Indian Farmer
Volume 11, Issue 08, 2024, Pp. 285-292
Available online at: www.indianfarmer.net
ISSN: 2394-1227 (Online)

Original Article

Laser Weeding: Revolutionizing Weed Management in Agriculture with Precision Technology

Hridesh Harsha Sarma[1*] and Santanu Kaushik Borah[2]

[1]*MSc. (Agriculture), Department of Agronomy, Assam Agricultural University, Jorhat, Assam*

[2]*Subject matter Specialist (Agronomy), KVK Kokrajhar, AAU, Jorhat-13*

**Corresponding author: hrideshsarma.official@gmail.com*

Received: 08/08/2024 *Published:11/08/2024*

INTRODUCTION

Globally, weed infestations pose significant challenges to crop production, hindering efforts to boost yields and meet the food demands of a growing population (FAO, 2021). The indiscriminate use of herbicides often leads to environmental contamination, as these chemicals frequently affect non-target areas or are lost due to spray drift (Harrison, 2011). Weeds pose a significant challenge to crop production, with herbicides being the primary method for their control in modern agriculture. However, the extensive use of herbicides has led to the emergence of herbicide-resistant weed strains. While mechanical weeding is used on organic farms and sometimes alongside herbicides on conventional farms, it has its drawbacks. Mechanical methods can disrupt beneficial soil organisms, such as predatory insects and earthworms, and contribute to soil erosion, moisture depletion, and nutrient leaching along with unnecessary mineralization of soil organic matter. Additionally, this approach may lead to the mineralization of soil organic matter and trigger the germination of new weed seeds. Implementing site-specific weed harrowing could help mitigate these environmental impacts and improve weed management. Additionally, the rise in herbicide-resistant weeds and the stagnation in new herbicide modes of action since the 1980s further complicate weed management (Duke, 2011). The adverse effects of pesticide use have led to stricter regulations and initiatives aimed at reducing their application. Flame weeding, though effective, is environmentally unsustainable due to its high gas consumption and CO_2 emissions.

As a result, there is a growing need for innovative weed control techniques to complement or replace existing methods. Laser technology presents a promising solution by delivering concentrated energy to targeted areas. A laser can be aimed at weed plants to heat and damage or kill them. Advanced identification tools utilizing artificial intelligence enable real-time differentiation between weeds and crops, enhancing efficiency. High-resolution cameras can detect the plant meristem, while precise laser scanners assist in positioning. Consequently, research into laser weeding has intensified, leading to the emergence of field robots equipped with these technologies.

Concept of laser weeding

Laser weeding is an innovative method aimed at controlling weeds using focused laser beams. This technique leverages advancements in artificial intelligence and robotics to selectively target and eliminate weeds while minimizing impact on surrounding crops and the environment. Laser weeding targets and eliminates weeds at their meristem, preventing them from competing for vital resources.

Traditional herbicides used by farmers can degrade soil health and are associated with health risks for humans and animals. In contrast, a laser-based autonomous weed management system significantly reduces or eliminates the need for herbicides. Cost-effective weed control remains a major challenge in organic farming, and a solution that avoids herbicides and reduces manual labour offers a viable path for farmers to label their crops as organic. Automated robots help lower the variable costs of manual labour and decrease the need for crop inputs like herbicides and fertilizers. Since labour is often one of the highest expenses for farmers and crop inputs represent 28.2% of total costs, minimizing these expenses offers considerable advantages. Additionally, lasers do not disturb soil microbiology, unlike tillage, supporting a regenerative farming approach that fosters healthy crops and enhances yields.

Fig. 1: LaserWeeder^{TM} by Carbon Robotics

(Source: https://carbonrobotics.com/)

Various types of lasers utilize different active media and emit at distinct wavelengths. Diode lasers use a semiconductor as their active medium, which is energized by an electrical current. These lasers can emit across a broad spectrum from ultraviolet to infrared, with common wavelengths at 940 and 980 nm and power outputs ranging from milliwatts to several kW. Fiber lasers, a subtype of solid-state lasers, utilize a doped glass fibre as the active medium and are excited by optical radiation. Their emission wavelengths are typically in the visible to near-infrared range, and they can achieve power outputs of several kilowatts.

For instance, the diode laser and fibre laser examined by Kaierle et al. (2013) operated at wavelengths of 1,908 nm and 532 nm, respectively. CO_2 lasers, on the other hand, employ a gas mixture of nitrogen (N_2), helium (He), and carbon dioxide (CO_2) as their active medium, which is excited by an electric gas discharge. CO_2 lasers are known for their emission in the far infrared spectrum, with commonly used wavelengths at 9.3 μm, 10.2 μm, and 10.6 μm. A laser weeder operates as a sophisticated system where numerous factors impact its accuracy. The precision of the weeder is high when the recognition system solely distinguishes crops from other plants. However, if the system must identify and select among various weed species, the complexity increases, potentially slowing down the processing and driving speed.

For row crops, which have limited competitive strength against weeds early in the growing season, effective weed control is crucial, requiring a high control rate from the laser. Uneven fields with obstacles such as stones, holes, and tractor tracks can cause vibrations and jolts that may reduce the laser's effectiveness and pose a risk of damaging the crop plants. To mitigate this, careful seedbed preparation is necessary to ensure a smooth, even field. Alternatively, operating at slower speeds can help minimize vibrations and improve accuracy. Inaccurate laser targeting can harm crops if the beam strikes them directly, and if weeds obscure the crops, there is a risk of inadvertent damage. When a laser beam only impacts a leaf, the leaf may be damaged, but the plant could potentially recover and regrow.

Methodology of Laser Weeding

1. Preparation and Setup

- **Equipment Selection:** The selection of an appropriate laser weeding system is crucial. These systems generally consist of a laser source, sensors, and a control unit designed for the specific type of crops and weeds present in the field.
- **Calibration:** The laser system must be calibrated to ensure accurate focusing and alignment. This step involves adjusting the lasers to the correct intensity and configuring the detection sensors to distinguish between weed and crop plants.

2. Field Assessment

- **Survey and Mapping:** A thorough survey of the field is conducted to map the distribution of crops and weeds. This process often utilizes GPS technology and imaging systems to gather data on weed locations and densities.
- **Weed Identification:** Advanced imaging systems are employed to differentiate weeds from crops based on size, shape, and sometimes colour. Some systems use machine learning algorithms to enhance weed detection accuracy.

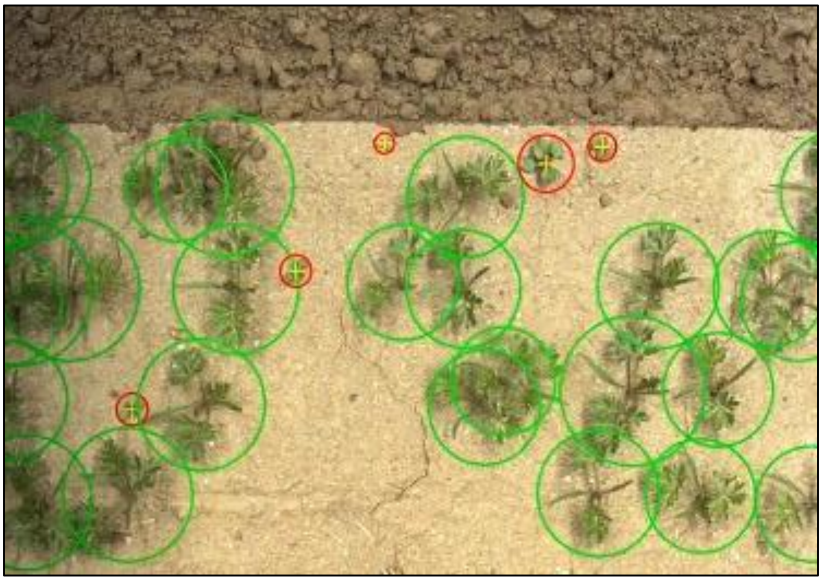

Fig. 2: Weed Detection via Advanced Imaging Systems

(Source: https://carbonrobotics.com/laserweeding)

3. Laser System Operation

- **Deployment:** The laser system is mounted on a vehicle, such as a tractor, or set up in a stationary position depending on the field layout and system design.
- **Real-Time Detection:** As the system operates in the field, sensors continuously scan the ground to detect weeds. The data collected is used by the control unit to identify weed locations accurately.

4. Laser Targeting

- **Precise Application:** The control unit processes the sensor data and directs the laser beams precisely at the identified weeds. The lasers are focused to target only the weed plants, avoiding harm to the surrounding crops.
- **Energy Regulation:** The laser's intensity and duration are adjusted to ensure that only the weed tissues are damaged or destroyed. This regulation is crucial for effectively killing the weeds while preventing damage to crops.

Fig. 3: Before and After Laser Weeding

(Source: https://optlasers.com/blue-lasers-in-laser-weeding)

5. Monitoring and Adjustment

- **Continuous Monitoring:** The system continuously monitors the effectiveness of the laser weeding process. It checks for proper targeting of weeds and ensures that no crops are inadvertently affected.
- **Adjustment and Optimization:** Real-time feedback is used to make necessary adjustments to the laser settings and system operation to optimize weed control and minimize any potential crop damage

6. Post-Operation

- **Field Review:** Following the completion of the laser weeding process, a review of the field is conducted to assess the operation's effectiveness. This review includes checking for any missed weeds or potential crop damage.
- **Maintenance:** Routine maintenance is performed on the laser system to ensure it remains in optimal working condition. Maintenance tasks include cleaning lenses, checking calibration, and inspecting sensors and controls.

7. Data Analysis

- **Effectiveness Assessment:** Data on weed reduction and crop health is analyzed to evaluate the success of the laser weeding operation. Comparisons with pre-operation data are made to assess overall effectiveness.
- **Reporting:** Results and observations regarding the system’s performance are documented, including any issues encountered and resolutions applied.

8. Integration with Other Practices

- **Combine with Conventional Methods:** Laser weeding is integrated with other weed management strategies, such as mechanical weeding or herbicide applications, to provide comprehensive weed control.

- **Adaptation for Future Use:** The laser weeding process is adapted and refined based on results and feedback to improve future operations and enhance overall efficiency.

Fig 4: Complete burning of weed by Laser

(Source: https://carbonrobotics.com/laserweeder)

Blue Laser Technology for Weeding

Blue light is notably absorbed by organic matter, including most plants, due to the presence of chlorophyll used in photosynthesis. Specifically, chlorophyll-a and chlorophyll-b absorb blue light effectively, with absorption peaks at 430 nm and 470 nm, respectively. This high absorption makes blue light particularly efficient for laser weeding, as it allows for effective weed removal with lower optical power. Beyond absorption, blue diode lasers offer additional advantages for weed control. These lasers are more compact compared to CO_2 systems, making them easier to install on various machines and enabling multiple units to be used in tandem. This capability allows for processing larger areas more quickly.

Blue diode lasers operate on low-voltage DC power, enhancing safety in dry environments and for operators, in contrast to the AC-powered CO_2 lasers. They are also lighter, eliminating the need for water cooling, which benefits vehicle fuel efficiency. The adjustable laser spot size accommodates both precise targeting and broader coverage. Additionally, blue diode lasers are more efficient and have a longer lifespan than CO_2 lasers, making them a cost-effective solution for laser weeding.

Key advantages of this technology are as follows:

1. Precision Weed Control: Laser weeding targets specific weed plants with high precision, reducing the likelihood of damaging surrounding crops and ensuring only the intended plants are affected.

2. Reduced Herbicide Use: By eliminating the need for chemical herbicides, laser weeding minimizes the impact of these chemicals on soil health and reduces potential health risks to humans and animals.

3. Minimized Soil Disturbance: Laser weeding operates on the surface, causing minimal disruption to the soil structure and preserving beneficial soil microorganisms compared to traditional mechanical weeding methods.

4. Enhanced Crop Health: The absence of herbicides and reduced soil disturbance contribute to healthier crops, as the soil remains rich in nutrients and free from chemical residues.

5. Lower Environmental Impact: Laser weeding is environmentally friendly as it avoids the pollution associated with chemical herbicides and reduces the carbon footprint compared to gas-intensive methods like flame weeding.

6. Cost Savings: Over time, laser weeding can lead to significant cost savings by reducing the need for herbicides and minimizing labour costs associated with manual weeding.

7. Improved Efficiency: The technology allows for rapid and efficient weeding across large areas, with automated systems that can work continuously without the need for frequent breaks or supervision.

8. Enhanced Safety: Laser weeding systems are generally safer to operate compared to traditional methods that involve heavy machinery or flammable gases, reducing the risk of accidents and injuries.

9. Reduced Water Usage: By targeting only weeds, laser weeding supports more efficient water use as it helps maintain optimal soil conditions and reduces competition for water between crops and weeds.

10. Support for Organic Farming: Laser weeding provides an effective alternative for weed management in organic farming, helping farmers meet organic certification requirements without relying on synthetic chemicals.

CONCLUSION

Laser weeding represents a transformative advancement in agricultural weed management, offering a range of benefits over conventional methods. By precisely targeting and eliminating weeds without the need for chemical herbicides, laser weeding reduces environmental pollution and enhances soil health. This technology improves efficiency by using advanced recognition systems and high-resolution lasers to identify and treat weeds, minimizing the labor and cost associated with manual weeding and chemical applications. Moreover, it supports sustainable farming practices by avoiding herbicide use and minimizing soil disruption, thus contributing to healthier crops and improved yields. As laser weeding technology continues to develop, its potential to advance sustainable agriculture and address persistent weed management challenges becomes increasingly apparent.

REFERENCES

Andreasen, C., Scholle, K., & Saberi, M. (2022). Laser weeding with small autonomous vehicles: Friends or foes?. *Frontiers in Agronomy*, *4*, 841086.

Duke, S. (2011). Why have no new herbicide modes of action appeared in recent years? *Pest. Manage*. *Sci*. 68, 505–512

FAO (2021). NSP–Weeds. Available online at: https://www.fao.org/agriculture/ crops/thematic-sitemap/theme/biodiversity/weeds/en/ (accessed December 10, 2021)

Harrison, J. L. (2011). Pesticide Drift and the Pursuit of Environmental Justice., Cambridge: MIT Press

https://carbonrobotics.com/laserweeding

https://optlasers.com/blue-lasers-in-laser-weeding

Kaierle, S., Marx, C., Rath, T., and Hustedt, M. (2013). Find and irradiate — lasers used for weed control. *Laser Technik J.* 10, 44–47.