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A PROPOSAL TO DESIGN AND DEVELOP A MICROWAVE WEED CONTROLLER FOR AGRICULTURAL USE

Hasan Şahin[1], Mustafa Hakkı Aydoğdu[2] and Mehmet Reşit Sevinç[3]

[1] Department of Agricultural Machinery, Harran University. Sanlıurfa, Turkey.
[2] Department of Agricultural Economics, Harran University. Sanlıurfa, Turkey.
[3] Bozova Vocational School, Harran University. Sanlıurfa, Turkey.

[1] http://orcid.org/0000-0002-3977-4252, [2] http://orcid.org/0000-0002-4945-5239, [3] http://orcid.org/0000-0002-0617-7822

Email: hsahin@harran.edu.tr, mhaydogdu@hotmail.com, *rsevinc@harran.edu.tr

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ABSTRACT

Problems based on agricultural activities are increasingly adversely affecting the environment and living health mostly due to chemical inputs used which cause concerns globally. One of the non-chemical weed control methods is the microwave weed control method. The purpose of this research is to propose an environmentally friendly agricultural machine design that can be an alternative to harmful chemicals used in weed control. In this study, microwave generators (magnetron) receive their energy from a generator fed from the tractor shaft. Multiple magnetrons, control, and leakage unit, and waveguides operating at 2.45 GHz ISM will be used. The design includes a magnetic shunt transformer, a high voltage capacitor, a filter, and a cooling fan with each magnetron where microwave leaks that occur during applications can be controlled and magnetron activities can also be monitored. Field applications and tractor working conditions will be analyzed and the device will be re-designed and developed according to the needs. In this study, unlike the other studies, more than one magnetron will be used and the device is designed for open agricultural areas applications. This design and application area differences are the most important feature that distinguishes this study from others, and it is made for the first time. Its use is expected to occur in all countries with similar characteristics for agricultural production.

I. INTRODUCTION

Environmental, ecological, and agricultural sustainability is one of the most global issues of concern recently especially due to climate change [1]. Agriculture is a strategic sector for all countries to ensure food security of the nations as well as for reasons such as the supply of raw materials to other sectors, rural development, and employment [2]. Globally, there is a decrease in agricultural lands while the population is increasing [3]. This inverse relationship has accelerated the search for higher yields from agricultural unit lands. Therefore, the amount of chemical inputs used in agricultural activities has been increasing day by day at least to meet the food needs of the increasing world population. While the use of artificial inputs in agricultural production causes an increase in productivity in the short term, it may also cause some negative effects on living things, natural resources, and the environment in the medium and long term [4]. Especially in agriculture, the use of uncontrolled artificial inputs has become more widespread with the development of chemical technology, which has become a cause for concern in all aspects as the chemical residual leftovers on the resources and the products [5]. Globally, the level of concern about safe food among the consumers has been increasing due to chemicals with pesticide residues [6].

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 [7]. The adverse effects of herbicides on human health as well as on bees, birds, and fish, microorganisms, and invertebrates are very serious. It is known that it causes cancer in people who are exposed to phenoxy group herbicides, which are widely used worldwide [8-11]. Besides, it has been stated that triazines are associated with breast cancer [12], while terbuthylazine causes lung cancer [13].

The prohibition of chemical substances used in weed control in agricultural production in most of the countries, which are harmful to natural resources, ecology, human and animal health, has increased the scientific studies on non-chemical alternative methods in weed control, especially in developed countries due to many reasons. As a result of the competition between the plant and weeds, significant yield losses may occur in the main crop depending on the weed type. In the fight against weeds, the weeds are generally expected to germinate and then the weed is tried to be destroyed by using chemical or mechanical methods. This situation creates direct costs on agricultural production, natural resources, and the environment arising from agricultural activities. Besides, it causes an indirect cost increase as weeds make it difficult to use machinery during product harvest, blending, and storage.

One of the non-chemical weed control methods is the microwave energy method. Although this method has not reached an economical and applicable level yet, it is a method that has been studied by many researchers. Because it is a more environmentally friendly method compared to chemical control methods. This method is expected to be developed and used widely soon.

The purpose of this research is to propose an environmentally friendly agricultural machine design that can be an alternative to harmful chemicals used in weed control.

II. THEORETICAL BACKGROUND

Electromagnetic waves cover a wide range of frequency or wavelengths and these waves are classified according to their source. Since all electromagnetic waves propagate in space at a speed (c) of $3x10^8$ m/s, between frequency (f) and wavelength (λ); There is a relation in the form of equation (1).

$$\lambda = c / f \quad (1)$$

However, this relation is valid for monochromatic plane waves. Today, microwave ovens for home use operate with a frequency of 2.45 GHz. In devices operating with this frequency, if the wavelength of microwaves λ is about 0.122 m. The solution of the three-dimensional wave equation with the help of boundary conditions gives the standing waves in the x, y, z direction conforming to the following equation (2).

$$\frac{1}{\lambda^2} = \frac{1}{{\lambda_x}^2} + \frac{1}{{\lambda_y}^2} + \frac{1}{{\lambda_z}^2} \quad (2)$$

Assuming microwave propagation in a volume with wavelengths $\lambda_x, \lambda_y\ ve\ \lambda_z$ and linear dimensions $are\ L_x, L_y\ ve\ L_z$.

The basis of microwave heating is to increase the speed of motion of molecules such as water by increasing the frequency and the resulting increase in molecular vibration and collision, and the temperature in the material. Because of this feature of microwaves, the energy of microwaves has been tested in many studies such as in agricultural soil disinfection, restriction of germination of weed seeds, and destruction of germinated weed seeds which are given as follows.

These studies are about, physical disinfection with high-frequency electromagnetic waves [14], [15], microwave energy applying to the plants germinated at 8, and 16 days for different periods [16]. Interest in the effects of electromagnetic waves on biological materials started at the end of the 19th century and most of the studies conducted in this period are related to the effects of Radio Frequencies (RF) on plant seeds [17]. Most of the studies have shown that the cause of living cell deaths is due to microwave thermal effect and microwave electric field [18]. Because, microwave energy is transferred directly to the material through molecular interaction in microwave heating, which is another advantage of microwave heat treatment application [19].

As a result of another study, we can say that disinfecting the soil with microwave heat treatment is an alternative to the chemical control method as it does not leave any chemical waste behind [20–22], which is very important in terms of sustainable use of natural resources. Similar results were also obtained in the study of removing organophosphorus (organic phosphorus) pesticides from the soil with the help of microwaves [23]. Extremely successful results have been obtained in studies of limiting the germination of unwanted plant seeds with microwave energy [24–31]. In most of the studies, although an increase in seed germination was observed in short-term microwave applications, it was found that seeds died in longer-term applications [32].

However, undesirable side effects such as physical damage, non-uniform heat distribution, and deterioration in biological values may occur in agricultural products during microwave drying processes [33]. It was stated that the non-uniform heat distribution of microwave energy used in food heating reduces the heating quality as well as threatens food safety in another study [34]. And the research was concluded that some of the microwaves (thermal losses) produced during weed control applications with microwave energy leak into the external environment and the microwave method increases the energy cost and decreases its competitiveness with chemical methods [35].

III. MATERIALS AND METHODS

Generally, a single magnetron was used in most of the microwave weed control experiments described in the literature. However, it is thought that it will be more effective to use more than one magnetron in the design to be made due to the very low heating effect and the non-uniform heat distribution of microwaves.

In this study, microwave generators (magnetron) will receive their energy from a 30 kVA AC generator (Fig.1) fed from the tractor shaft. 10 standards 700 watts' magnetrons (Fig.2) and 10 waveguides operating at 2.45 GHz ISM will be used in the design. The design includes a magnetic shunt transformer, a high voltage capacitor, a filter, and a cooling fan together with each magnetron.

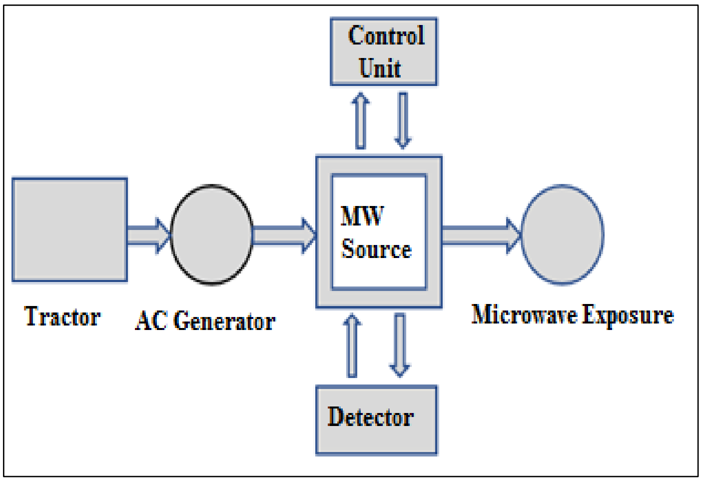

Figure 1: Block diagram of the MW weed controller.
Source: Authors, (2020).

It is very difficult to notice that if one of the magnetrons fails due to any malfunction. Therefore, to eliminate this problem, a monitor will be used to monitoring the operation of each magnetron. Besides, 4 microwave leakage detectors will be used to detect whether microwave leaks that may threaten the health of employees during the implementation exceed the 5 mW/cm² safety limit determined by the FDA (U.S. Food and Drug Administration) and EPA (U.S. Environmental Protection Agency). These detectors have a frequency calibration of 2.45 GHz and a measurement range of 0-9.99 mW/cm^2. Measurement accuracy precision is ± 1 dB and the warning measurement value is 5 mW/cm². Since the distance of microwaves to the target plant will reduce the penetration depth, the device is designed to be adjustable in height according to the target plant height to be applied. Also, to prevent non-uniform heat distribution, which is an important problem in microwave thermal applications, the placement positions of the magnetrons are designed to provide optimum uniformity (Fig.2).

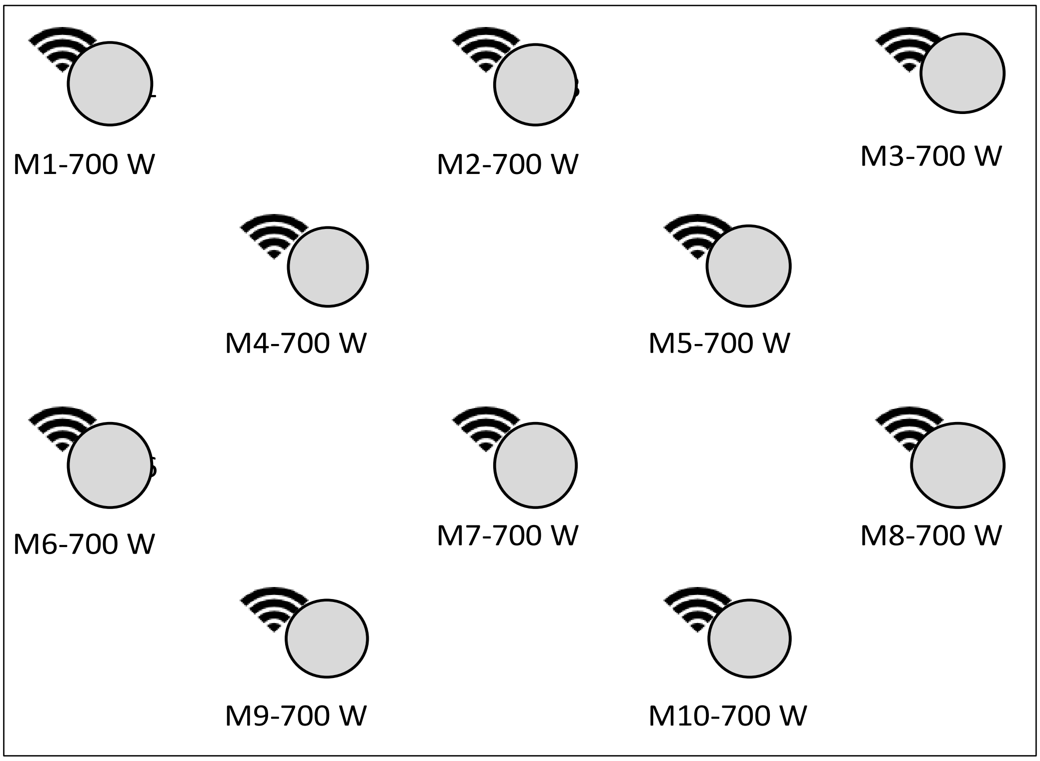

Figure 2: The layout of 10 pcs of 700-watt magnetrons.
Source: Authors, (2020).

IV. RESULTS AND DISCUSSIONS

In most of the studies, the trials have been made in a closed volume with a single magnetron about the use of 2.45 GHz microwaves as a weed control method. In this study, unlike the other studies, more than one magnetron will be used and the device is designed for open agricultural areas applications. This design and application area differences are the most important feature that distinguishes this study from others, and it is made for the first time. This device, which takes the necessary electrical energy from the tractor tail shaft, will feed 10 psc of 700 watts' microwave output power magnetrons and other control units. It can control the detect thermal leaks and operations of magnetrons during microwave applications. The device will be tested on common weeds in the research area, Şanlıurfa, which is located within GAP (The Southeastern Anatolia Project) and necessary improvements will be made according to the results to be obtained. GAP Project is Turkey's largest regional development project based on water and land resources and Şanlıurfa is the most important province in terms of agricultural potential in the GAP project [36], [37].

The efficiency of the device in the field conditions and its compatibility with the tractor will be analyzed after the trials. The device will be re-designed and developed according to the needs if required.

IV.1 HAZARDS AND CONSTRAINTS IN MICROWAVE APPLICATIONS

Every innovation and design has its constraints and risks. During microwave applications, microwave leak detectors are used against microwave leaks. As is known, microwave energy can be absorbed by the body and generate heat in exposed tissues. Weak organs with temperature-sensitive tissue such as the eyes with blood flow and temperature control are more they have a high risk of heat damage.

It is also important to know that microwaves and radiofrequency radiation are non-ionizing radiation and microwaves do not leave any residue on plants, foods, or water [38]. Microwave applications provide the opportunity to deactivate weed seeds in the soil seed bank. However, most of these technologies require medium to high energy investments and, in some cases, involve high risks to human health and safety, such as electric shock or electrostatic fields, which should be considered [39].

Internal friction occurring in the polar environment causes heating in the reaction mixture. However, reflections and refractions that occur at local boundaries cause "hot spots" and "superheating" [40]. This process is usually described by a friction model. The majority of polar materials show dielectric losses in contact with microwave [41]. One of the main problems with microwave heating is non-uniform heat distribution. Non-uniform heat distribution has been studied by various researchers [42]. Numerical analysis of the electromagnetic field and temperature in a microwave-applied volume and the characteristics of microwave heating have also been studied [43]. Correct determination of energy density or thermal distribution in dielectric heating with microwave provides significant benefits in studies. Microwave heating or drying sometimes leads to poor quality products [44–49]. It has also been shown in studies that low voltage electric current and short-term microwave exposure accelerate the germination of plant seeds [50–53].

What is important in such innovative designs is whether the constraints and risks are manageable. Risks that are expected to arise in both literature studies and this design are acceptable and manageable risks by taking basic precautions.

V. CONCLUSIONS

While the world population is increasing globally, agricultural areas are decreasing. On the other hand, agricultural areas have a sustainability problem. Besides, the negative effects of artificial inputs using agricultural production on ecology and life are increasing. Every design and innovation has its advantages and disadvantages. The important thing is that the advantages are more than disadvantages and the expected problems are manageable. Instead of herbicides with such obvious negative effects, the development of more environmentally friendly alternative methods should be encouraged.

This design will reduce the possible use of chemical herbicides on the environment and living health. With simple basic precautions, possible harmful effects can be prevented during use. On the other hand, this device needs to be tested and developed under field conditions. Although it is a high-cost device under current conditions, it is a fact that this cost will decrease if it is developed and mass production is started. It should not be forgotten that this high cost will be less than the money to be spent on the elimination of environmental problems caused by agricultural activities. This design will be the first in its field. Its use is expected to occur in all countries with similar characteristics for agricultural production. Since this design is in the patent stage, drawings and models are not given here in detail.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Hasan Şahin, Mustafa Hakkı Aydoğdu and Mehmet Reşit Sevinç.
Methodology: Hasan Şahin and Mustafa Hakkı Aydoğdu.
Investigation: Hasan Şahin.
Discussion of results: Hasan Şahin and Mustafa Hakkı Aydoğdu.
Writing – Original Draft: Hasan Şahin.
Writing – Review and Editing: Hasan Şahin and Mustafa Hakkı Aydoğdu.
Resources: Hasan Şahin, Mustafa Hakkı Aydoğdu and Mehmet Reşit Sevinç.
Supervision: Hasan Şahin and Mustafa Hakkı Aydoğdu.
Approval of the final text: Hasan Şahin, Mustafa Hakkı Aydoğdu and Mehmet Reşit Sevinç.

VII. ACKNOWLEDGMENTS

The model design, drawings, dimensions, and concept are not given in detail as the device design is in the patent stage.

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