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Directed Energy Flora Control: An Overview

Directed Energy Flora Control (DEFC) is the use of a blend of light, applied in high intensities for short durations, to affect plants and seeds. This application of non-laser light disrupts plant growth, enabling an alternative to herbicide treatments for weed control, in addition to a multitude of other beneficial uses, as described below.

The initial development of DEFC centered on eradication of established weeds and weed seedlings. Application of excessive light disrupts plant photosynthesis, resulting in rapid visible foliar damage. Exposure to high intensity blue light (for some species, alternative wavelengths are more effective than blue) manifests as blackening of the leaves, the visual result of damage to the plant's chloroplasts.

Unfortunately, simply denuding a weed provides only short-term satisfaction, because if the root is not affected, most weeds will soon regenerate. To solve this problem, DEFC includes simultaneous exposure with Mid-wave Infra-Red (MWIR) wavelengths at or near the base of the plant—where it grows out of the soil—to damage the root crown. MWIR illumination is ground-penetrating, which provides an efficient and effective form of treatment to the root crown.

While the idea of using light to kill plants may seem counter-intuitive, it should be understood that the wavelengths and the intensities applied are not natural. Sunlight at ground level contains almost no MWIR wavelengths at all. While sunlight does contain blue light, the levels applied in DEFC are approximately 30 times the natural sunlight level.

A commercial consumer weed-killing product was introduced for home lawn & garden use based on the DEFC technology (shown here, sold under license, branded as "WeedErase" and GNI's WeedOut Weed Elimination Tool). Through early user testing it was found that if users didn't properly follow usage instructions, which dictated that the device's emitter head be held in close proximity to the weed, the treatment was found to have a stimulating effect. Incorrect usage resulted in lower doses being applied. Under such circumstances, the treated weeds would not die, and in some cases, would instead actually grow faster. Subsequent testing showed this stimulating effect to be consistently repeatable, which opened up the possibility of other beneficial applications, leading to a patent filing for DEFC plant stimulation.

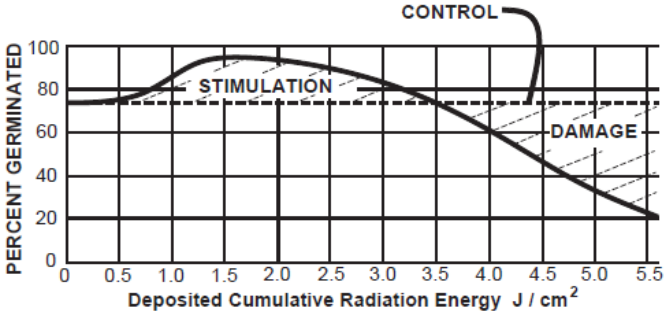
Other research found DEFC to be effective at devitalizing seeds, enabling agricultural application in harvest weed seed control. In the process of testing DEFC for weed seed devitalization, researchers made another surprising discovery: it was observed that DEFC could also *stimulate* seed germination. Use of a malfunctioning early prototype repeatedly resulted in an *increased* rate of weed seed germination. An illustrative example of this result is shown in the image below, where rye grass seeds planted in each tray were subjected to one additional low-dosage treatment (imparting more energy to the seeds each time through the system, as arranged from left to right). In this image, each tray contains rye seeds that were planted in soil at equal seeding rates. The left-most tray is the control tray, which received no DE treatment, and each tray from left to right received an additional exposure run, with the seeds in the rightmost tray receiving four runs through the system. Visually, it is easy to see that rye

seeds exposed to lower energy doses (one pass through the system) generated a substantially more vigorous stand vs. control, while seedling count decreased with increasing number of passes through the system.

Rye Grass with seeds treated with DE, from left (control) to right, showing stimulating and devitalization effects

Troubleshooting found that the malfunctioning device was applying lower levels of energy than intended, due to a component failure. But this discovery initiated further testing, which confirmed DEFC can provide either a damaging effect, wherein seeds can be devitalized when exposed to high doses, or a stimulating effect, wherein lower doses can provide a priming effect on seeds. A patent application was subsequently filed relating to DEFC seed priming.

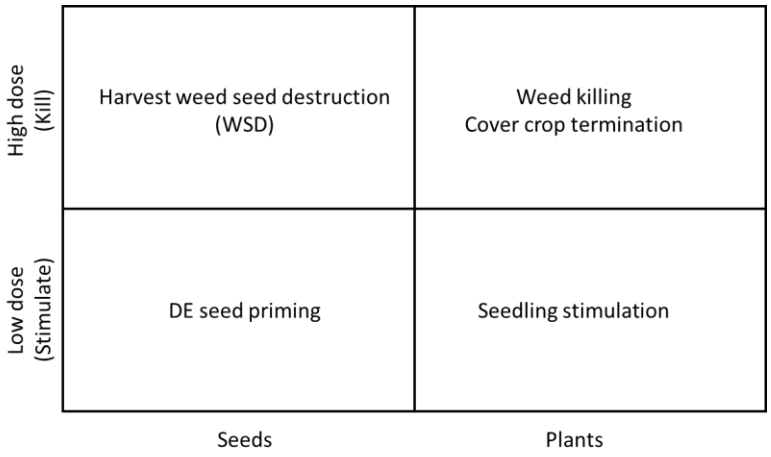
The dual effect on seeds is similar to what was previously observed with plants, where a higher dosage kills the plant, while a lower dosage has a stimulating effect on the plant. The technical term for this dual-effect biological phenomenon is “hormesis,” where low doses of an otherwise toxic treatment provide a beneficial effect. This effect is illustrated with recorded data on field corn seeds, graphed in the image below.



Measured Hormesis Effect on Field Corn

Applications

As described above, DEFC offers a broad range of applications in agriculture, as depicted in the following matrix, where the X axis depicts targeting of either seeds or plants, and the Y axis depicts either low or high doses.



Matrix showing DEFC applications

Harvest weed seed devitalization:

Many of the most problematic weeds in agriculture retain their seeds until the time of crop harvest. Seeds of these weeds can be devitalized with DEFC during the harvest operation prior to redistributing them over the field. This results in a lower weed seed bank in the soil, reducing future weed pressures.

GNI developed a weed seed destroyer in the form of an auger which mounts onto the rear of a combine, treating weed seeds contained within the chaff as it exits. To devitalize seeds, the weed seed is exposed to MWIR. The MWIR mostly passes through or reflects off the chaff, so it serves as a very efficient way to target the energy into just the seeds. The MWIR treatment makes the weed seeds receptive to the blue light treatment, which damages the cells responsible for reticle growth, devitalizing the weed seeds. This harvest weed seed destroyer is currently undergoing prototype testing.

Seed priming

Studies have shown that accelerating crop seed germination and improving germination rates helps establish earlier vigor in the crop. Earlier vigor enables the stand to out-compete weeds and improves resilience against environmental stresses, resulting in increased yields and farmer profitability. As described above, when applied in lower dosages, DEFC provides a priming effect on seeds. This technology is referred to as DE Seed Priming (DESP).

University researchers demonstrated that DE can prime soybeans through a combination of exposure to MWIR and blue light around its circumference. A proof-of-concept system was used to provide this DE exposure to a continuous flow of seeds in a short amount of time. After planting, the primed seeds went on to germinate more quickly and uniformly, ultimately leading to increased vigor of the seedlings and yields.

DESP technology provides a way to increase germination rates and hasten emergence of seeds without environmental impact. Tests show that seeds treated immediately before sowing had

the highest germination. This result indicates the optimum place to incorporate DESP may be the planter itself. DEFC is being integrated into a leading global ag equipment OEM's planter to demonstrate this capability.

Weed killing

Weed management in conventional agricultural production practices involves application of herbicides, the cost of which has been increasing substantially and has been subject to supply disruptions. Herbicide usage also introduces human health and environmental impacts. Local weather forecasts affect herbicide application planning, since herbicides cannot be applied during windy conditions due to the risk of drift, or when there's a chance of rain that would rinse the chemicals off the weeds before they can take effect. Additionally, many species of weeds have developed herbicide resistance, a problem that is expected to continue increasing with time.

The primary means of weed management in organic production currently requires additional labor for field preparations and maintenance, which, with rising labor costs and the labor shortage, is becoming prohibitively expensive, if it can be found at all. These labor factors have caused some organic producers to abandon organic production practices. Alternative forms of non-chemical weed management include killing weeds with dangerously high voltage electricity upon contact, and killing seedlings with lasers. Despite their health and safety risks, both hold promise as useful tools, although the former is more of a rescue treatment, since it only works on weeds that have grown above the crop canopy, and the latter falls short on weeds that have become established (after the seedling stage).

DEFC offers a chemical-free form of weed control as an additional tool that can complement other forms of weed management in both organic and conventional agriculture practices. Many weeds (particularly smaller and/or herbaceous plants) can be controlled with a single DEFC treatment. Particularly well-established and/or woody-stalked weeds may require a second treatment 5-7 days after the first, in which case the MWIR illumination passes through the dried biomass of the damaged leaves, further increasing the treatment's efficacy. Coupled with robotics, DEFC holds the promise of improving agricultural yields while reducing input costs.

Cover crop management

Cover crops are being increasingly adopted in agriculture by both organic and conventional producers (the latter as a means to reduce herbicide usage). Cover crops help crowd out weeds and improve soil health by reducing dependency on tillage, which degrades soil health and accelerates erosion. Global interest in cover crops has also grown due to the demonstrated high potential for carbon sequestration. Organic producers struggle with perennial weeds that persist through the cover crop, and depend on crimping to terminate cover crops, which is only effective at certain points in the season. DEFC can simplify and augment the use of cover crops by providing a means of managing weeds that persist through the cover crop mat, and providing a non-chemical means of terminating cover crops earlier in the growing season than what crimping allows. DEFC systems are under early development for the termination of cover crops and eradication of weeds persisting through the cover crop.

Seed destruction on the ground

Shattered weed seeds and volunteer seeds (crop seeds left over from the previous season) become part of the soil's seed bank, and can germinate the following season or in subsequent seasons. Weed seeds can remain viable in the soil for many decades. The MWIR spectrum used in DEFC is able to penetrate up to 0.25" (~0.6 cm) of soil depth, providing a means for devitalizing weed seeds on or in the upper crust of the soil, reducing future weed pressures. DEFC systems that will control shattered and volunteer weeds in the soil or on the soil surface are under early development, including joint university testing research.

About Global Neighbor Inc.

The developer of DEFC is Global Neighbor, Inc. (GNI), a venture-capital funded Xenia, Ohio-based agricultural technology company who developed the technology through the support of a US Department of Defense Small Business Innovation Research (SBIR) project with Edwards AFB. In this initial work, DEFC was demonstrated to be an effective alternative to chemical treatment for weed management. More recently, GNI was awarded Phase I and II USDA SBIRs to develop a DE-based harvest weed seed control product and on-planter seed stimulation. Several universities (including Central State University, Louisiana State University, Ohio State University, and Texas A&M University) have provided third-party validation of GNI's DEFC. In 2023, GNI was awarded another SBIR from the Department of Defense to automate chemical-free weed eradication around Air Force bases by integrating DEFC into an Autonomous Mobile Robot. Also in 2023, GNI was awarded an SBIR from the USDA to apply DEFC to a commercial planter, and will be demonstrating a seed-priming planter under this project. GNI was founded by Jon Jackson, an engineer with an MBA who worked the family farm growing up, and leads the development of DEFC.