EFFECT OF MICROWAVE TREATED WATER ON THE GROWTH OF CORN (*ZEA MAYS*) AND PEPPER (*CAPSICUM ANNUUM*) SEEDLINGS

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Abstract. This paper presents the investigation of the influence of microwave treated water on the growth of the plants. For this experiment, four groups of seedlings were used and subjected to the study. We took drinking water and divided it into four parts, each group was given only one part. The first group was given water that had been heated to boiling in a glass cup on a gas stove. The second and third group was given water that had been heated in a microwave to boiling (100 °C) and 60 °C respectively. The fourth group of seedlings was given water that had not been heated at all and used as control. The growth of seedlings was studied for 30 days. The analysis of the results shows that corn seedlings that exposed to microwaved water show lower growth rate in comparison to the control ones. Corn seedlings when watered with normal water or with water heated on the stove grew faster and have shoot length significantly bigger than the corns which were watered with water heated in a microwave at 60 °C/100 °C. On the other hand, pepper seedlings watered with either microwaved water or not microwaved water were found with no significant effects on their growth characteristics.

Key words: Microwave, *Zea mays*, *Capsicum annuum*, microwaved water.

INTRODUCTION

The extensive use of wireless telecommunication devices increased the exposure of electromagnetic radiations (EMR) including microwaves in our environment. Microwaves exert different effects on the living organisms. The impact of microwaves depends on multiple factors such as exposure duration [17], frequency, power level, pulsed or continuous wave and the properties of exposed tissue [3, 8, 16]. The current studies show that microwave has a long term effect on living things [5]. Microwaves have the ability to produces changes in permeability of the cell membrane. They also affect the cell growth rate as well as interaction with ions and organic molecules [ ]. Biological effects of microwave radiation can

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be divided into two sections: thermal effects and non-thermal effects. Thermal effect is the one in which the microwave energy is converted into heat energy [12], whereas non-thermal effects result from a direct stabilizing interaction of electric field with specific molecules (polar) in reaction medium with no rise in temperature [6, 15]. The use of microwave ovens motivated the researchers to study the impact of microwaves on the health of living organisms.

Microwave oven uses microwaves to heat food. Microwaves are not a form of heat, but a form of energy which manifests as heat through its interaction with molecules [9].

The treatment of water by microwave causes changes in pH, conductivity and mobility of water molecules. In other words, microwaved water had higher pH, conductivity and water molecule mobility [24]. The pH of untreated water is lower than microwaved water due to the removal of carbon dioxide from water by heat. Also, the conductivity of microwaved water was found to be higher than that of untreated water due to the promotion of the motility of water molecules by microwave through reducing their clustering propensity in bulk phase [10, 20].

Of the thousands of articles on the biological effects of electromagnetic radiation, few studies on the effect of microwaved water on the growth of plants as a whole have been achieved. Special focus was paid on the effect of microwave on germination and growth rate of plants after exposure their seeds to microwave radiation.

Plants are essential components of our environment, therefore it would be necessary to identify their growth after exposure to microwave treated water. The objective of this paper is to investigate the changes in growth rate of corn and pepper seedlings after exposed to microwaved water. Specifically the study aims to determining the growth characteristics of seedlings which were watered with and not watered with microwaved water with respect to length of shoot and morphology of leaves.

MATERIALS AND METHODS

The experiment was conducted in May 2017 for one month at the Laboratories of Biology & Biotechnology, Faculty of Science, Islamic University of Gaza, Palestine, in order to investigate the effect of microwaves treated water on the growth of plants as a whole. The investigation was carried out with water exposed to microwave radiations at a power level 1000 Watt. The growth of the seedlings was studied for 30 days.

PLANT MATERIALS

For the investigation of microwaved water on the growth of seedlings as a whole, two tested seedlings were used and subjected to the study. The plant material was purchased locally from the market and divided into four groups. One week old of each corn and pepper seedlings were used in the study. These seedlings were chosen because of their growth during the period of the present study as well as ability to cultivate it in the plastic pots. Moreover, these plants are considered one of the most important crops in Gaza Strip and the inhabitants planting it continuously in their homes. The tested seedlings were grown in plastic pots. The industrial soil (peat moss, SUBSTRATE SUB3 50/50, Nord Agri) without any addition was used, free of heavy metals. Throughout the experiment, the seedlings were not treated with any kind of pesticides. Table 1 illustrates the number and distribution of seedlings in each group. The block diagram of the experiment is shown in Figure 1.

Table 1

The distribution of seedlings in each group

Type of experimental groups	**Number of corns in experimental groups**	**Number of peppers in experimental groups**
Ordinary water (control)	10	10
Normal boiled water	10	10
Water boiled in a microwave	10	10
Water heated in a microwave at 60 °C	10	10
Total	40	40

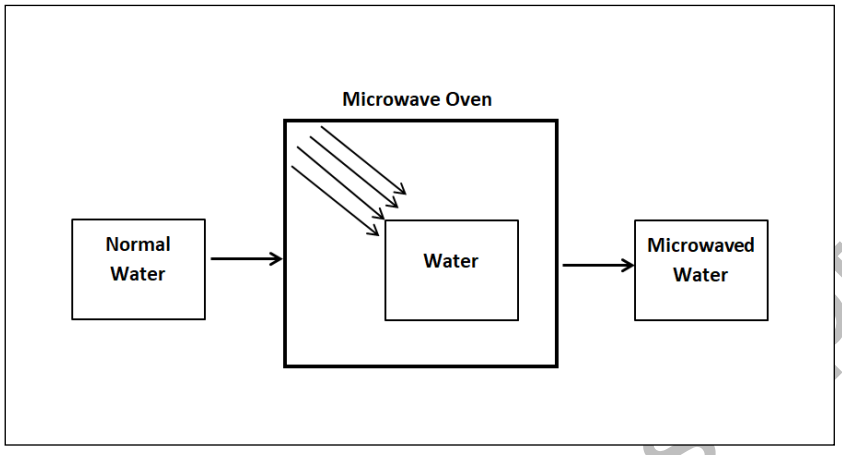

Fig. 1. Block diagram of the experimental setup.

TREATMENTS

To carry out this experiment, a household type microwave of power level 1000 Watt, with energy supplied by magnetron operating at 2450 MHz was used to prepare microwaved water. We took drinking water and divided it into four parts, each group was given only one part. The first group was given water that had been heated to boiling in a glass cup on a gas stove. The second and third groups were given water that had been heated in a microwave to boiling (100 °C) and 60 °C, respectively. The fourth group of seedlings was given water that had not been boiled at all and used as control. Then, after cooling (at room temperature) we used the water to water four groups of identical seedlings to see if there would be any difference in the growth between the control, gas stove boiled water and the water boiled in a microwave.

The seedlings were watered day after day. All the water used in the experiment came from the same source, the same vessel was used for boiling water both on the stove and in the microwave, and the four types of water were stored in identical vessels. The seedlings were kept in a controlled environment and watered in an orderly manner for a period of time identical to all groups. During investigations, the four groups were exposed to the same other control variables such as temperature, humidity and atmospheric pressure.

MEASURING GROWTH RELATED CHARACTERISTICS

The seedlings were followed-up daily for 30 days with regard to the specific parameters. After proper watering, the following measurements and observations were weekly recorded:

1. shoot length (cm);
2. color, texture and number of leaves per seedling.

The investigated parameters have been chosen because they give a general indication for the growth rate of plants under the specific environmental condition. Also, these parameters have been studied extensively in previous experiments [3, 10, 11, 12, 24] regard to the impact of microwaved water on seed germination and the growth of tubers.

As a complement study, we followed up the effect of previously microwave-heated water on the whole seedlings after the germination period and selected corn and pepper as other plant species for investigation.

The length of the growing seedlings was measured using a ruler from the base of the seedling to the tip. Each seedling was observed with respect to change in length of shoot and morphology of leaves. Experiment was terminated at day 30.

STATISTICAL ANALYSIS

Data were statistically analyzed using SPSS computer program version 22.0 for Windows (Statistical Package for Social Sciences Inc, Chicago, Illinois). In the case of normal distribution, a two-tailed student t-test was used to determine statistical significance ($\alpha = 0.05$) of the differences between experimental and control groups assuming equal variance. On the other hand, in the case of skewed distribution, a nonparametric test (Mann-Whitney Test) was used to determine statistical significance ($\alpha = 0.05$) of the differences between each two groups. Also data were statistically analyzed using an analysis of variance (ANOVA) to compare between control, normal boiled water and microwaved boiled water groups.

RESULTS

EFFECTS OF MICROWAVED WATER ON SHOOT LENGTH OF CORN SEEDLINGS

The lengths of the 7 days old corn seedlings were carefully measured with a ruler. The average lengths and the standard deviations were calculated for each group of test seedlings. The confidence interval was calculated for every group of seedlings using the Student test, for the confidence level $p = 95\%$, too. The results

of measurements of shoot length are shown in Table 2. These values were taken as mean values of the length of ten seedlings grown in each group.

Table 2

The average of length (cm) of corn seedlings for control and treated groups

Experimental group	Initial length		At day 30	
	Mean	SD	Mean	SD
Control water (neither heated nor boiled)	5.21	1.04	6.60	1.062
Gas stove boiled water	4.90	1.01	6.11	0.904
Water boiled in a microwave	. 0	0.93	5.15	0.962
Water heated in a microwave at 60 °C	. 0	0.82	4.96	0.316

The data which are recorded in Table 2 illustrated that the growth of corn seedlings was significantly lowered when exposed to microwaved water. Analysis of the results revealed that the difference observed between the corn seedlings that watered with water heated in a microwave at 60 °C and those corn seedlings that watered with water boiled in a microwave 100 °C was not significant. In this case both watered with water heated in a microwave at 60 °C or at 100 °C have almost the same shoot length. Furthermore, the difference between the seedlings which was given gas stove boiled water and other control (not boiled) was not significant. In other words, the two groups have almost similar shoot length.

On the other hand, a different effect occurred between the corn seedlings which were watered with water boiled in a microwave and other which were watered with water boiled on the stove. As reflected from the previous table, corn seedlings that were watered with water boiled in a microwave came to be shorter than those corns that were watered with water boiled on the gas stove. Analysis of the results showed that the difference among each group was significant. Thus, implying that microwaved water has effect to corns with respect to shoot length.

EFFECTS OF MICROWAVED WATER ON SHOOT LENGTH OF PEPPER SEEDLINGS

The results presented in Table 3 show variation in the length of pepper seedlings watered with microwaved water after 30 days.

As reflected from the Table 3, pepper seedlings that were watered with water heated in a microwave at 60 °C came to be shorter than those pepper seedlings that were watered with water boiled in a microwave. Analysis of this result revealed that the difference observed between two pepper groups was not significant (at $\alpha = 0.05$). In this case, pepper seedlings watered with water heated in a microwave

either at 60 °C or at 100 °C have almost the same shoot length. In addition, analysis of the results of the seedlings which were watered with gas stove boiled water and seedlings that were watered with control water (unheated) pointed out that the two sets of pepper seedlings have almost the same shoot length and the differences between them were not significant.

Table 3

The average of length (cm) of pepper seedlings for control and treated group

Experimental group	**Initial length**		**At day 30**	
	Mean	**SD**	**Mean**	**SD**
Control water (neither heated nor boiled)	13.8	1.52	24.8	2.76
Gas stove boiled water	13.8	0.52	23.5	1.75
Water boiled in a microwave	14.0	1.35	23.8	2.79
Water heated in a microwave at 60 °C	13.6	1.32	22.6	2.08

Furthermore, as can be seen in the previous table, treatment of pepper seedlings with water boiled in a microwave showed a slight increase as compared to seedlings that were watered with water boiled on the stove. The difference among two groups was not significant and the seedlings of two groups have almost the same shoot length. Thus, implying that microwaved water has no effect to pepper seedlings with respect to shoot length.

EFFECTS OF MICROWAVED WATER ON LEAVES MORPHOLOGY

In a morphological analysis of the leaves of each group of tested seedlings, different changes were observed, in comparison to the control one. At the beginning of the experiment and after the 7 days, no different changes were observed, but after the 14 days, different changes were observed in terms of color and texture of leaves. Table 4 illustrates the response of corn and pepper seedlings to microwaved water in terms of leaves morphology.

It could be gleaned that the leaves of seedlings that were watered with microwaved water had a color of pale green and their texture was smooth as compared to the control. On the other hand, in the case of control, the leaves had a color of dark green and the texture was rough.

Table 4

Effects of microwaved water on leaves morphology for control and treated group

Plant	Exposed to microwave treated water (at 60 °C / 100 °C)		Exposed to normal water or water heated on a gas stove	
	Color	Texture	Color	Texture
Corn	Pale green	Smooth	Dark green	Rough
Pepper	Pale green	Smooth	Dark green	Rough

DISCUSSION

Investigations were carried out to study the effect of microwave treated water on the growth of corn and pepper seedlings.

This study may proof that the microwaved water lowered the growth rate of plants as other previous study [15]. In his study, Mikkelson [15] showed that water that was heated in a microwave oven was harmful to plants. At the end of the experiment and after watering the plants with microwaved water, all plants were fairly thriving.

On contrary, our results disagree with that of Jaffer *et al.* [9, 10, 11]; they investigated the effect of microwaves treated water on growth rate and germination of chick pea, chavli and massor seeds respectively. Overall results of these studies showed that exposure to microwaved water for specific time duration showed better growth rate as compared to normal water. Also, the results of the present study are different from those obtained by Gupta *et al.* [4]. They conducted an experiment to study the effect of microwaved soil on the growth of mustard plants. The soil was microwaved for different exposure times ranging from 30–150 seconds (s) and exposure levels ranging from 30–90 W. They found out that the exposure level of about 90 W and exposure time in the range of 30 s to 60 s helped in growth of the plants. In other study [5], the same authors investigated the effect of microwaves on growth rate of *Brassica* seeds. The seeds were exposed to microwaves at different power levels and exposure durations. They proved that power level below 90 W with exposure time 60 s helped in growth of the seedlings, but high power level (above 90 W) or long exposure durations (more than 60 s) inhibited the growth of seedlings.

Regarding to color of leaves, our results clear that a negative effect on color of leaves of those seedlings that were watered with microwaved water. The leaves of seedlings that exposed to microwaved water were pale green and their texture was smooth, while the seedlings that were given water heated on the stove or normal water were dark green and their texture was rough. These differences may be due to different levels of chlorophyll content and other pigments among each group. Biological effects of microwaves exposure on chlorophyll content of the exposed seedlings were mentioned by Hamada [6], who declared that under the

effect of microwaves, the exposed seedlings exhibited decreased ratio chlorophyll a/chlorophyll b.

Similar results were observed by Ursache *et al.* [22]. They found that the level of photosynthetic pigment (chlorophylls and carotenes) could be decreased after exposure to microwaves for long period of time. Also, these findings of the current experiment seem to coincide with that stated by Kumar *et al*. [14] and Vian *et al.* [23]. They reported that the direct exposure of maize seedlings to EMR, including microwaves, at specific frequency caused a drop in total carotene, chlorophyll a and chlorophyll b content as well as changed ratio chlorophyll a/b. These modifications may be due to abnormal photosynthetic activity which relies on many parameters, including chlorophyll and carotenoid content [14, 23].

On contrast, different results have been reported by Khalafallah and Sallam [13] and Aladjadjiyan [2]. They mentioned that photosynthetic pigments were positively affected by EMR exposure including microwaves. The suitable EMR increased photochemical activities in a unit of chlorophyll molecule resulting in an increase in the green pigment of wheat and soybean [21]. Our results also differ from the study of Isaac *et al.* [9], who observed an increase in the concentration of chlorophyll a, chlorophyll b and carotene in corn seedlings obtained from seeds treated electromagnetically. Radzevicius and co-workers [19] observed that irradiation of seeds with high power microwave (HPM) resulted in a significant increase in the content of chlorophyll a, chlorophyll b, chlorophyll a+b and carotenoids in tomato seedlings, but the opposite effect was determined in carrot seedlings. The reasons standing behind altering chlorophyll level, photochemical and photosynthetic activities in treated leaves were found to be similar to the reasons mentioned by other studies [19]. They suggested a hypothesis about the absorption of the microwave radiation energy by the electrons of hydrogen or magnesium atoms in the chlorophyll molecule. The energy absorbed is redistributed and causes changes in the chlorophyll molecules [1] as well as affects the redox reactions implicated in the photosynthesis process [18].

CONCLUSION

The current study was conducted to explore the effects of microwave treated water on growth rate of corn and pepper seedlings. The study has found out that the microwave treated water caused changes in growth rate and morphology of seedlings. Exposure of seedlings to microwaved water may significantly alter growth related characters, such as shoot length. Of the two species we tested, peppers seemed to be the least responsive to microwaved water, whereas corns were the most sensitive under laboratory conditions. It was noticed that the corn seedlings which were watered with normal water recorded the highest in shoot

length as compared to those of the other treated groups. The study concluded that corn seedlings when watered with normal water or water heated on the stove grew faster and had shoot length significantly taller than the corns which were watered with water heated in a microwave at 60 °C / 100 °C. On contrast, pepper seedlings, both watered with microwaved water or not microwaved water manifested no significant effects on their growth characteristics such as shoot length.

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