A Review on Parameters Affecting the Choice of Alternative (Non-Chemical) Weed Control Methods

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Abstract—Using chemicals as a weed control method is the most preferred method in weed control because they are easily accessible, easily applicable and inexpensive. But, with the new environment-friendly regulations, the importance of non-chemical methods has increased all over the world. In addition, organic farm and non-chemical agricultural methods are gaining importance with increasing social environment and health awareness. Non-chemical methods, called, "alternative methods" have been one of the most popular research subjects in recent years. The physical removal or killing of weeds is usually done by hand or by means designed tools for this task, which varies from country to country. The most known modern non-chemical weed control methods are; electric current, microwave heating, superheated steam, infrared using, pneumatic system, freeze-drying, laser cutting, and fresnel lens systems. The most popular of these methods are; electric current method and microwave heating. In electric current and microwave heating methods, there are no chemical residues in soil and plants after application. It has been shown in the studies that, the microwave weed control method can destroy weeds and seeds when appropriate frequency, sufficient time and required power level are selected. Therefore, in the selection of non-chemical weed control methods, some important parameters of plant and soil should be known. The electrical and dielectric properties of plants and soil such as, electrical resistance (R), impedance (Z), dielectric constant (ε'), loss factor (ε''), the permittivity (ε), permeability (μ) and conductivity (σ) should be known especially in microwave and electric current methods. The other parameters like the age, height, and density of the plant is an issue to be considered in all control methods. But, the moisture content of soil and plant may not be taken into consideration in hot water and steam applications. For the freeze-drying method, the moisture and water content of the plant and soil must also be taken into account.

Index Terms—Weed Control, Parameters, Microwave, Non-Chemical, Electric Current.

I. INTRODUCTION

In the past years, herbicides (chemicals) have been accepted as the main tool in weed control, but with the new regulations made especially in the European Union, the importance of non-chemical methods has increased all over the world. The most known non-chemical weed control methods are; fire-fighting, superheated steam, infrared using, pneumatic system, freeze-drying, laser, electric current, microwave heating, and fresnel lens systems.

From a detailed survey of the application of models to weed control, it is concluded that modeling has fundamentally been concerned with answering issues that contribute comparatively little to our understanding of ‘sustainable’ systems of crop protection [1]. Chemical used in weed control has led to an increase in the number of herbicide-resistant weed populations [2].

On the other hand, organic production and non-chemical agricultural methods are gaining importance with increasing social environment and health awareness. Especially in weed control management, non-chemical methods, called, "alternative methods" have been one of the most researched subjects in recent years. The physical removal or killing of weeds is usually done by hand or by means designed tools for this task, which varies between cultures. Pre and post-sowing, pre and post-emergence with chemicals applied methods, provides a sustainable and long-term strategy to minimize weeds and maximize crop yields [3]. The widespread use of herbicides in agricultural fields has led to the development of anti-herbicide resistance in weeds. The resulting herbicide activity has increased the demand for alternative weed control technologies. Alternative control methods, which determine the most appropriate method for commercial development, have not yet reached the desired technological level due to the lack of an accurate and fair comparison [4]. Management in large-scale agricultural production, the SSWM (site-specific weed management), provides a fair and accurate comparison of non-chemical weed control methods [5].

Chemicals used as a weed control method effect the development of weeds and aim to minimize or completely eliminate economic loss. Control methods using chemicals are used in the control of weeds in agricultural areas as well as in non-agricultural areas. However, in scientific studies, it was determined that the herbicides detected in drinking water can only be separated from the water by ozone purification method. In a study, the herbicides used in the vineyards such as; orflurazon and oxadiazone, at the end of a month in the grape grains and soil residue was found to be a serious danger in consumption [6], [7]. As the damages of chemical drugs used in weed control are understood and environmental sensitivity increases, it is observed that there is a rise in the tendency towards non-chemical control methods especially in organic farming applications [8]. The abandonment of chemical control methods and moving towards organic agriculture emerges as a highly desirable situation in society. However, many manufacturers accept the use of chemicals very quickly because of their ease of application [9].

Although the only method of combating any weed is sometimes sufficient, it may not be sufficient for some weed species. Therefore, it may sometimes be necessary to apply several methods simultaneously or in a certain order. The recent expansion of organic farming has increased interest.
in non-chemical weed control methods. Some of the non-chemical methods used in weed control are:

- Electric current
- Microwave heating
- Superheated steam
- Freeze drying
- Hot water application
- Pneumatic system
- Infrared using
- Laser cutting
- Fresnel Lens heating

Fresnel lens weed control method is to concentrate solar radiation on a plant or region. The experiment results show that to calculate the effect of Fresnel lens concentrated solar radiation at different exposure times, stages of plant growth, and moisture of soil surface conditions. On a dry soil surface, exposure times of 1 to 10 s reaches 290° C [10].

Weed control with electric current is not a new technic. Electric current control method has experimented since 1970 for restriction of germination of weed seeds. The using electrical energy to inhibition weed was developed in 1800, and a few patents have been registered in the USA [11]. As the disinfection of soil with electric current or microwave method does not leave any chemical residue [12], [13], [14] it seems to be an alternative to the chemical weed control method.

Weed cut with a laser is another alternative weed control method. It delays the re-growth of weed, weakens and killed weeds. It’s also a low-cost and ecological weed control method [15].

In another study, the applicability of the microwave method of destroying weeds, which causes significant losses in agricultural production. Mustard, oats, and cress were used as an experimental plant in this study. After microwave application to the plants, most plants lost their viability [16]. Reference [17], in his study investigated to determine the level of restriction of germination of the weed seeds instead of plants. In the study, weed seeds were sown at equal depths (8-10 mm) to the soil, to investigate the effects of microwave energy on the germination of plant seeds. The results show that a restriction of 100 % was observed in the germination of seeds exposed to microwave for 2.8 kW and 126 seconds.

Reference [18], emphasized the necessity of knowing the dielectric properties of agricultural products in thermal processes using the microwave and radiofrequency. When the dielectric properties of agricultural products are examined, it is stated that their reactions as a function of temperature and moisture content at different microwave frequencies.

Site-specific weed management (SSWM) techniques have gained interest in the precision farming community over the last years. Because the SSWM, application technology can save the large amounts of herbicides. On the other hand, the mechanical weed management technologies adapting to the weed location in the field can be applied to a large spectrum of crops [19].

Weed management systems should be re-studied in light of new, developing weed control technologies. The science of weed management needs to refocus on the foundation’s ecology to enable an ecological promote agricultural sustainability [20].

II. PARAMETERS AFFECTING THE METHOD SELECTION

In this study, selection parameters only for the non-chemical (alternative) methods will be discussed as shown in Table I. In the selection of non-chemical weed control methods, the parameters listed below are decisive.

- Soil properties
- Weed length
- Weed age
- Weed dielectric properties
- Weed electrical properties
- Weed density per unit area
- Root thickness and depth of weed
- Leaf width of weed
- The water content of weed
- Soil moisture content

Parameters such as plant age, height, root thickness, and depth are the factors that determine the amount of energy to be applied to the weed. The main problem in determining the economic applicability of non-chemical weed control methods is the complexity of many factors listed above. Cost, yield, timeless and the effect of alternative labor use are factors to be considered when comparing non-chemical weed control methods. It is an advantage to chemical methods that mechanical methods are not preferred because of their latency or time dependence. Although the use of alternative labor is a common debate in the choice of chemical or mechanical methods, it is a factor that has little impact on cost [21].

Especially in electric current method and microwave method, electrical resistance (R), impedance (Z), dielectric constant (ε′), loss factor (ε′′) of the weed species and soil in order to calculate the energy exposure time and the resulting energy losses. and distribution factor (tan δ). However, the moisture contained in the soil and the plant, the properties of the soil, the root and the leaf structure of the plant are important factors affecting the heat treatment efficiency. The behavior of the soil and the plant under the influence of microwave radiation is determined by the percentage of the radiation absorbed, transmitted or reflected. The dielectric constant (ε′) and the loss factor (ε′′) of the applied material is also the basic parameters in the design of microwave applicators.

Dielectric properties of agricultural products are important in terms of measuring moisture content in cereals, accurately determining the behavior of agricultural products exposed to RF and microwave in dielectric heating applications [22].

When electric current applied to the body of the plant according to Eqn. (1) and (2) the amount of energy (E) transferred to one plant depends on the electrical resistance (R_p) of the plant the contact time of the electrodes to the plant (T_c) and the applied voltage (V) has to be known [23]. The effective contact time of the plants contacted by the electrodes at any time (n_c) is equal to the product of electrode length (L), effective electrode width (W_{eff}) and plant density is (D), [23].

\[
E = \frac{V^2 T_c}{R_p}
\]
Similarly, it can be seen at Eqn. (3), the total resistance load ($R_L$) is equal to the sum of the resistance of each plant ($R_p$) touching to the electrodes simultaneously and plus the resistance of the ($R_s$) soil.

$$R_L = \sum_{i=1}^{N} \frac{1}{R_p} + R_s$$  

(3)

The required power generator will increase as the numbers of touching electrodes increase.

If we want to use microwaves efficiently in weed control, we need to know about the dielectric properties of the plants. The dielectric properties of materials are usually expressed by relative complex permittivity, where the real part ($\varepsilon'$) is the dielectric constant and the imaginary part ($\varepsilon''$) is the loss factor. The interaction of electromagnetic waves with the material is closely related to the dielectric properties of the matter. Electromagnetic properties such as permittivity, conduction, reflection, scattering, and refraction are expressed depending on the dielectric properties of the materials. The small amount of water or moisture contained in the material significantly affects the dielectric properties of the material [18].

$$\tan \delta = \frac{\varepsilon''}{\varepsilon'} = \frac{\text{energy loss per cycle}}{\text{energy stored per cycle}}$$  

(4)

The dielectric properties of agricultural products and plants have great importance because of their direct relation with moisture and water content. Dielectric properties of different fruits and nectars have been reported in the literature such as apples, cherries, grapefruits, and oranges [24].

In the study conducted to understand the effect of water stress on the dielectric properties of plant leaves, the significant effect of water stress on the resonance frequency of individual leaves was statistically shown [25].

The effects of frequency, electric field strength, seed moisture content, seed temperature, variant change, and other factors were discussed and practical application aspects in the seed industry were discussed in the study on RF exposure to germination increase and alfalfa seed improvement [26].

In all non-chemical methods, the parameters affecting the control efficiency are also directly affecting the energy efficiency and the cost itself. Therefore, plant and soil properties are of great importance in non-chemical control methods.

Any material is electromagnetically characterized by three parameters; the permittivity ($\varepsilon$), permeability ($\mu$) and conductivity ($\sigma$) of a material. The greater the tan $\delta$ (dielectric loss tangent) value of a material, the greater it's capacity to absorb microwave energy, Eqn. (4), [27].

## III. Conclusion

As can be seen in Table I, the age, height and density of the plant is an issue to be considered in all control methods. The electrical properties like electrical resistance (R), impedance (Z) of weed species and the soil is important for the electric current method. However, the energy losses occurring in both electric current and microwave methods and the lack of knowledge of the electrical-dielectric properties of the plants make the applicability of the methods economically difficult.

Therefore, electrical and microwave applications of weed and soil electrical resistance (R), impedance (Z), dielectric constant ($\varepsilon'$), loss factor ($\varepsilon''$) and distribution factor (tan $\delta$) needs to be known.

The moisture content of soil and plant may not be taken into consideration in hot water and steam applications. However, if the freeze-drying method is to be used, the moisture and water content of the plant and soil must be taken into account.

It is superior to alternative (non-chemical) methods because the chemicals used in weed control are easily accessible, easily applicable and inexpensive.

The use of microwave energy in the weed control has gained popularity today. High energy-based microwaves are used very efficiently in weed control [28]. The use of microwaves that do not produce chemical residues in the environment as a weed control method seems to be a good alternative [29]. Therefore, alternative production methods have not yet reached an economic advantage in terms of technological production and application costs.

In addition, the electroporation method, which is one of the newly applied methods, also aims to damage the cell membrane by a pulsed high voltage electric field. It causes a dielectric breakdown that damages the cell membrane and results in the cell membrane collapsing and cell death. The electroporation technique applied to weed seeds is becoming a non-chemical method for weed control [30].

Similarly, in an experimental study, it was stated that (pulse) pulsed electric current is more effective than the sinusoidal current in creating depth of damage in tissues of different plants [31]. In a study, a voltage multiplier of Cockroft-Walton type was used which can produce variable voltage for variable load. This voltage multiplier provides the required voltage according to the changing plant density without the need for any additional circuit, processor or controller [32]. It is also important to note that low DC voltages such as 8-16 volts increase plant viability and quality [33].

Inadequate stresses to kill weeds can cause adverse effects on the strengthening and proliferation of weeds.

All these studies show that non-chemical weed control methods are strengthened with new studies day by day. In a short period of time, these methods, which are environment-friendly, energy-saving, fast and economical, will contribute to agricultural life through field applications.

Especially in microwave and electric weed control methods, the electrical and dielectric properties of the plant must be determined before the selection of parameters such as microwave power and electric current. In addition, in the weed control method of electricity, it is necessary to know the electrical and dielectric properties of the plant as well as its soil. It is also important to know the dielectric properties in measuring the amount of water that agricultural products and weeds contain during and after drying/destroying processes.
REFERENCES


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