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Research Article/Araştırma Makalesi

Investigation of the effect of non-uniform heat distribution of microwave on the mortality rates of some plants

Mikrodalganın düzgün olmayan ısı dağılımının bazı bitkilerin ölüm oranlarına etkisinin araştırılması

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ABSTRACT

Weeds, cause significant losses in agricultural production and are mostly controlled by herbicides, which are harmful to the environment. An alternative method that can be applied instead of these chemicals that pollute the soil and water is the microwave weed control method. But, one of the main problems with the microwave weed control method is the non-uniform heat distribution. This study aims to investigate the effect of non-uniform heat distribution on the mortality rate in the microwave weed control method by the NDVI (Normalized Difference Vegetation Index) technique. The NDVI technique has been used for the first time in this study to determine the mortality rate in microwave weed control. Mortality rates in one-week germinated *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grasses that were exposed to microwave energy for 10, 20, and 30 seconds were measured. It was determined that a higher rate of mortality occurred in the uniform heat distribution condition, compared to the non-uniform heat distribution ($p < 0.05$). Mortality rates in both *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grasses increased as the microwave application time increased. The highest mortality rate occurred in *Lepidium sativum* (cress) grass (69.81%) and *Hordeum vulgare* (barley) grass (61.01%) with uniform heat distribution for 30 seconds. In the non-uniform heat distribution for 10 seconds, an increase was observed in *Hordeum vulgare* (barley) grass compared to the control group (7.01%). As a result, it can be said that weed control with microwave energy has the potential to be a good "environmentally friendly alternative method" to chemical weed control methods.

Key Words: Non-chemical, Environmentally friendly, Alternative weed control, NDVI.

ÖZ

Tarımsal üretimde önemli kayıplara neden olan yabancı otlar, çoğunlukla herbisit adı verilen çevreye zararlı olduğu bilinen kimyasallarla kontrol edilir. Toprağı ve suyu kirleten bu kimyasalların yerine uygulanabilecek alternatif yöntemlerden birisi de mikrodalga ile yabancı ot kontrolü yöntemidir. Ancak, mikrodalga ile yabancı ot kontrolü yöntemiyle ilgili temel sorunlardan birisi, düzgün olmayan ısı dağılımıdır. Bu çalışmada, mikrodalga ile yabancı ot kontrolünde, düzgün olmayan ısı dağılımının mortalite oranına etkisini NDVI tekniği ile araştırmak amaçlanmıştır. NDVI tekniği, mikrodalga ile yabancı ot kontrolünde mortalite oranı tespiti amacıyla ilk defa bu çalışmada kullanılmıştır. Mikrodalga enerjiye, 10, 20 ve 30 saniye süreyle maruz bırakılan bir haftalık çimlendirilmiş *Lepidium sativum* (tere) ve *Hordeum vulgare* (arpa) bitkilerinin mortalite oranları ölçülmüştür. Düzgün ısı dağılımı koşulunda, düzgün olmayan ısı dağılımına göre daha yüksek oranda mortalitenin meydana geldiği tespit edilmiştir ($p < 0.05$). Mikrodalga uygulama süresi arttıkça hem *Hordeum vulgare* (arpa), hem de *Lepidium sativum* (tere) bitkisinde mortalite oranları da artmıştır. En yüksek mortalite, 30 saniye boyunca düzgün ısı dağılımı uygulamasında, % 69.81 ile *Lepidium sativumda* (tere) ve % 61.01 ile *Hordeum vulgarede* (arpa) meydana gelmiştir. 10 saniye süreli düzgün olmayan ısı dağılımı uygulamasında, *Hordeum vulgare* (arpa) bitkisi çimlenme oranı kontrol grubuna göre % 7.01 artış gözlenmiştir. Sonuç olarak, mikrodalga enerji ile yabancı ot kontrolünün, kimyasal yabancı ot kontrol yöntemlerine iyi bir "çevre dostu alternatif yöntem" olma potansiyeline sahip olduğu söylenebilir.

Anahtar Kelimeler: Kimyasal olmayan, Çevre dostu, Alternative yabancı ot kontrolü, NDVI.

Introduction

The most common weed control method is the use of chemicals (herbicides) (Shaner,2014), (Rüegg,2007), (Qasem,2011). However, the possibility of these chemicals getting into drinking water over time, the damage they cause to the soil and the environment has highlighted non-chemical methods of struggle today. The chemicals (herbicides) used in weed control affect the physiological development of weeds and aim to minimize or completely remove economic loss. Necessary researches should be carried out on the elimination of the damage caused by weeds, their prevalence, and intensity, and the determination of important species and the most appropriate methods of struggle (Aslan, 2018), (Koutica, 2010). The yield loss caused by weeds only in wheat plants is around 20-40% (Erdal, 2020), (Zimdahl, 2018). The methods of control using herbicides are widely used in the control of weeds, as well as in non-agricultural areas. However, in scientific studies (Cengiz et al., 2017) it has been determined that the herbicides detected in drinking water can be separated by the ozone purification method, the norflurazon and oxadiazon leave residues in plants and soil even after one month, and this poses a danger in consumption (Janaki, 2015).

The effects of herbicides on human health as well as on animals such as bees, birds, and fish, microorganisms, and invertebrates are very serious. It also causes cancer in people who are exposed to phenoxy group herbicides, which are widely used around the world. Additionally, it has been stated that triazines are associated with breast cancer, while terbuthylazine causes lung cancer (Mladinic et al., 2012). The known side effects of herbicides include deaths in non-target organisms and long-term effects such as changes in the structure of the ecosystem and the number of species (Solomon et al., 2013).

As the harms of these agricultural chemicals emerge and environmental sensitivity increases, interest in non-chemical alternative control methods (such as microwave and electric current) has increased (Sahin, 2012).

Herbicides such as atrazine and simazine are widely used in agricultural production areas, railway networks, airports, road and sidewalk edges. Besides, restrictions have been imposed on the use of triazines outside of agricultural areas in some countries. It is highly desired by society to give up natural plant production by giving up chemical control methods. However, many farmers prefer the use of herbicides due to their ease of application (Ngowi, 2007).

In studies conducted with microwave energy, it has also been found that it can kill plant roots and seeds buried a few centimeters deep into the soil (Sahin, 2014). Most of the studies conducted under experimental conditions (De Wilde, 2017), aimed to determine the best microwave process based on power, time, and soil moisture to prevent invasive species from germinating and seed embedding depth was taken as 2, 12 cm. It was exposed to microwaves by germinating ryegrass and rapeseed to determine the amount of energy required for the destruction of weeds (Valezquez, 2008). As a result, it has been found that it is technically possible to eliminate the herbaceous species already germinated in the field. According to the results obtained, there was a 100% restriction on the germination of seeds exposed to the microwave for 126 seconds (Sahin, 2014). Microwaves based on high energy can kill weeds very efficiently (Bajwa, 2015). Using microwave radiation as a weed control method seems to be a good alternative because it does not produce chemical residues in the environment (Rana, 2018).

In the soil exposed to microwave energy, it has been determined in the studies (Khan, 2016) that the agricultural product yield increases. In the study on RF (Radio Frequency) exposures for germination increase and alfalfa seed improvement, frequency, electric field intensity, seed moisture content, seed temperature, variant change, and practical application possibilities in the seed industry were discussed (Nelson, 2018).

Khalafalah, (2009), study on *Hordeum vulgare* (barley) seeds, it was stated that high germination rates were obtained after the *Hordeum vulgare* (barley) seeds were treated with a microwave output power of 400 W. Also, it has been stated that microwave radiation should be tried on different plants to fully understand the effects of cell organelles, enzyme activity, genetic changes, and yield infrastructures (Cretescu, 2013). Miler, (2018), stated that the effect of microwaves on the DNA of plant cells is still uncertain, but it can be very advantageous to use this electromagnetic radiation as a source of change in mutation breeding. In the study performed by applying 2.45 GHz microwave and 4 different power levels, mortality rates ranging from 4% to 90% were obtained in wild mustard and wild oat and *Lepidium sativum* (cress) plants (Sahin, 2015). But, the thermal leaks that occur during microwave applications also cause a significant energy loss (Sahin, 2019). Taheri, (2018), emphasized the necessity of knowing the dielectric properties of agricultural products in thermal processes that use the microwave and radiofrequency. Any misinterpretation negatively affects the perceived value of the microwave weed control technology and predicts the required energy load more than it is (Rana, 2017).

As the world population increases, agricultural cultivation areas decrease, on the contrary. This situation creates an agricultural sustainability problem. Besides, the negative effects of agricultural chemicals on ecology and life are increasing. Instead of herbicides with such obvious negative effects, the development of more environmentally friendly alternative methods should be encouraged. One of the non-chemical weed control methods is the microwave weed control method. This method is new and environmentally friendly, but it is still in the research and trial phase.

Materials and Methods

In the study, a speed-controlled microwave tunnel with 4 pcs of 1 kW magnetrons was used as a microwave tunnel (Figure 1). The microwave output power of each magnetron is 850 watts. To obtain uniform heat distribution during microwave application, the test platform was rotated with a 3 watts 6 rpm synchronous motor. The non-uniform heat distribution conditions have been achieved by deactivating the rotary motor. The movement of the tractor in the field conditions was tried to be simulated by using the conveyor belt.

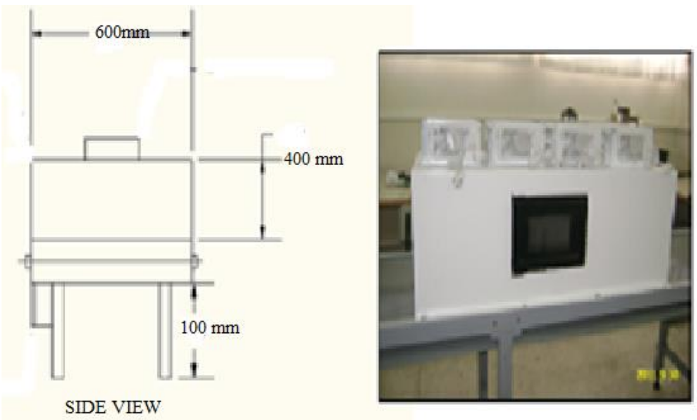

Figure 1. Microwave speed control tunnel with 4 pcs of 1 kW magnetron (Source: Author,2021)

Hordeum vulgare (barley) and *Lepidium sativum* (cress) seeds that are easily germinated and easily available were preferred. For each recurrence, *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) seeds were planted in 4 pots, one for the control group and the other for three samples. All pots were kept in an air conditioning cabinet at 20-22°C temperature, average 1000-1200 lux light, and 60-70% humidity during germination and post-experiment observation. 1 week of germinated *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) seeds was exposed to a microwave frequency of 2.45 GHz with the help of a magnetron with an output power of 850 kW for 10, 20, and 30 seconds.

To solve the problem of non-uniform heat distribution in microwave heating, the target material is placed on a circular moving plate. Infield conditions, this problem will be solved by using circular motion microwave guides. For that reason, the samples were exposed to the microwave with the help of a circular motion of a 6 rpm table motor to obtain a uniform heat distribution condition. Non-uniform heat distribution conditions were obtained by exposing the samples to microwave energy while the rotating motor was off. Soil and humidity values of the soil were measured before and after the microwave application.

NDVI (normalized difference vegetation index) Meter: NVDI values before the exposure of plants to microwave and 1 week after application were measured with the Trimble Green Seeker handheld device shown in Figure 2. The emission wavelengths of the device are red 660 nm, 25 nm FWHM, near-infrared 780 nm, and 25 nm FWHM, and the field of view of the device is 25 cm at 60 cm or 50 cm at 122 cm. The height range is from 60 to120 cm. The normalized difference vegetation index (NDVI) provides information about vegetation viability by measuring the difference between near-infrared reflected from vegetation and the red light absorbed by vegetation. It is a technology for distinguishing bare soil from green plants or forests, detecting plants under stress, and determining the health level of plants.

Figure 2. NDVI meter device (Source: Trimble,2021)

$NDVI_1$ (Normalized Difference Vegetation Index) values of the plants were measured and recorded before application. Plants exposed to microwave energy were monitored for 1 week at the appropriate temperature and humid environment and $NDVI_2$ values of plants were measured 1 week after microwave application. Mortality (%) values occurring in plants were obtained with the help of Equation (1).

$$Mortality = \frac{NDVI_1 - NDVI_2}{NDVI_1} \tag{1}$$

Although the normalized difference vegetation index (NDVI) is a widely used method to monitor vegetation dynamics, NDVI values are also known to be deeply affected by various external factors (Arjasakusuma, 2018). When calculating NDVI, in the Normalized Difference Vegetation Index (NDVI) formula, NIR (near infra-red) near-infrared and red (red) channels use, Equation (2).

$$NDVI = (NIR - Red)/(NIR + Red) \tag{2}$$

This method can help natural resource managers prioritize forest treatment and restoration activities by offering tree mortality rates (Spruce, 2019). Normalized difference vegetation index (NDVI) images derived from processed satellite data were also used in the analysis of the relationship between urban foliage rate and infant mortality in Philadelphia (Schinasi, 2019). A similar study was conducted in Canada using NDVI data (Crouse, 2017). With a machine learning method that distinguishes between crop and weed species based on spectral reflection differences (NDVI), studies on remote sensing-based solutions are also conducted to quickly estimate biodiversity spectral properties (Pantazi, 2016), (Khare, 2018), (Nagler, 2016). NDVI, which is based on the technique that plants reflect energy at the near-infrared wavelength and absorb energy at visible red wavelength, is widely used to monitor changes in climate and agricultural areas (Çelik, 2013).

Statistical analysis

To compare the mortality rates of *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grass exposed to microwave energy, each variable was determined by taking the power of the test at least 80% and 1. type error 5%, in calculating the sample width. Descriptive statistics in our study are expressed as a percentage. Z-ratio test was used to compare mortality rates in *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grass, where microwave energy was applied for 10, 20, and 30 seconds in the uniform heat distribution conditions and non-uniform heat distribution conditions. The statistical significance level (α) was taken as 5% in calculations and Minitab (Statistical Software for Windows, Ver.17) statistical software was used for calculations.

Results and Discussion

The microwave application results of comparison of mortality rates in the UHD (Uniform Heat Distribution) conditions and Non-UHD (Non-Uniform Heat Distribution) conditions for 10, 20, and 30 seconds, in the *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) are given. During the same period, when the mortality rates in the UHD conditions and the Non-UHD conditions where the microwave energy is applied are examined; A statistical similarity was found between the mortality rates of *Lepidium sativum* (cress) grass applied microwave energy in UHD and Non-UHD conditions for 10 seconds ($p > 0.05$), (Table 1). In *Lepidium sativum* (cress) grasses, there was no significant difference between the mortality rates in the heat distributions.

Similarly; A statistical similarity was found between the mortality rates in *Hordeum vulgare* (barley) grass with microwave energy in UHD and Non-UHD conditions for 10 seconds ($p > 0.05$). In other words; In *Hordeum vulgare* (barley) lawns, there was no significant difference between the mortality rates in these heat distribution conditions.

A statistically significant difference was observed between the mortality rates in *Hordeum vulgare* (barley) grass where microwave energy was applied in UHD and Non-UHD conditions for 20 seconds ($p < 0.05$). In other words; In *Hordeum vulgare* (barley) lawns, a significant difference was observed between the mortality rates in these heat distribution conditions.

Table 1. Comparison of mortality rates in microwave exposed *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grasses

	Time (s)	*Mortality rates at UHD (%)*	*Mortality rates at Non-UHD (%)*	*p.
Lepidium sativum (cress)	10	29.63	20.02	**0.141**
Hordeum vulgare (barley)	10	7.01	7.20	**1.000**
****p.**		**<0.001**	**0.006**	
Lepidium sativum (cress)	20	57.70	36.40	**0.003**
Hordeum vulgare (barley)	20	40.10	38.09	**0.772**
****p.**		**0.010**	**0.770**	
Lepidium sativum (cress)	30	69.81	54.90	**0.027**
Hordeum vulgare (barley)	30	61.01	45.45	**0.022**
****p.**		**0.179**	**0.155**	

** Significance levels of mortality rates occurring in the grass where microwave applied under UHD and Non-UHD conditions according to the results of the Z-ratio test.*
*** Significance levels of mortality rates in Lepidium sativum (cress) and Hordeum vulgare (barley) grass within the same duration and the same heat distribution conditions according to the results of comparison with Z-ratio test.,*

Here, mortality rates in uniform heat distribution are higher (57.7%). A statistical similarity was found between the mortality rates in microwave applied *Hordeum vulgare* (barley) grass in UHD and Non-UHD conditions for 20 seconds ($p > 0.05$). In *Hordeum vulgare* (barley) lawns, there was no significant difference between the mortality rates in these heat distribution conditions.

In the UHD and Non-UHD environments for 30 seconds, a statistically significant difference was observed between the mortality rates in microwave applied *Lepidium sativum* (cress) grasses ($p < 0.05$). In other words; In *Lepidium sativum* (cress) lawns, a significant difference was observed between the mortality rates in these

heat distribution conditions. Mortality rates in the UHD conditions occurred at a higher rate (69.8%).
A statistically significant difference was observed between the mortality rates in microwave energy applied *Hordeum vulgare* (barley) grasses under UHD and Non-UHD conditions for 30 seconds ($p < 0.05$). In other words; In *Hordeum vulgare* (barley) lawns, a significant difference was observed between the Mortality Rates in these heat distribution conditions. Mortality rates in the UHD conditions occurred at a higher rate (61.0%).
Comparison results of mortality rates in *Lepidium sativum-Lepidium sativum (cress) and Hordeum vulgare-Hordeum vulgare (barley)* grass in the same periods and the same heat distribution conditions:

A statistically significant difference was observed between the mortality rates in the microwave energy applied *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grasses for 10 seconds, in the UHD conditions ($p < 0.05$). In the *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grasses, a significant difference was observed between the mortality rates in these heat distribution conditions. Here, the mortality rate in *Lepidium sativum* (cress) grasses is higher than that of *Hordeum vulgare* (barley) (29.63%), (Figure 3).

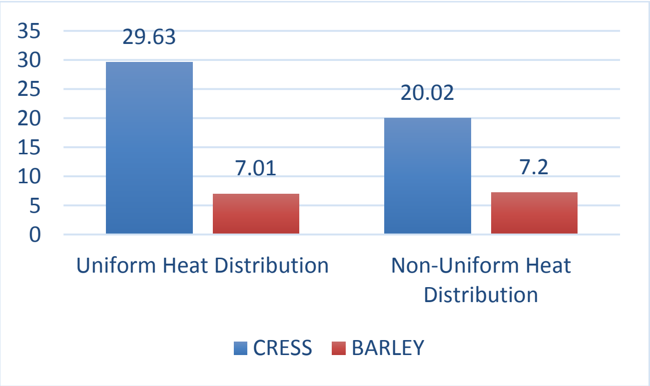

Figure 3. Mortality rates in *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grasses for 10s microwave exposed in UHD and Non-UHD conditions

A statistically significant difference was observed between the mortality rates in the *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) lawns applied in microwave energy for 20 seconds in the UHD conditions ($p < 0.05$). In the *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grass, a significant difference was observed between the mortality rates in these heat distribution conditions. Here, the mortality rate in *Lepidium sativum* (cress) grass is higher than that of *Hordeum vulgare* (barley) (57.7%), (Figure 4).

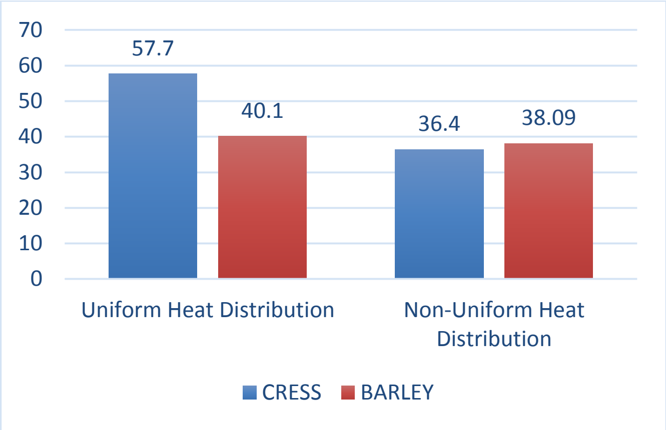

Figure 4. Mortality rates in *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grass for 20s microwave exposed in UHD and Non-UHD conditions

A statistical similarity was found between the mortality rates in *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grasses, in which microwave energy was applied in the Non-UHD environment for 30 seconds ($p > 0.05$). In the *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grasses, there was no significant difference between the mortality rates in these heat distribution conditions (Figure 5).

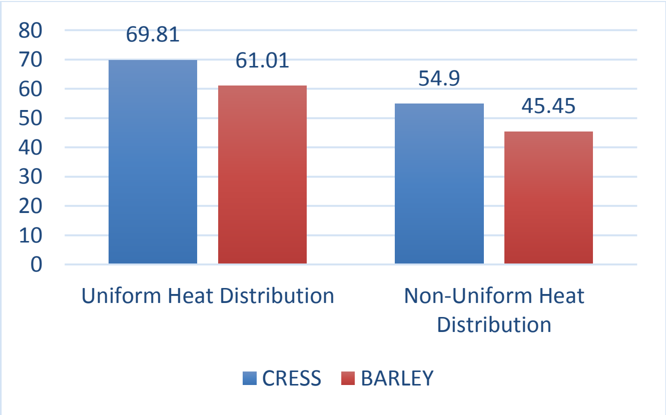

Figure 5. Mortality rates in *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grasses for 30s microwave exposed in UHD and Non-UHD conditions

Looking at the mortality rates in *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grass for 10, 20, and 30s in the UHD conditions (Figure 6); It can be observed that, mortality rates in *Lepidium sativum* (cress) grasses are higher in all 10s, 20s, and 30s applications.

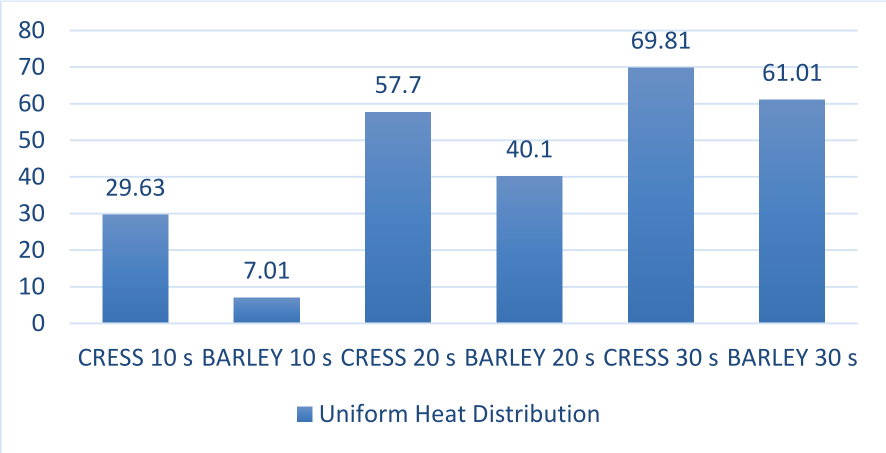

Figure 6. Mortality rates in *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grasses microwave energy exposed for 10, 20, and 30 seconds in UHD conditions

In non-UHD conditions, when the mortality rates in *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grass were examined for 10, 20, and 30s (Figure 7); Mortality rates in *Lepidium sativum* (cress) grass were higher in all 10s, 20s, and 30s applications. As the microwave exposure time increases, mortality rates increase in both plant species. This result was observed in both UHD conditions and Non-UHD conditions.

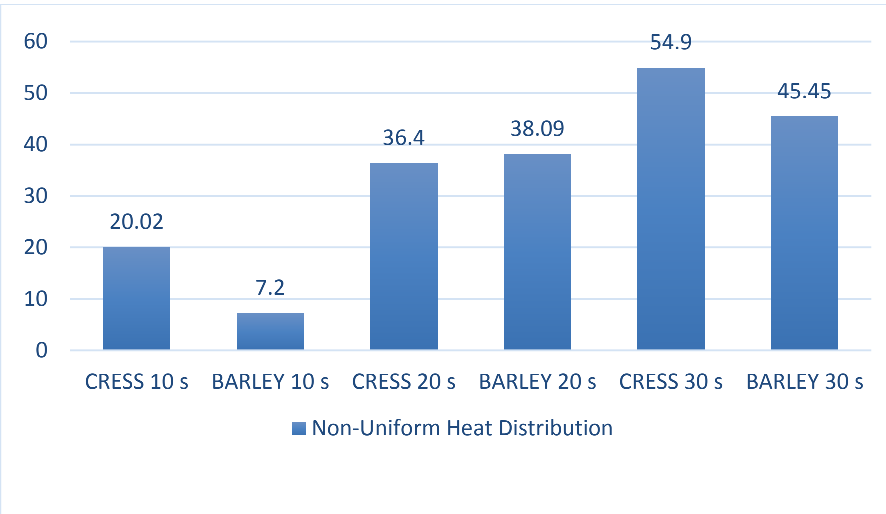

Figure 7. Mortality rates in *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grasses microwave energy exposed for 10, 20, and 30 seconds in Non-UHD conditions

In non-UHD conditions, when the mortality rates occurring in *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grasses for 20 and 30s are examined; It was observed that mortality rates in *Lepidium sativum* (cress) grass are higher in all 10s, 20s, and 30s applications. As the microwave exposure time increases, mortality rates increase in both plant species (Figure 8).

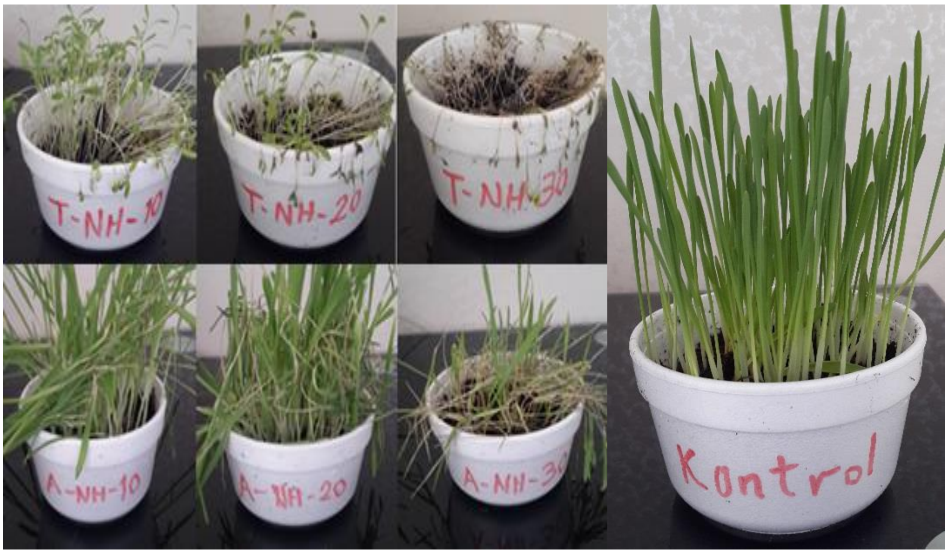

Figure 8. 10, 20, and 30 seconds microwave exposed *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grasses in Non-UHD conditions

When the mortality rates that occur in 10, 20, and 30s of *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grass under UHD conditions were examined; It was observed that the mortality rates occurring in *Lepidium sativum* (cress) grass was higher in all 10s, 20s, and 30s applications compared to *Hordeum vulgare* (barley) grass. As the microwave exposure time increases, mortality rates increase in both plant species (Figure 9).

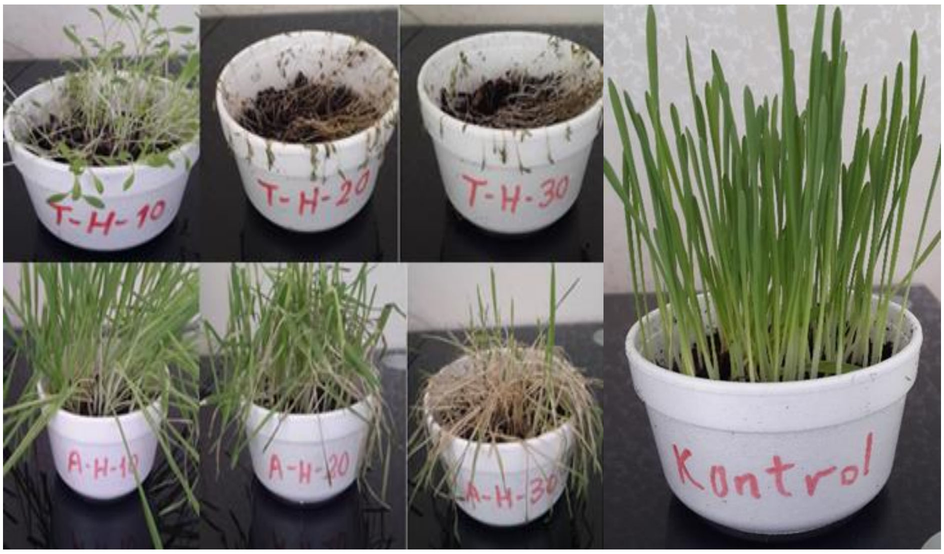

Figure 9. 10, 20, and 30 seconds microwave exposed *Lepidium sativum* (cress) and *Hordeum vulgare* (barley) grasses in UHD conditions

Mortality rates and soil temperature changes occurring in *Hordeum vulgare* (barley) and *Lepidium sativum* (cress) grasses for 10, 20, and 30s in UHD and Non-UHD conditions; It shows that as the microwave exposure time increases, the soil temperature increases, and accordingly, the mortality rates increases. As a result, there was an increase in soil temperatures both in the UHD and Non-UHD conditions along with the microwave application time (Table 2).

Table 2. Mortality rates and Δt change for 10 s, the 20s, 30s in uniform and non-uniform heat distribution

	Time (s)	UHD Mortality (%)	Δt (°C)	Non-UHD Mortality (%)	Δt (°C)
Lepidium sativum (cress)	*10*	*29.63*	*9.20*	*20.02*	*7.50*
	20	*57.70*	*20.30*	*36.40*	*17.20*
	30	*69.81*	*23.00*	*54.90*	*20.40*
	Control	***-3.63***			
Hordeum vulgare (barley)	*10*	*-7.01*	*7*	*7.20*	*6.20*
	20	*40.10*	*16.20*	*38.09*	*12.9*
	30	*61.01*	*19.90*	*45.45*	*18.4*
	Control	***-5.17***			

In weed control and other microwave thermal applications, one of its main problems is non-uniform heat distribution. This problem causes non-uniform heating and energy loss (Fakhouri, 1993), (Funawatashi, 2003), (Sahin, 2012), (Sahin, 2014), (Sahin, 2015).

A difference was observed between the mortality rates of plants microwave energy applied for 10, 20, and 30 s, under UHD and Non-UHD conditions.

Under UHD conditions, an increase of approximately 7% was observed in *Hordeum vulgare* (barley) grasses that were microwaved for 10 s (Table 2). Microwave and electric current applications at low power levels may cause an increase in germination rate in plants (Sahin, 2012), (Sahin, 2014), (Sahin, 2015), (Sahin 2017), (Sahin, 2020), (Bajwa, 2015).

As the microwave application time increases (10, 20, and 30 seconds) in UHD conditions, an increase in mortality rates observed in plants (except UHD, 10 s, *Hordeum vulgare* (barley)) was observed (Table 2), (UHD *Lepidium sativum* (cress); 29.63%, 57.70%, 69.81%, UHD *Hordeum vulgare* (barley); 40.10%, 61.01%, respectively), (Sahin, 2014), (Sahin, 2015), (Sahin 2017), (Cretescu, 2013), (De Wilde, 2017).

In UHD and Non-UHD conditions for 10, 20, and 30 s, mortality rates in *Lepidium sativum* (cress) grass was higher than *Hordeum vulgare* (barley) grass. This is thought to be due to physical property differences (stem thickness, leaf shape, total plant mass) between plant grass.

Besides, in electrical and microwave applications, the properties of weed species and soil such as electrical resistance (R), impedance (Z), dielectric constant (ε'), loss factor (ε'') and dissipation factor (tan δ) should be taken into account (Kafarski, et al., 2018), (Taheri et al., 2018). (Van, 2016), (Sahin, 2019).

Microwaves based on high energy can kill weeds very efficiently (Bajwa, 2015). Therefore, the use of microwave radiation as a weed control method seems to be a good alternative because it does not leave any chemical residue in the environment (Rana, 2018).

Rapid urbanization increased per capita water consumption and increased water pollution in parallel with industrial development (Muratoglu, 2020). Besides, the decrease in the capacity of the dam basins due to the accumulation of solids (Güvel,2020) indicates potable water problems that may arise in the future. Land-use changes made for economic development increase pressures especially on sensitive ecosystems (Kuru,2020). In this context, the proliferation of non-chemical weed control methods is important to reduce the use of agricultural chemicals that also cause drinking water pollution.

Conclusion

One of the main problems in microwave weed control management is the non-uniform heat distribution. This problem causes non-uniform heating, energy loss, and poor heating quality. In this study, it was found that, as the microwave application time increases in UHD conditions, an increase is observed in the mortality rates of plants. It has been observed that the efficiency of the method increases even more when provided in the uniform heat distribution mode. It is thought that as the technologies used in this method are developed, it will be accepted as a more efficient and economical method. To determine the applicability of weed control with microwave under field conditions, it will be tested with a microwave application device to be developed and the results obtained will be re-evaluated.

As a result, weed control with microwave energy has the potential to be a good “environmentally friendly alternative method” to chemical weed control methods.

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