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OPPORTUNITIES IN THE USE OF MICROWAVE TECHNOLOGY FOR WEED MANAGEMENT

Ikbal Aygun[1], Koray Kacan[2,*], Engin Cakir[1]

[1]Department of Agricultural Engineering and Technology, Faculty of Agriculture, Ege University, Izmir, Turkey
[2]Ortaca Vocational School, Sitki Kocman University, Mugla, Turkey

ABSTRACT

Different methods other than herbicides are used for controlling weeds, especially in organic farming. New methods such as microwave applications are considered for controlling weed plants due to the growing concerns about herbicide resistance and chemical residues in the environment.

In this study, different levels of microwave power with different forward speeds effects on the killing efficiency were determined on four weed varieties in three growing stages; cocklebur (*Xanthium strumarium* L.), Johnson Grass (*Sorghum halepense* (L.) Pers.), Black Nightshade (*Solanum nigrum* L.), Bermuda Grass (*Cynodon dactylon* (L.) Pers.) at laboratory conditions. For this purpose, weeds with three different development stages: weeds with four leaves, eight leaves, and weeds at seeding stage were exposed to minimum 1.6 kW and maximum 5.6 kW microwave power using laboratory prototype microwave oven with forward speeds in the range of 1 – 0.1 m s^{-1}. The 0–5 scale method was used for the evaluation of the data.

Results showed that weeds could be killed only at lower speeds. Generally, cocklebur was required 2.4 kW energy at 0.3 m s^{-1} forward speed. Black Nightshade, Johnson Grass and Bermuda Grass required much power than cocklebur. Johnson Grass and Bermuda Grass were killed at 4 and 5.6 kW microwave power level at 0.1 m s^{-1} forward speed respectively.

KEYWORDS:
Microwave technology, weed management

INTRODUCTION

The most important targets in agricultural production are reducing costs and increasing production. Besides increasing production quality is also an important factor in agricultural production. Weed control is one of the big factors having a direct impact in terms of yield and quality. Herbicides used for controlling weeds is the most common method applied by farmers. But, the use of herbicides destroys the environment and increases the cost. Recently, microwave applications are considered for controlling weed plants due to the growing concerns about herbicide resistance and chemical residues in the environment. Recent studies proved that microwave energy can kill the weeds effectively [1, 2]. Unfortunately, microwave application is still quite expensive comparing traditional weed control systems. As reported, pre-emergence microwave applications can control the weed emergency in the soil [3, 4, 5].

Burnside et al. reported that viable weed seeds in the soil can be reduced by 95% after five years of consistent herbicide management [6]; however, [7] pointed out that in spite of achieving good weed control over several years, weed infestations will recur in succeeding years if intensive weed management is discontinued or interrupted. These efforts to deplete the soil seed bank are hindered by the growing list of herbicide-resistant weed biotypes [8].

Interest in the effects of high-frequency electromagnetic waves on biological materials dates back to the late 19th century [9], while interest in the effect of high-frequency waves on plant material began in the 1920s [9]. Many of the earlier experiments on plant material focused on the effect of radio frequencies (RF) on seeds [9]. In many cases, short exposure resulted in increased germination and vigor of the emerging seedlings [5, 10, 11, 12]; however long exposure usually resulted in seed death [9, 13, 14, 15].

Experience to date confirms that microwaves can kill a range of weed seeds in the soil [3, 4, 7, 10, 16], however, far fewer studies have considered the efficacy of using microwave energy to manage weed plants.

MATERIALS AND METHODS

The research was conducted at the laboratory of Agricultural Engineering & Technology Department, Faculty of Agriculture, Ege University in the years of 2015 and 2017. For killing the weeds 16 kW laboratory prototype microwave oven was designed and manufactured which shown in Figure 1. The specifications of the microwave oven were given in Table 1.

Four different weed varieties were selected. Selected weed varieties were Cocklebur (*Xanthium strumarium),* Johnson Grass (*Sorghum halepense*), Black Nightshade (*Solanum nigrum*)*,* and Bermuda Grass (*Cynodon dactylon*) which shown in Figure 2.

FIGURE 1
Laboratory prototype microwave oven

TABLE 1
The specifications of the microwave oven

Microwave Power	Min: 2.4 kW Max: 16 kW
Length	Total 7.5 m (every 3 sections 2.5 m)
Speed	Min: 0.001 m sec^{-1} Max: 1 m sec^{-1}

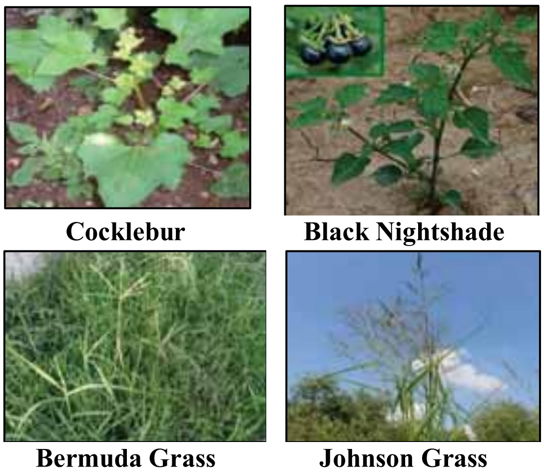

FIGURE 2
Weed Species

To examine the microwave energy effect on the weeds, all microwave power levels at different forward speeds were used to determine the level of power to kill the weeds. Six different power levels with four different forward speeds were used to kill the weeds at 3 different growing stages. In the first stage, the weeds had 4 leaves, in the second stage 6-8 leaves and the last stage was the seeding stage of the weed.

Weeds were exposed to minimum 1.6 kW and maximum 5.6 kW microwave power with four different forward speeds of 1, 0.5, 0.3 and 0.1 m s^{-1} for each growing stage of the weeds to determine the effect of the microwave power for killing the weeds. To determine the killing effects, 0–5 scale was used. For evaluation using the 0–5 scale, scale 5 was assigned when the whole weed is killed, and 0 scale was assumed to be no effect at all, as seen in Table 2.

TABLE 2
Scales indicating the level of microwave energy effect on killing weeds

Scale	*Scale*
No Effect	0
A Small decrease in plant height	1
Decrease in plant height and few dead plants	2
Physical deformation and dead plants	3
Dead plants and few brown leaves	4
Dead plants and brown leaves	5

RESULTS AND DISCUSSION

According to the results; all four types of weeds could be killed by microwave applications. Figure 3 shows the conditions of the weeds before and after the microwave applications. As seen in Figure 3, all types of weeds dried out and reached a mortal case after effective microwave power applications.

After Application
FIGURE 3
Weeds before and after the microwave application

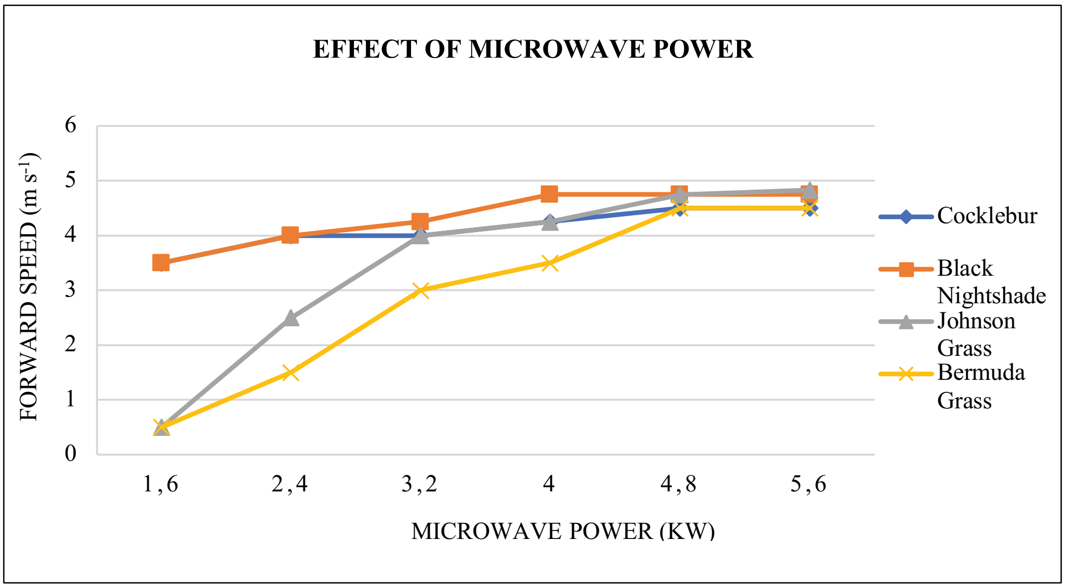

FIGURE 4
Effect of microwave power at first growing stage 0.1 m s^{-1} forward speed

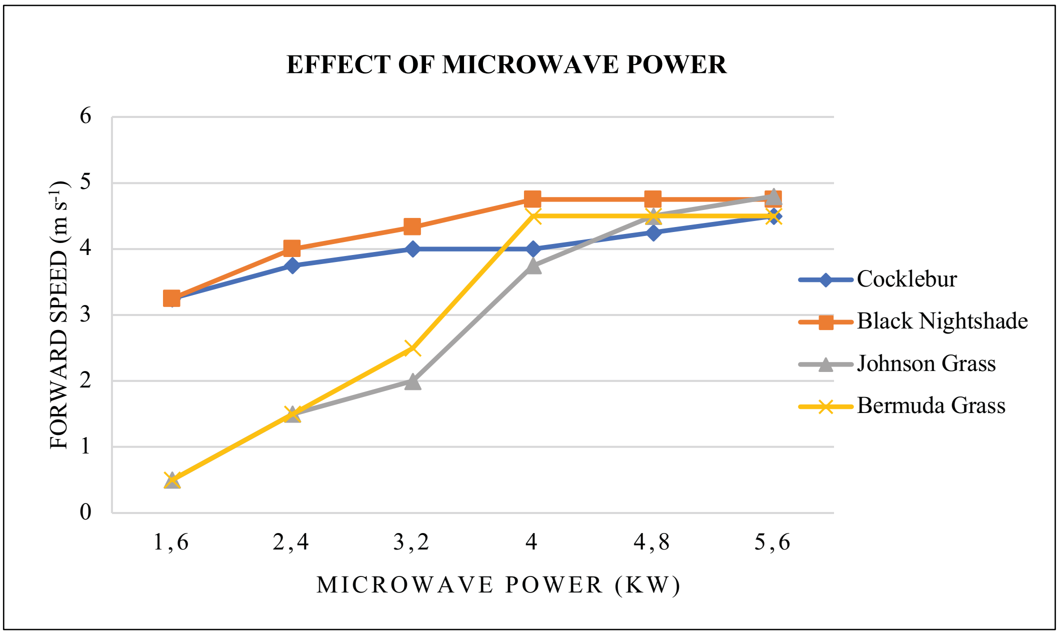

FIGURE 5
Effect of microwave power at first growing stage 0.3 m s^{-1} forward speed

Results showed that the forward speeds of1 1 and 0.5 m s^{-1} were too fast to kill the weeds at the maximum power level of 5.6 kW. Weeds could be killed only at lower speeds, for this reason, the results were given with 0.3 and 0.1 m s^{-1} forward speeds. The evaluated results by scale method were given in Figures 4–8.

As seen in Figure 4, in the first growing stage, perennial weeds were affected by high energy levels when we compared to the annual weeds Cocklebur and Black Nightshade were required minimum microwave energy level of 1.6 kW, whereas Johnson Grass and Bermuda Grass required minimum 3.2 kW in 0.1 m s^{-1} forward speed.

When we increased the forward speed, required minimum microwave energy level to kill the weeds increased as seen in Figure 5. With increasing speed, Johnson Grass and Bermuda Grass started to die at a power level of 4 kW instead this was 3.2 at a forward speed of 1 m s^{-1}.

In the second growing stage, the energy that was required to kill the weeds increased by the growing stage as seen in Figure 6. When the results evaluated in the second growing stage, required microwave power to kill the weeds were increased when we compared with the first stage. At second growing stage minimum power that effects weeds was 3.2 kW at 0.1 m s^{-1} forward speed for both perennial and annual weeds. Brodie and his friends applied 2 kW microwave energy to Kikuyu grass (*Pennisetum clandestinum*) by the help of the trailer and it was moved over the grass at between 700 and 900 m hr^{-1}. After 4 days, the treated strips were 100 % affected [17].

Second growing stage the microwave power levels for killing the weeds at a minimum speed of 0.1 m s^{-1} were measured as 3.2 kW, 4.8 kW, 5.6 kW for Cocklebur, Black Nightshade, Johnson Grass and Bermuda Grass respectively. In addition, the required microwave power to kill the weeds increased with increasing forward speed as seen in Figure 7.

The growing stage was found effective on the required power level to kill the weeds. In the third growing stage of the weeds, when the weeds were overgrown vegetative, more power needed to kill the weeds (Figure 8). All four weeds required more power for killing when they are in late growing stages when comparing the first and second growing stages:

Similarly, the required microwave power to kill the weeds increased with increasing forward speed in the third growing stage of the weeds (Figure 9).

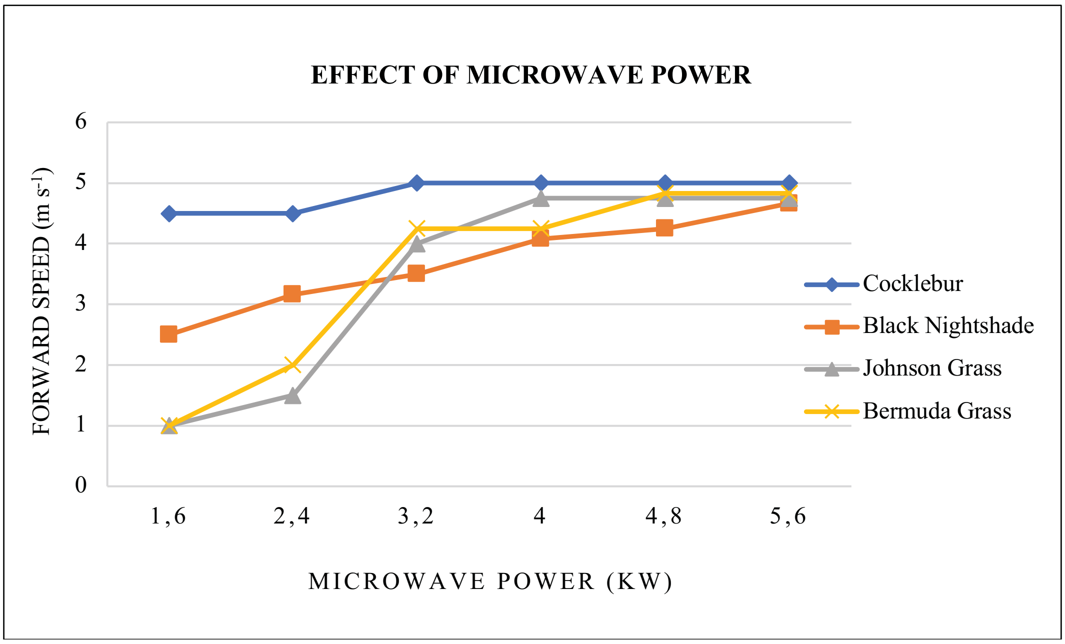

FIGURE 6
Effect of microwave power at second growing stage 0.1 m s^{-1} forward speed

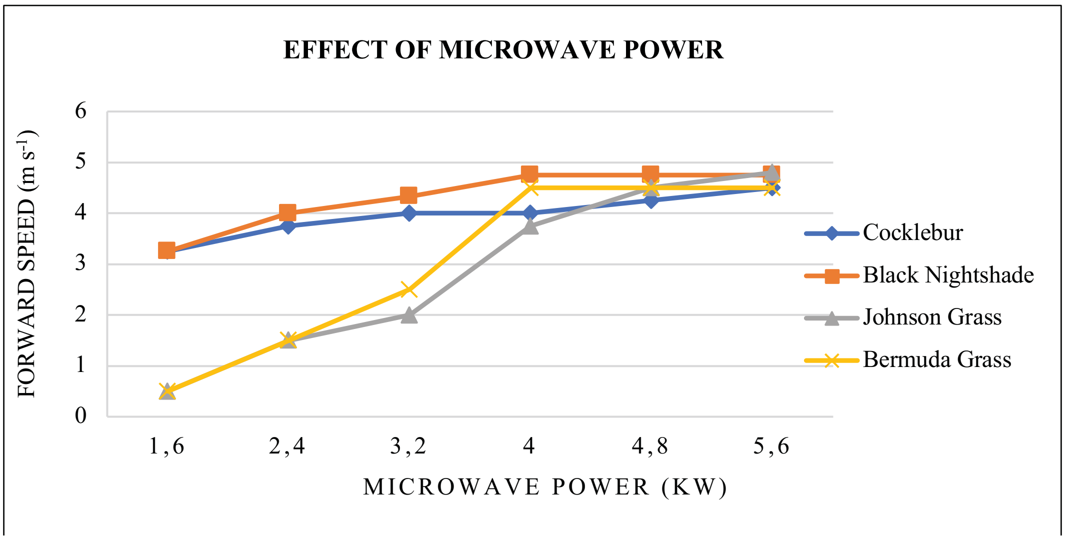

FIGURE 7
Effect of microwave power at second growing stage 0.3 m s^{-1} forward speed

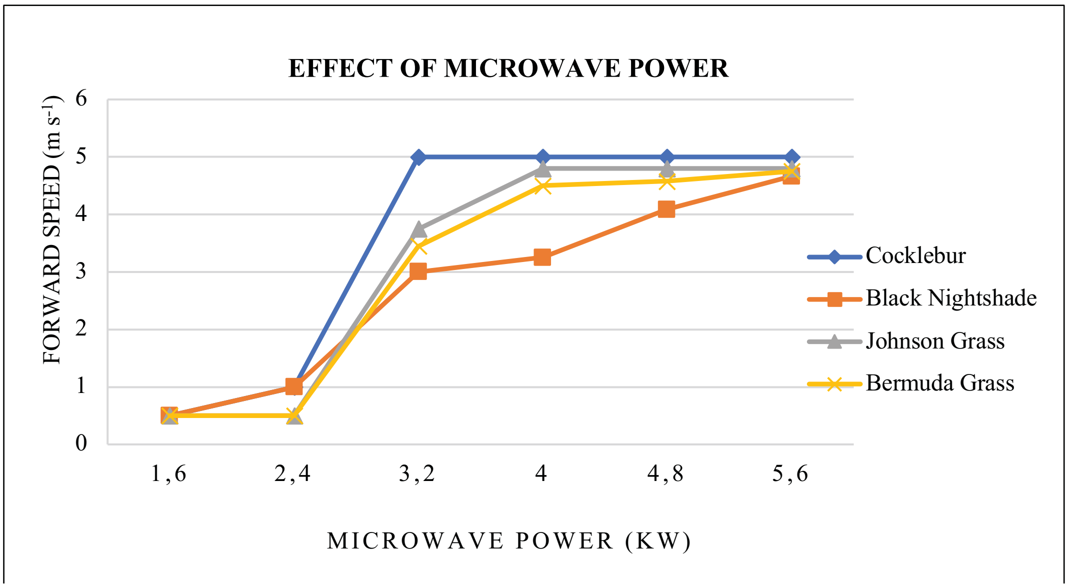

FIGURE 8
Effect of microwave power at third growing stage 0.1 m s^{-1} forward speed

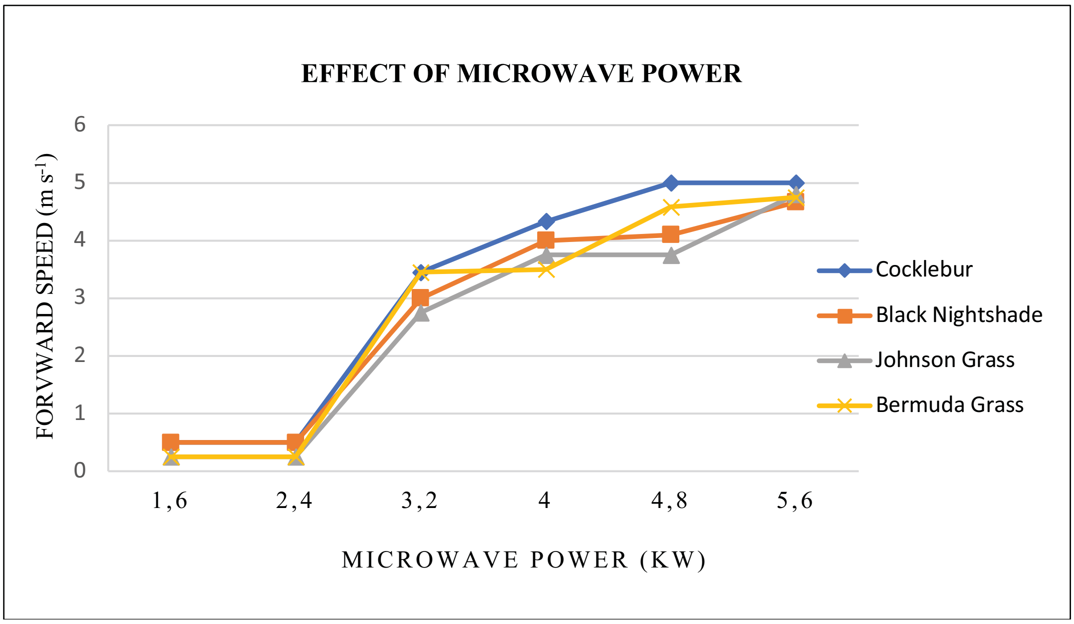

FIGURE 9
Effect of microwave power at last growing stage 0,3 m s^{-1} forward speed

Generally, cocklebur and Black Nightshade required much less power comparing Johnson Grass and Bermuda Grass. Bermuda Grass was the only weed which required maximum 5.6 kW microwave power level at all forward speeds at laboratory conditions.

The required microwave power to kill the weeds increased with increasing forward speed and at late growing stages of the weeds. Results showed that the forward speeds of 1 and 0.5 m s^{-1} were too fast to kill the weeds at the maximum power level of 5.6 kW. Weeds could be killed only at lower speeds. Generally, cocklebur and Black nightshade required much less power comparing Johnson grass and Bermuda grass. Bermuda grass was the only weed, which required maximum 5.6 kW microwave power level at all forward speeds at laboratory conditions.

CONCLUSION

In this study, the microwave has enabled on weeds to be controlled in the fastest and easiest way. Further studies must be conducted with the machine having higher power levels. Also, a similar study can be conducted on different weeds. Authors of this study have already developed a prototype microwave weed killing machine for field applications. The prototype is still under construction. It has been modified according to the different weed species. Generally, it can be said that although it's low field efficiency, microwave weed killing machines will be a good solution for killing the weeds in organic farming.

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CORRESPONDING AUTHOR

Koray Kacan
Department of Plant and Animal Production,
Ortaca Vocational School,
Sitki Kocman University,
Mugla – Turkey

e-mail: koraykacan@gmail.com