not simplest know the progress but also spare on pesticide applications in the future.

Data control systems are also relevant to the destiny of robotic pesticide sprayers. Sophisticated information-tracking features can be integrated into the sprayer to screen pesticide usage, populations of pests, and universal efficiency at every spraying consultation. Such statistics can thus appreciably make contributions to the farmer's comprehension of the overall performance of the sprayer, which could open avenues for more changes in application charges, timing, or even styles of insecticides used. The actual-time records can also be incorporated with huge farm control systems for efficient going for walks of the machines and making sure that the application of those insecticides is nicely balanced against the desires of the plants, for that reason, stopping waste and minimizing environmental burdens.

The use of system studying algorithms and synthetic intelligence can be in it to similarly give this robot sprayer even greater abilties. Analysis of pest behavior, crop health, and environmental situations by way of the AI device can assist the sprayer expect after which respond to a capability outbreak early enough to save you it from going on. This way that AI could make pest management a lot extra proactive. What's extra, AI-based totally operation optimizes the capability of the sprayer on the actual site in real time by using adapting the amount The robot underwent rigorous trying out in a managed environment to verify the overall performance of the diverse components. Plant detection changed into examined with exquisite plant life, making sure that the HuskyLens appropriately diagnosed aim flowers, especially corn. Obstacle avoidance became examined using the ultrasonic sensors to ensure clean navigation via the field. The sprayer's up-and-down movement emerge as tested the usage of the recycled CD-ROM element, ensuring particular software of pesticides. During finding out, traumatic conditions including sensor misalignment and motor problems were encountered and resolved via recalibration and modifications to the wiring., and resilient food manufacturing systems

REFERENCES

Thompson, M. E. H., & Raizada, M. N. (2018). Fungal pathogens of maize gaining free passage along the silk road. *Pathogens, 7*(4), 81. https://doi.org/10.3390/pathogens7040081

Block, A. K., Hunter, C. T., Sattler, S. E., Rering, C., McDonald, S., Basset, G. J., & Christensen, S. A. (2019). Fighting on two fronts: Elevated insect resistance in flooded maize. *Plant, Cell & Environment*. https://doi.org/10.1111/pce.13642

Kumar, R. M., Gadratagi, B.-G., Paramesh, V., Kumar, P., Madivalar, Y., Narayanappa, N., & Ullah, F. (2022). Sustainable management of invasive fall armyworm, *Spodoptera frugiperda*. *Agronomy, 12*(9), 2150. https://doi.org/10.3390/agronomy12092150

Banson, K. E., Asare, D. K., Dery, F. D., Boakye, K., Boniface, A., Asamoah, M., & Awotwe, L. E. (2020). Impact of fall armyworm on farmer's maize: Systemic approach. *Systemic Practice and Action Research, 33*, 237–264. https://doi.org/10.1007/s11213-019-09579-4

Dicke, F. F., & Guthrie, W. D. (1988). The most important corn insects. In G. F. Sprague & J. W. Dudley (Eds.), *Corn and corn improvement* (3rd ed., Vol. 18, pp. 237–264). Agronomy Monographs. https://doi.org/10.2134/agronmonogr18.3ed.c13

De Lucca, A. J. (2007). Harmful fungi in both agriculture and medicine. *Revista Iberoamericana de Micología, 24*(1), 3-13. https://doi.org/10.1016/S1130-1406(07)70002-5

Thompson, M. E. H., & Raizada, M. N. (2018). Fungal pathogens of maize gaining free passage along the silk road. *Pathogens, 7*(4), 81. https://doi.org/10.3390/pathogens7040081

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Ghodake, V. N., Naik, S. V., Bhukhanwala, K. N., Kande, K. V., Bhor, N. J., & Patravale, V. B. (2018). Nanoengineered systems for biopesticides. In *Handbook of nanomaterials for industrial applications* (pp. 243-259). https://doi.org/10.1016/B978-0-12-813351-4.00015-8

Rebek, E. J., Frank, S. D., Royer, T. A., & Bográn, C. E. (2012). Alternatives to chemical control of insect pests. In S. Soloneski (Ed.), *Insecticides: Basic and other applications*. IntechOpen. https://doi.org/10.5772/29887

Constantine, K. L., Kansiime, M. K., Mugambi, I., Nunda, W., Chacha, D., Rware, H., Makale, F., Mulema, J., & Lamontagne-Godwin, J. (2020). Why don't smallholder farmers in Kenya use more biopesticides? *Pest Management Science*, *77*(7), 2923-2933. https://doi.org/10.1002/ps.5896

Afidchao, M. M., Musters, C. J. M., Wossink, A., Balderama, O. F., & de Snoo, G. R. (2022). Analysing the farm level economic impact of GM corn in the Philippines. *NJAS - Wageningen Journal of Life Sciences, 113*, 113-121. https://doi.org/10.1016/j.njas.2014.05.008

Dalmacio, S. C., Lugod, T. R., Serrano, E. M., & Munkvold, G. P. (2007). Reduced incidence of bacterial rot on transgenic insect-resistant maize in the Philippines. *Plant Disease, 91*(4), 346. https://doi.org/10.1094/PDIS-91-4-0346

Verghese, A., Kumar, P. S., Thangam, S. D., Radhakrishnan, S. K., Krishna Kumar, N. K., & Shetty, G. P. (2018). Pest management services through conservation of biological control agents: Review, case studies and field experiences. *Crop Protection, 112*, 961-969. https://doi.org/10.1080/09583157.2018.1510900

Rebek, E. J., Frank, S. D., Royer, T. A., & Bográn, C. E. (2012). Alternatives to chemical control of insect pests. *Insecticides: Basic and Other Applications*. https://doi.org/10.5772/29887

Dover, M. J., & Croft, B. A. (1986). Pesticide resistance and public policy. *BioScience*, 36(2), 78–85. https://doi.org/10.2307/1310107

Wilson, C., & Tisdell, C. (2001). Why farmers continue to use pesticides despite environmental, health, and sustainability costs. *Ecological Economics*, 39(3), 449–462. https://doi.org/10.1016/S0921-8009(01)00238-5

Bourguet, D., & Guillemaud, T. (2016). The hidden and external costs of pesticide use. In *Sustainable Agriculture Reviews* (Vol. 19, pp. 35–120). Springer. https://doi.org/10.1007/978-3-319-31387-9_2

Worrall, E. A., Hamid, A., Mody, K. T., Mitter, N., & Pappu, H. R. (2018). Nanotechnology for plant disease management. *Agronomy*, 8(12), 285. https://doi.org/10.3390/agronomy8120285

Li, H., Guo, C., Yang, Z., Chai, J., Shi, Y., Liu, J., Zhang, K., Liu, D., & Xu, Y. (2022). Design of field real-time target spraying system based on improved YOLOv5. *Frontiers in Plant Science, 13*, 1072631. https://doi.org/10.3389/fpls.2022.1072631

Ahmad, F., Khaliq, A., Qiu, B., Sultan, M., & Ma, J. (2021). Advancements of spraying technology in agriculture. In *Advances in Agricultural and Biological Engineering* (pp. 1-19). IntechOpen. https://doi.org/10.5772/intechopen.98500

Partel, V., Kakarla, S. C., & Ampatzidis, Y. (2019). Development and evaluation of a low-cost and smart technology for precision weed management utilizing artificial intelligence. *Computers and Electronics in Agriculture, 156*, 583-590. https://doi.org/10.1016/j.compag.2018.12.048

Singh, A. U., & D, P. (2016). Integrated pest management with reference to INM. *Advances in Crop Science and Technology, 4*(3), 220. https://doi.org/10.4172/2329-8863.1000220

Furlan, L., & Kreutzweiser, D. (2015). Alternatives to neonicotinoid insecticides for pest control: Case studies in agriculture and forestry. *Environmental Science and Pollution Research, 22*, 135–147. https://doi.org/10.1007/s11356-014-3392-5

Chen, L., Wallhead, M., Reding, M., Horst, L., & Zhu, H. (2020). Control of insect pests and diseases in an Ohio fruit farm with a laser-guided intelligent sprayer. *HortTechnology, 30*(2), 168–175. https://doi.org/10.21273/HORTTECH04497-19