

## Effects of Microwaves on the Germination of Weed Seeds

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### Abstract

**Purpose:** Weeds cause significant losses in agricultural production. In this study, we investigated the effect of microwaves on the germination rates of cress and arugula seeds to determine whether microwaves could be developed as an effective alternative to conventional chemical-based herbicides. **Methods:** Seeds were planted at equal depths (8–10 mm) in a soil-turf mixture, and seeds were exposed to microwaves for 126 s, 70 s, and 50 s in a device constructed specifically for this study. A microwave tunnel was built using a variable speed conveyor belt and 4 magnetrons with a combined output power of 2.8 kW. Seeds that were not exposed to microwaves were germinated with regulated irrigation, temperature, and humidity controls in parallel with the treated seeds, and the germination rates were compared among the treatment groups. **Results:** We found that the exposure of cress and arugula seeds to microwaves for 126 s inhibited germination close to 100%. Cress seeds treated with microwaves for 50 s showed 95% germination compared to 65% germination of the untreated cress seeds. **Conclusions:** We predict that the thermal effect of microwave energy affects the germination ratio and germination rate of seeds.

**Keywords:** Agriculture, Germination, Inhibition, Microwave, Weed seeds

### Introduction

Current agricultural weed control strategies include chemical agents that are harmful to both human and animal health. Concern over the safety of chemical herbicides has led to the banning of certain agents in developed nations and an increased focus on scientific research aimed at developing alternative methods of weed control. The competition between agricultural crops and weeds results in significant losses in yield and contamination of the crop of interest.

Weed control strategies generally involve the delay or inhibition of weed seed germination using both chemical and mechanical methods. Even with current tactics, weed management competes for agricultural machinery during crop harvest, blending, and storage, resulting in unnecessary expenditures.

One potential non-chemical weed control method makes use of microwave energy. Though this approach requires the development of economical treatment regimens, the approach is of interest from an environmental impact standpoint.

Here we demonstrate the elimination of weed seeds using microwave energy. Our work sets the groundwork for future development of applied microwave herbicidal methodologies in the agricultural field and the future characterization of the financial impact of weeds.

In addition, we show that, at certain temperatures, the rate of seed germination increases as a result of microwave exposure. This raises the possibility of destroying weed seeds by inducing germination prior to the growing season.

Since 1970, the herbicidal use of microwaves has been the focus of research as a means to disinfect agricultural soil, impede the germination of weed seeds, and eradicate germinated weed seeds by prolonged exposure to microwave energy.

The physical disinfestation method, which uses high

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frequency electromagnetic waves, increases the temperature of pathogens and weed seeds in the treatment area (Davis, 1971; Nelson, 1996). In this method, the plant stem and leaves wither shortly after exposure and the plant dies.

Likewise, 8- and 16-day-old germinated plants die approximately 10 days after the application of microwave energy through different periods (Wayland and Menges, 1975).

An analysis of growth rates in corn indicates that water loss is a likely cause of germination inhibition due to microwave exposure (Bigu-Del-Blanco et al., 1977). Interest in the effects of electromagnetic waves on biological organisms arose in the late 19<sup>th</sup> century as studies on the effects Radio Frequencies (RF) had on the plant seeds (Ark and Perry, 1979).

Since the disinfection of soil using microwaves does not leave behind chemical residue (Olsen & Hammer, 1982; Nelson, 1985; Mavrogianopoulos, 2000), it provides a possible alternative to chemical herbicides. Mavrogianopoulos et al. (2000) researched whether soil disinfection in agriculture can be performed using microwaves. Heisel et al. (2002) indicated that the multi-photon and electron ionization produced by UV and IR lasers works as a weed control method by causing plant tissues to lyse.

Banik (2003) proposed that microwaves cause cell death due to a thermal effect within the targeted area. Venkatesh and Raghavan (2004) further indicated that the heat energy of microwaves would be transferred directly by molecular motion, which would preclude certain uses of thermal process applications of microwaves. Likewise, Cheng et al. (2005) discussed the potential for additional adverse effects such as physical damage to agricultural crops, abnormal temperature distribution, and impairment of biological functions.

Velazquez et al. (2005) studied the effects of microwave radiation on the germination inhibition of undesired seeds, Vidmar (2005) described a weed control machine, and Sartorato et al. (2006) examined the potential of microwave energy as a weed control method.

Skiles (2006) investigated the difference in development between plants exposed to 2.45-GHz microwaves and untreated plants not exposed to microwaves.

As suggested by Matthiassen et al. (2006), lasers can be used in weed elimination. Fuentes et al. (2007) investigated the ability of microwaves to remove organophosphorus pesticides from the soil. Vadivambal and Jayas (2007) compared the quality of agricultural products dried using

microwaves, and found that the quality to be the same or better than conventional drying methods.

Velazquez et al. (2008) developed a machine capable of applying microwaves to eliminate undesirable plants from agricultural areas. Aladjadjiyan (2010) researched the effects of microwave radiation on lentil seeds. Vadivambal (2010) determined that improper temperature distribution of microwave energy during food heating decreases food quality.

In most studies, seed germination increases following short-term microwave applications, but seeds die with longer microwave exposure (Bebawi et al. 2007). Brodie et al. (2012) suggested that some of the microwave energy produced during weed control applications is lost as thermal energy. This loss decreases the efficiency and energy cost of the microwave-based herbicidal methods compared to conventional chemical methods.

## Materials and Methods

### Instrumentation

An (Simsek Laborteknik K-300 incubator )with controls for temperature, moisture, and light was used for seed germination. Purified water for the incubator moistening unit was obtained from the AVSUMAY QM 00178 pure water device.

A variable-speed conveyor belt (approximate dimensions: 4.5 m in length, 60-cm band width, and 70-cm height) and the Power F 4M motor drive with a frequency range of 0.01–1.00 Hz was used in combination to simulate the speed of a tractor moving across the cropland (Figure 1).



Figure 1. Conveyor belt, 4 kW microwave tunnel, and driver unit.

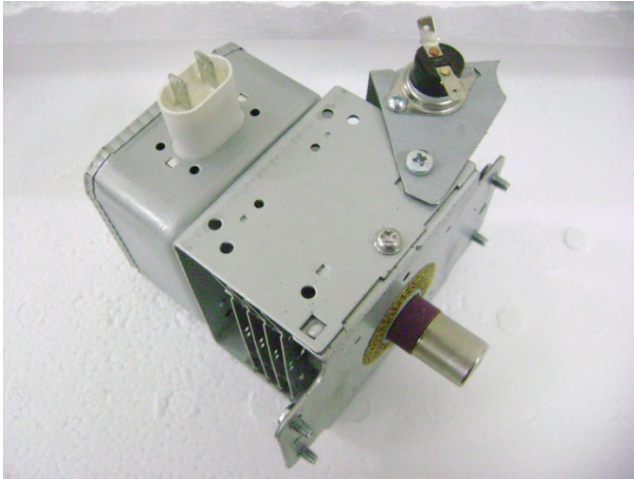


Figure 2. 1 kW Magnetron.



Figure 3. Microwave leakage detector.

The microwave treatment tunnel was constructed by mounting four 1-kW magnetrons to a galvanized steel tunnel frame with the dimensions of 125 × 60 × 40 cm. The microwave output power of each magnetron is 700 W (Figure 2).

An EX400 model RMS digital multimeter provided ongoing measurement of grid voltage, grid current, and the durability test of electronic units with a voltage measurement accuracy of ± 0.3% readout plus 2 digits and a current measurement accuracy of ±1.5% readout plus 6 digits.

Two BR15 model microwave detectors were placed in separate locations during experimental runs and were used to detect microwave energy leakage and to determine whether this leakage exceeded the 5 mW/cm security limit that was established by the FDA (U.S. Food and Drug Administration) and the EPA (U.S. Environmental Protection



Figure 4. Thermometer and humidimeter digital thermocouple.

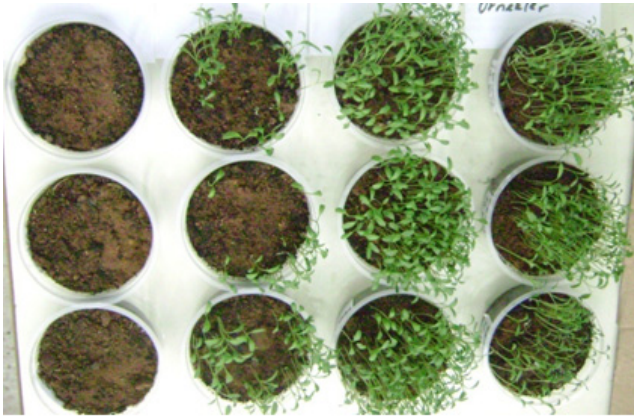
Agency). Each of the microwave detectors has a 2.45-MHz frequency caliber and a measurement range of 0–9.99 mW/cm with an accuracy of ± 1 dB. The warning measurement value is 5 mW/cm (Figure 3).

A DT-615 digital thermometer and humidimeter thermocouple was used to measure the existing soil temperature and moisture of the weed seeds prior to microwave exposure and immediately following their exit from the microwave tunnel. Semi-conductor sensor measurement of the device is 0°C to 40°C and its thermocouple large calorimetric range is -20°C to 1000°C. Moisture measurement is 0.1% relative humidity (RH) and 100% RH, and its accuracy is ±3.5% RH. The K-tip probe accuracy is ±3.0 °C and the readout ± 4 °C (Figure 4).

## Method

Seeds were treated with 2.45 GHz, 2.8 kW microwave energy for 126 s, 70 s, and 50 s and then were incubated at 23–25°C and a humidity of 75–80%. Seeds were irrigated at defined intervals that were recorded by the incubator. The number of seeds in each condition at the beginning of the experiment was counted, and the average germination state of seeds was determined by detecting the number of germinated seeds.

Each of the microwave generators used in the tunnel has a 2.45-GHz constant frequency and a 700-W microwave output power. The study utilizes the microwave tunnel that has four 1-kW magnetrons at the maximum power level, which provides a total of 2.8-kW output power. At the maximum energy level, all 4 magnetrons were active. Given the treatment area of 0.288 m<sup>3</sup>, the microwave energy density was 9.72 kWm<sup>-3</sup>.



**Figure 5.** 126 s, 70 s, and 50 s MW-applied cress seeds and non-applied seeds at day 6.

## Results and Discussion

Cress seeds were treated with 2.45-GHz, 2.8-kW microwaves for 126 s, 70 s, or 50 s and then were planted at equal depths (8–10 mm) in pots filled with a soil-turf compound and maintained in the incubator cabinet. The planted seeds were irrigated daily in the cabinet under temperatures of 23–25°C and 75–80% humidity. Microwave-treated seeds were compared to untreated cress seeds, to which microwaves were not applied. The control cress seeds were germinated and the relative germination rates were compared (Figure 5). The soil temperature during microwave exposure was measured for each pot and then recorded. Thus the temperature change was detected as the difference between the initial and final temperatures ( $\Delta T = T_f - T_i$ ; Table 1).

To test the germination inhibition effect on another type of seed, arugula seeds were planted in a turf-soil compound at equal depths and were subjected to microwave treatment with a power level of 2.8 kW for 126 s, 70 s, or 50 s. The germination rates of microwave treated and untreated arugula seeds were compared on the on the fifth and sixth day post-exposure, and are shown together



**Figure 6.** 126 s, 70 s, and 50 s microwave-applied and non-applied arugula seeds, respectively, at day 6.

in the Figure 6 and Table 2.

In the shortest microwave exposure time tested – 50 s – both the cress and arugula seeds showed germination rates close to or higher than that seen with untreated seeds (Table 3). The cress germination rate was 96% in the 50 s condition compared to 65% for untreated seeds. This result is consistent with Bebawi et al. (2007), who states “seed germination in short-term microwave applications was observed to have increased, however seeds were detected to have died in long-term applications.”

Bigu-Del-Blanco et al. (1977) investigated the effect of microwave and radiation treatment on corn seed growth rates and concluded that germination was likely inhibited due to water loss as a result of microwave exposure with densities of 10 mW/cm<sup>2</sup> and 30 mW/cm<sup>2</sup> for a 22–24-h time period.

Velazquez et al. (2005) demonstrated that microwave affects seed germination at approximately 20% or 35% of

**Table 1.** Germination rates of the cress seeds exposed to microwave

Samples	Time (s)	Power (kW)-Frequency(Hz)	NPS	$\Delta T = T_f - T_i$ (°C)	PGS	PQS%
TC-A-V1	126	2.8-2.45 GHz	100 ± 10	81 - 23 = 58	0	100
TC-A-V2	70	2.8-2.45 GHz	100 ± 10	76 - 23 = 53	30.3	69.7
TC-A-V3	50	2.8-2.45 GHz	100 ± 10	67 - 23 = 44	96.0	4.0
<i>Untreated</i>			100 ± 10		65.7	34.3

Untreated samples were not exposed to microwaves. NPS: Number of planted seeds (number);  $\Delta T$ : Initial and final temperature difference (°C); PQS%: Percentage of quiescent seeds; PGS: Percentage of germinated seeds (%).

**Table 2.** Germination rates of the arugula seeds exposed to microwave

Samples	Time (s)	Power (kW)-Frequency(Hz)	NPS	$\Delta T = T_f - T_i$ (°C)	PGS	PQS%
TC-R-A-V1	126	2.8-2.45 GHz	130 ± 10	80 - 23 = 57	0	100
TC-R-A-V2	70	2.8-2.45 GHz	130 ± 10	75 - 23 = 52	52.7	47.3
TC-R-A-V3	50	2.8-2.45 GHz	130 ± 10	66 - 23 = 43	67.8	3232.2
<i>Untreated</i>			130 ± 10	0	7372.8	2827.2

**Table 3.** Germination inhibition in the weed seeds exposed to microwave

	A- Power Level (2.8 kW) PQS (%)			
	126 s	70 s	50 s	<i>Untreated</i>
Cress	100	69.7	4	65.7
Arugula	100	47	32	73

the soil depth for seeds planted 5 cm or 10 cm deep, respectively. These results are consistent with our results for a 10-cm seed depth.

## Conclusions

Here we have studied cress and arugula seeds planted into a soil-turf compound in equal depths (8–10 mm) and subjected to the microwaves at a power level of 2.8 kW, for durations of 126 s, 70 s, and 50 s and then placed under conditions supportive of germination. Untreated samples that were not exposed to microwave were likewise germinated, and the relative number of germinated seeds of the groups were compared in order to detect the effects of microwave energy on seed germination.

After the microwave treatment ended, the seeds were irrigated at defined intervals within an incubator kept at constant environmental parameters (23–25°C and 75–80% humidity) and the germination states of the seeds were monitored. We found that inhibition of cress and arugula seed germination would not change following the shorter 70- and 50-s applications. We predict that this is due to the dielectric properties of weed seeds.

In the study, we investigated the impact of microwave exposure on germination capacity of weed seed at certain soil depths. In comparison to untreated seeds, we find that germination rates for longer treatment durations are decreased, but rates for shorter durations are increased slightly. During the maximal application duration tested, germination is inhibited approximately 100%. Possible contributing factors in seed germination are presumed to be the seed shell thickness, water content of seeds, and

dielectric properties of seeds and soil.

## Conflict of Interest

The authors have no conflicting financial or other interests.

## Abbreviations and Symbols

Power	Microwave tunnel total output power
Period	Exposure period of seeds to microwave energy
NPS	Number of planted seeds (number)
PGS	Percentage of germinated seeds (%)
$\Delta T$	Initial and final temperature difference (°C)
PQS%	Percentage of quiescent seeds

## References

- Aladjadjiyan, A. 2010. Effect of microwave irradiation on seeds of lentils. *Romanian Biophys.*, 20(3):213-221, Bucharest, 2010.
- Ark, P.A. and Perry, W. 1979. "Application of high frequency electrostatic field in agriculture. *The Quarterly Review Of Biology*, 6(3):277-287.
- Banik, S., Bandyopadhyay, S. and Ganguly, S. 2003. Bioeffects of Microwave-A Brief Review. *Bioresource Technology* 87:155-159.
- Bebawi, E.F., Cooper, A.F., Brodie, G.I. and Et Al. 2007. Effect of microwave radiation on seed mortality of rubber wine, parthenium and bellyache bush. *Plant*

- Protection Quarterly 26(4):136-142.
- Bigu-Del-Blanco, J., Bristow, J.M. and Romero-Sierra, C. 1977. Effects of low-level microwave radiation on germination and growth rate in corn seeds. *Proceeding Of Ieee* 65(7):1086-1088.
- Brodie G., Ryan, C. and Lancaster, C. 2012. Microwave technologies as part of integrated weed management strategy: A Review. *International Journal Of Agronomy* Volume 2012, Article Id 636905.
- Cheng, W.M., Raghavan, G.S.V., Ngadi, M. and Wang, N. 2005. Microwave power control strategies on the drying process I. Development And Evaluation Of New Microwave Drying System. *Journal Of Food Engineering* 76:188-194.
- Davis, F., Wayland, J. and Merkle, M. 1971. Ultrahigh-Frequency electromagnetic fields for weed control. *Phytotoxicity And Selectivity. Science* 173:535-537.
- Fuentes, E., Baez, M. and Labra, R. 2007. Parameters affecting microwave-assisted extraction of organophosphorus pesticides from agricultural soil. *Journal Of Chromatography A* 1169:40-46.
- Heisel, T., Schou, J., Andreasen, C. and Christensen, S. 2002. Using laser to measure stem thickness and cut weed stems. *European Weed Research Society Weed Research* 42:242-248.
- Mathiassen, K., Bak T., Christensen S. and Kudsk P. 2006. The effect of laser treatment as a weed control method. *Biyosistem Engineering* 95(4):497-505.
- Mavrogianopoulos, G., N., Frangoudakis, A. and Pandelakis, J. 2000. Energy efficient soil disinfestations by microwaves. *Agricultural Engineering Resources* 75:146-153.
- Nelson, S.O. 1985. Rf and microwave energy for potential agricultural applications. *Journal Of Microwave Power* 20(2):65-70.
- Nelson, S.O. 1996. A Review and assessment of microwave energy for soil treatment to control pests. *Transactions Of The Asae* 39(1):281-289.
- Olsen, R.G. and Hammer, W.C. 1982. Thermographic analysis of waveguide-irradiated insect pupae. *Radio Science* 17:95-104.
- Sartorato I., Zanin G., Baldoin, C. and Zanche, C. 2006. Observations on the potential of microwaves for weed control. *European Weed Research Society. Weed Reseach* 46:1-9.
- Skiles, J.W. 2006. Plant Response To Microwaves At 2.45 Ghz. *Acta Astronautica* 58:258-263.
- Vadivambal, R. and Jayas, D.S. 2007. Changes in quality of microwave-treated agricultural products-a review. *Biosystems Engineering* 98:1-16.
- Vadivambal, R. and Jayas D.S., 2010. Non-Uniform temperature distribution during microwave heating of food material. *Food Bioprocess Technology* 3:161-171.
- Venkatesh, M.S. and Raghavan, G.S.V. 2004. An overview of microwave processing and dielectric properties of agri-food materials. *Biosystems Engineering* 88(1):1-18.
- Velazquez, B., Gracia-Lopez, C. and Puerta, R. 2008. Work conditions for microwave applicators designed to eliminate undesired vegetation in a field. *Biosystems Engineering*, 100:31-37.
- Velazquez, B., Gracia-Lo Pez, C. and Plaza Gozolez, P. J. 2005. Determination of dielectric properties in the agricultural soils. *Biosystems Engineering*, 91(1):119-125.
- Vidmar, M. 2005. An improved microwave weed killer. *Microwave Journal* October 1, 2005.
- Wayland, J. and Menges, M. 1975. *Weed Research*, 15, 1-5.