Scholars Journal of Agriculture and Veterinary Sciences
OPEN ACCESS
Abbreviated Key Title: Sch J Agric Vet Sci
ISSN 2348–8883 (Print) | ISSN 2348–1854 (Online)
Journal homepage: https://saspublishers.com

Evaluation of Maize (*Zea mays* L.) Germination Traits by Hydro-and Microwave Priming

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DOI: 10.36347/sjavs.2023.v10i11.001 | **Received:** 26.09.2023 | **Accepted:** 01.11.2023 | **Published:** 16.11.2023

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Abstract **Original Research Article**

To study the effects of hydropriming and seed priming with microwaves (MW) on the germination traits of maize (*Zea mays* L.), a laboratory pot experiment was carried out in 2023. The selected seed treatments were hydropriming with distilled water (0, 6, and 12 h) and microwave priming (0, 10, and 20 s) of the maize seeds. Studied traits were final germination percentage (FPG%), mean germination time (MGT), germination rate index (GRI), coefficient of velocity of germination (CVG), mean daily germination (MDG), peak value (PV), and Germination value (GV). According to the variance analysis of this study, the results indicated that both the priming treatments, hydro and MW, significantly affected all studied traits. The best values for FGP (88.88, 78.99%), MGT (4.07, 4.72 day), GRI (25.08, 21.46 % day^{-1}), CVG (25.79, 23.86), MDG (7.4, 6.66 seed day^{-1}), PV (1.9, 1.64), and GV (14.6, 12.19) were observed in priming with 10 s MW and 12 h hydro, respectively. The combination of hydro and MW priming also showed a significant effect for all traits, except FGP and MDG. Among the combination treatments, MW for 10 s and hydropriming for 12 h were the most effective in improving MGT (3.17 days), GRI (33.27 % day^{-1}), CVG (31.62), PV (2.55), and GV (21.23). In contrast, the interaction between priming treatments had no significant effect on FGP or MDG. However, the MW for 10 s and hydropriming for 12 h resulted in a higher FGP (100%) and MDG (8.33 days). Overall, the findings suggest that hydropriming and seed priming with microwaves is a promising technique for improving maize germination.

Keywords: Hydropriming, microwaves, germination traits, maize.

INTRODUCTION

Seed priming is one of the main processes under normal and stressful conditions, and significantly improves seed germination and the emergence of seeds and vigorous seedlings in different crops. Various pre-sowing seed treatments (seed priming) have been successfully applied to improve germination by partially hydrating the seed to a point where germination processes are initiated, but not completed. Pre-sowing hydropriming, which involves soaking seeds in water before sowing, is one of the most well-known methods to initiate seed germination without radicle emergence. The beneficial effects of hydropriming have been documented in many field crops, such as sorghum (Dembele *et al*., 2021), sugar beets (Sacała *et al*., 2016), maize (Moradi Dezfuli *et al*., 2008), and rice (Prasad *et al*., 2012). In contrast, previous studies have shown that the treatment of plant seeds with physical seed priming materials, including ultraviolet irradiation (Lazim, 2023a), laser irradiation (Sacała *et al*., 2016), magnetic fields (Lazim, 2023b), and microwaves (Wang *et al*., 2018), has the potential to enhance their germination characteristics. Radiation of seeds with microwaves is one of the physical methods used to stimulate seed germination. Microwave radiation is part of the electromagnetic spectrum, as a non-ionizing electromagnetic spectrum with a high-frequency range of 300 GHz to 300 MHz and a low wavelength range of one millimetre to one meter, respectively. These electromagnetic waves are absorbed at the molecular level and can affect the energy of molecular vibrations or produce heat and other biological effects (Banik *et al*., 2003). Low microwave exposure effectively has a good impact on accelerating seed germination in several crops, while long-term exposure typically results in seed death (Lazim and Ramadhan, 2020a; Abu-Elsaoud, 2015; Abu-Elsaoud and Qari, 2017). Although the effects of different priming treatments on the germination of some seed crops have been studied, relatively little research has been conducted on the combined effects of seed priming with microwave radiation and hydropriming. Therefore, this study aimed to investigate the influence of three different pre-sowing seed treatments (microwave irradiation, hydropriming, and a combination of hydropriming and microwave irradiation) on physiological parameters of maize seeds.

MATERIALS AND METHODS

This study was conducted in September 2023 at the Physics Laboratory of the Agricultural College, Department of Agricultural Machinery and Equipment, University of Basrah to examine the physiological aspects of maize seed priming using different hydropriming durations and microwave radiation. The experiment was conducted under a completely random design (CRD) with three replicates, two factors, and 27 treatment permutations. Healthy maize (*Zea mays* L.) seeds of uniform size and shape (30 seeds per treatment) were soaked separately in distilled water at room temperature (25 °C) for 0, 6, and 12 hours. Non-primed seeds at 0 h were considered as the control (NP). At the end of each soaking, the seeds were dried to their original moisture content at room temperature. Then, both primed seeds and non-primed seeds were exposed to microwave radiation (MW) using an 600W microwave oven at 2450 MHz, for 0 (MW0) as a control, 10 sec (MW1), and 20 sec (MW3), as per the procedure described by Lazim and Ramadhan (2020b). Subsequently, all primed and unprimed seeds were planted at a constant depth of approximately 1 cm in ordinary plastic pots (20 cm in diameter and 15 cm in depth) containing soil peat-moss with ten seeds in each pot. Pots were placed under laboratory conditions with natural light and watered with distilled water whenever required. Then, the number of germinated seeds was counted in every pot daily for a specific hour after two days of planting until the tenth day, when no further germination occurred. The measured parameters were recorded with respect to the observation data collected daily by counting until the end of the experiment, as follows:

The final germination percentage (FGP%) represents the total number of seedlings at the end of the test after the tenth day, calculated as follows:

$$\text{FGP \%} = \frac{\text{Number of germinated seeds after ten days}}{\text{Total number of planted seeds}} \times 100$$

Mean germination time (MGT) was calculated using the formula developed by Ellis and Roberts (1981) as follows: $MGT = \frac{\sum nD}{\sum n}$ (Day), where n is the number of seeds that germinated corresponding to the day D observation (not the accumulated number), and D is the number of days counted from the beginning of germination.

The following equation (Esechie, 1994) was utilized to generate the germination rate index (GRI): $GRI = G_1/1 + G_2/2 + \ldots + G_n/n$ (%/day), where $G_1, G_2 \ldots G_n$ are the germination percentage × 100 at the first, second, and subsequent days after sowing until the 10th day, and 1, 2…, and n are the days of first, second, and final count, respectively.

The coefficient of velocity of germination (CVG) was developed by Jones and Sanders (1987) as $CVG = [(N_1 + N_2 \ldots + N_x) / (N_1 T_1 + \ldots + N_x T_x)] \times 100$, where N is the number of seeds that have just begun to germinate on day T and T is the number of days since planting that corresponds to N.

The germination value (GV) was calculated as the product of the peak value (PV) and mean daily germination (MDG) using Czabator (1962) modified by Kolotelo *et al.*, (2001). PV is the cumulative percentage of germination on any day divided by the number of days required to reach these percentages. MDG is the final germination capacity of the test divided by the maximum number of germination days.

RESULTS AND DISCUSSION

Final germination percentage:

The mean final germination percentage (FGP%) in seed priming with microwave (MW) after ten days is presented in Table 1. The highest value of FGB (88.88%) was observed with an exposure time of 10 s compared to the control treatment (75.55%), with a significant increase (17.64%). In contrast, the lowest values were observed at an exposure time of 20 s (51.10%), and a significant negative impact was observed, with a reduction (47.84%) compared to the control treatment (75.55%). According to the results obtained in this investigation, seed priming with MW had both positive and negative effects on maize seed germination, which is consistent with other previous studies in several crops (Wang *et al.*, 2018; Abu-Elsaoud, 2015; Abu-Elsaoud and Qari, 2017). The beneficial effect of pre-treating seeds with microwave radiation may have been due to the activation of several germination enzymes, which in turn alters the internal energy of the seed. The increase in enzyme activity could be a primary positive effect of MW priming, leading to higher germination rates (Iuliana *et al.*, 2013). On the other hand, the data in the same table show that the FGP was significantly affected by hydropriming duration. According to these data, compared with the non-primed maize seeds, the maximum FGP (79.99%) was recorded for seeds hydroprimed for 12 h, followed by seeds hydro-primed for 6 h (73.33). Similar positive effects of seed hydropriming for 12 h have been reported for maize (Nyoni *et al.*, 2020) and sorghum (Moradi and Younesi, 2009). However, Damalas *et al.*, (2019) showed that hydropriming of faba bean seeds for 8 and 16 h enhanced the final seed germination percentage. The resulting improvement in germination could be due to the changes in the metabolic activities of embryo proteins associated with accelerated germination of maize seeds in 12 hours of hydro priming (Gong *et al.*, 2013). On the other hand, the combination of hydropriming and MW radiation treatments had no significant effect on FGP; however, exposure to MW for 10 s with hydropriming for 12 h had a higher FGB (100%). In another study, Sari *et al.*, (2023) reported that magnetopriming combinations with hydro-priming improved germination in onion and lettuce seeds.

Table 1: Effects of seed hydropriming duration, microwave radiation, and their interactions on the final germination percentage of maize seeds

Hydropriming duration (h)	Microwave radiation exposure time (sec)			Mean
	0 (Control)	10	20	
NP	66.66	76.66	43.33	62.21
6	76.66	90	53.33	73.33
12	83.33	100	56.66	79.99
Mean	75.55	88.88	51.10	

Note: NP= Non-primed (control); $L.S.D_{0.05}$ (Microwave) =6.03, $L.S.D_{0.05}$ (Hydropriming) =6.03, $L.S.D_{0.05}$ (interaction) =N.S; $L.S.D_{0.05}$: Least significant difference at a probability of 5%; N.S=Non-significance.

Mean germination time:

The effects of seed priming with MW on the mean germination time (MGT) of maize seeds are shown in Table 2. The difference between the treatments was statistically significant. Seeds exposed to MW for 20 s had a maximum germination time of 7.58 days, while the data in the same table show that priming with MW for 10 s resulted in a minimum germination time of 4.07 days, which decreased significantly by 26.13 and 46.3 % compared to non-primed (control) and MW primed with 20 s, respectively. The time required for priming with MW for 10 s to germinate was less than that of the corresponding control, and MW primed with 20 s values. As a result, seeds priming for 10 s have more rapidly germinated than untreated seeds and those treated for 20 s. These results might be parallel to the data recorded by Wang *et al*., (2018), where authors found a decrease in mean germination time (MGT) when exposing the Buckwheat seeds to 600 W MW for 10 s. Similar results found a decrease in MGT by Lazim and Ramadhan (2020b) and Abu-Elsaoud and Qari (2017) on priming barley seeds with the MW radiation. The stimulated germination might be due to the disruption of the seed coat through microwave treatment, which allows water to diffuse into the seeds, inducing a higher rate of enzymatic reactions and the start of the development process, thus resulting in fast and effective germination (Iuliana *et al*., 2013). In hydropriming treatments, the results of the variance analysis (Table 2) showed that priming of seeds for 6 and 12 h had a statistically significant positive effect on the decrease in MGT compared with that of the control. As shown in Table 2, the lowest value was found in MGT at 4.72 days by seed hydro-priming for 12 h, followed by 6 h, with decreased MGT in days by 31.4 and 19%, respectively, compared with the control. In general, the priming duration for 6 and 12 h recorded germination time was less than the comparable values in the controls; hence, hydro-primed seeds germinated at a higher rate than unprimed seeds. Similar optimal times of hydropriming were recorded by Mahmoodi *et al*., (2011) on maize for 18 h, Damalas *et al*., (2019) on faba bean for 8 h, and Sumbal *et al.,* (2023) on wheat for 12 h. Hydropriming for 12 h might be acceptable to partway hydrate the seeds to the point where the germination metabolic process starts, increasing the germination rate. On the other hand, the results of the variance analysis (Table 2) showed that MGT was affected significantly by MW priming and its interaction with hydropriming duration. The lowest MGT (3.17 days) was reported in the combination with MW priming seed for time exposure for 10 s and hydropriming for 12 h. Thus, a lower MGT indicates a faster seed germination rate. Similar effects on MGT were observed in onion and lettuce seeds by Sari *et al*., (2023) in seeds combined with hydro and magnetic priming.

Table 2: Effects of seed hydropriming duration, microwave radiation, and their interactions on mean germination time of maize seeds

Hydropriming duration (h)	Microwave radiation exposure time (sec)			Mean
	0 (Control)	10	20	
NP	7.39^{b}	5.32^{c}	7.93^{a}	6.88
6	5.32^{c}	3.74^{d}	7.67^{ab}	5.57
12	3.83^{d}	3.17^{e}	7.16^{ab}	4.72
Mean	5.51	4.07	7.58	

Note: NP= Non-primed (control); Different superscript letters across each column indicate significant differences at P< 0.05 level; $L.S.D_{0.05}$ (Microwave) =0.309, $L.S.D_{0.05}$ (Hydropriming) =0.309, $L.S.D_{0.05}$ (interaction) =0.536; $L.S.D_{0.05}$: Least significant difference at a probability of 5%.

Germination rate index:

Data from Table (3) show that seed priming with MW significantly improved seed performance with increasing germination rate index (GRI). Comparing the values of MW-treated seeds with untreated seeds, the maximum GRI (25.08 % day-1) observed a positive effect at a shorter exposure time of 10s, which increased by 54.43%. Moreover, the lowest value, GRI (6.72%

day-1), had a negative impact at an exposure time of 20 s, which was reduced by 58.62% compared to untreated seeds. Similarly, Ibrahim *et al*., (2020) found an increase in GRI when priming red bean seeds with MW radiation for 5, 15, and 30 s. Wang *et al*., (2018) found that in buckwheat, there is an increase in flavonoid content and soluble protein contents involved in the highest final germination rate under radiation exposure to 600 W microwaves for 10 s. Likewise, in hydropriming, the results of the variance analysis (Table 3) showed that priming of seeds for 6 and 12 h had a statistically significant positive effect on the GRI. In the given data, the maximum value was found in GRI at 21.46 % day^{-1} by seed hydropriming for 12 h, followed by 6 h (16.5 % day^{-1}), with an increased GRI of 112.68 and 63.52 %, respectively, compared with the control. These results are in agreement with those obtained by Dembele *et al*., (2021) for sorghum. In another study by Moradi Dezfuli *et al*., (2008), soaking maize seeds in water for 12, 24, or 36 h led to a high germination rate index. On the other hand, the results of the variance analysis (Table 3) showed that GRI was significantly affected by MW priming and its interaction with the hydropriming duration. The highest value of GRI (33.27 % day^{-1}) was reported in combination with MW priming seed for 10 s of exposure and hydropriming for 12 h.

Table 3: Effects of seed hydropriming duration, microwave radiation, and their interactions on germination rate index of maize seeds

Hydropriming duration (h)	Microwave radiation exposure time (sec)			Mean
	0 (Control)	10	20	
NP	8.70^{d}	16.11^{c}	5.48^{d}	10.09
6	16.94^{c}	25.88^{b}	6.68^{d}	16.5
12	23.09^{b}	33.27^{a}	8.02^{d}	21.46
Mean	16.24	25.08	6.72	

Note: NP= Non-primed (control); Different superscript letters across each column indicate significant differences at P< 0.05 level; L.S.D$_{0.05}$ (Microwave) =2.095, L.S.D$_{0.05}$ (hydropriming) =2.095, L.S.D$_{0.05}$ (interaction) =3.628; L.S.D$_{0.05}$: Least significant difference at a probability of 5%.

Coefficient of velocity of germination:

The data presented in Table 4 show that a significantly higher seed coefficient of velocity of germination (CVG) was reported in the MW primed with an exposure time of 10 s (25.79), with an increase of 32.46% compared with the control (19.47). Moreover, the lowest value, CVG (12.92), had a negative impact at an exposure time of 20 s, which was reduced by 33.64% compared with that of the control. Similarly, Abu-Elsaoud and Qari (2017) found an increase in the relative germination coefficient of barley primed with MW irradiation for 1 and 5 s. According to Chen *et al*., (2005), microwaves enhance germination by stimulating enzyme activity, resulting in improved metabolism and cell division, thereby increasing seed germination. Likewise, in the hydropriming treatments, the results of the variance analysis (Table 4) showed that priming of seeds for 6 and 12 h had a statistically significant positive effect on CVG. In the given data, the maximum value was found in CVG at 23.86 by seed hydropriming for 12 h, followed by 6 h (19.37), with increased of 59.70 and 29. 93 %, respectively, compared to the control. Similarly, a significantly increased CVG in hydroprimed pepper seeds for 18 or 24 h was reported by Uche *et al*., (2016). Afzal et al., (2008) reported that an enhancement in α-amylase activity in primed seeds may be attributed to proper hydration during imbibition, which increased starch hydrolysis and successfully established good germination. However, the results of the variance analysis (Table 4) showed that CVG was significantly affected by MW priming and its interaction with hydropriming duration. The highest value of CVG (31.62) was reported in combination with microwave priming of seeds for 10 s of exposure and hydropriming for 12 h.

Table 4: Effects of seed hydropriming duration, microwave radiation, and their interactions on coefficient of velocity of germination of maize seeds

Hydropriming duration (h)	Microwave radiation exposure time (sec)			Mean
	0 (Control)	10	20	
NP	13.51^{d}	18.90^{c}	12.43^{d}	14.94
6	18.90^{c}	26.85^{b}	12.38^{d}	19.37
12	26.02^{b}	31.62^{a}	13.95^{d}	23.86
Mean	19.47	25.79	12.92	

Note: NP= Non-primed (control); Different superscript letters across each column indicate significant differences at P< 0.05 level; L.S.D$_{0.05}$ (Microwave) =1.113, L.S.D$_{0.05}$ (hydropriming) =1.113, L.S.D$_{0.05}$ (interaction) =1.928; L.S.D$_{0.05}$: Least significant difference at a probability of 5%.

Mean daily germination:

According to the results of mean daily germination (MDG) in Table 5, exposing seeds to MW for 10 s resulted in the highest effect (7.4 seed day-1), with significant differences compared to the control (6.29 seed day^{-1}), which increased by 17.64%. The treatment for 20 s resulted in the lowest values of MDG (4.25 seed day^{-1}) and had a significant negative impact compared to untreated seeds, with a reduction of (32.43%). Hassan (2023) proposed an explanation that microwave electromagnetic treatment caused disturbance of the seed coat, which enabled water diffusion into the seeds, inducing a higher rate of enzymatic reactions, and the start of the initial development stages consequently resulted in faster and more effective germination. Likewise, in the hydropriming treatments, the results of the variance analysis (Table 5) showed that priming the seeds for 6 and 12 h had a statistically significant positive effect on the MDG. In the given data, the maximum value was found in the MDG at 6.66 seed day-$^{-1}$ by seed hydropriming for 12 h, followed by 6 h (6.10 seed day^{-1}), with increased MDG by 28.82 and 17.98 %, respectively, compared with the control. Similar results have been found in maize by Nyoni *et al*., (2020), who reported that 12 h hydro-primed seeds showed the highest MDG. However, similar positive effects in the MDG of seed hydropriming for 8 and 16 h have been reported in faba beans by Damalas *et al*., (2019). In contrast, a combination of hydropriming and microwave radiation had no significant effect on MDG; however, exposure to MW for 10 s with hydropriming for 12 h had a higher MDG (8.33 seed day^{-1}).

Table 5: Effects of seed hydropriming duration, microwave radiation, and their interactions on mean daily germination of maize seeds

Hydropriming duration (h)	Microwave radiation exposure time (sec)			Mean
	0 (Control)	10	20	
NP	5.55	6.38	3.60	5.17
6	6.38	7.49	4.44	6.10
12	6.94	8.33	4.72	6.66
Mean	6.29	7.4	4.25	

Note: NP= Non-primed (control); $L.S.D_{0.05}$ (Microwave) =0.501, $L.S.D_{0.05}$ (hydropriming) =0.501, $L.S.D_{0.05}$ (interaction) = N.S; N.S=Non-significan; $L.S.D_{0.05}$: Least significant difference at a probability of 5%.

Peak value:

In this study, the effects of MW irradiation with different exposure times on peak value (PV) was investigated, and the results are presented in Table 6. A significantly higher PV (1.9) was reported in the MW treatment at 10 s compared to the control (1.21), which increased by 57.02%. The data in the same table show that seed treatment for 20 s resulted in the lowest PV values (0.56) and had a significant negative impact compared to untreated seeds, with a reduction of (53.71%). A dose-dependent effect was observed for germination rate and growth characteristics, with low microwave doses stimulating germination and growth and higher microwave doses inhibiting germination and decreasing growth. Generally, low microwave exposure has been successfully used to positively enhance the peak value of seed germination, while long exposure usually tends to reduce peak germination. Likewise, in the hydropriming treatments, the results of the variance analysis (Table 6) showed that priming of seeds for 6 and 12 h had a statistically significant positive effect on PV. In the given data, the maximum value was found in PV at 1.64 by seed hydropriming for 12 h, followed by 6 h (1.24), with increased PV by 110.25 and 58.97%, respectively, compared to the control. Nyoni *et al*., (2020) also reported that 12 h hydro-primed seeds showed the highest PV of maize. Prasad *et al*., (2012) showed that hydro-priming of rice seeds for 8, 16, 24, 32, 40, and 48 h enhanced PV, but the best values were recorded with 40 and 48 h priming durations. Hydropriming might be strongly correlated with the enzymatic activities present in the seed during seed germination and enhance seedling vigor, as indicated by the high value of germination and peck value (Prasad *et al*., 2012). On the other hand, the results of the variance analysis (Table 6) showed that PV was significantly affected by MW priming and its interaction with the hydropriming duration. The highest value of PV (2.55) was reported in combination with MW priming seed for 10 s of exposure and hydropriming for 12 h.

Table 6: Effects of seed hydropriming duration, microwave radiation, and their interactions on peak value of maize seeds

Hydropriming duration (h)	Microwave radiation exposure time (sec)			Mean
	0 (Control)	10	20	
NP	0.71^{d}	1.16^{c}	0.49^{d}	0.78
6	1.2^{c}	1.99^{b}	0.54^{d}	1.24
12	1.72^{b}	2.55^{a}	0.66^{d}	1.64
Mean	1.21	1.9	0.56	

Note: NP= Non-primed (control); Different superscript letters across each column indicate significant differences at $P< 0.05$ level; $L.S.D_{0.05}$ (Microwave) =0.162, $L.S.D_{0.05}$ (hydropriming) =0.162, $L.S.D_{0.05}$ (interaction) =0.162; $L.S.D_{0.05}$: Least significant difference at a probability of 5%.

Germination value:

According to the results of Germination value (GV) in Table 7, exposing seeds to MW for 10 s resulted in the highest effect (14.6) with significant differences compared to the control (7.86), which increased by 85.75%. Seed treatment for 20 s resulted in the lowest GV (2.46) and had a significant negative impact compared to untreated seeds, with a reduction of (68.70%). The eventual disturbance of the seed coat caused by the microwave treatment at a dose of 10 s might promote water access to the seeds, leading to a higher rate of enzymatic reactions, the beginning of the earliest developmental stages, and improved germinating energy (Iuliana *et al*., 2013). Likewise, in hydropriming treatments, the results of the variance analysis (Table 7) showed that priming of seeds for 6 and 12 h had a statistically significant positive effect on GV. In the given data, the maximum value was found in GV at (12.19) by seed hydropriming for 12 h, followed by 6 h (8.17), with GV increased by 177.67 and 86.10 %, respectively, compared with the control. Similar results have been found in maize by Nyoni *et al*., (2020), who reported that 12 h hydro-primed seeds showed the highest GV. Prasad *et al*., (2012) showed that hydro-priming of rice seeds for 8, 16, 24, 32, 40, and 48 h enhanced GV, but the best values were recorded with 40 and 48 h priming durations. Wattanakulpakin *et al*., (2010) investigated the enhanced maize seed vigor as affected by hydropriming and found that priming-enhanced seed establishment is due to higher activities of antioxidant enzymes. On the other hand, the results of the variance analysis (Table 7) showed that GV was significantly affected by microwave priming and its interaction with the hydropriming duration. The highest value of GV (21.23) was reported in combination with MW priming for 10 s of exposure and hydropriming for 12 h.

Table 7: Effects of seed hydropriming duration, microwave radiation, and their interactions on the germination value of maize seeds

Hydropriming duration (h)	Microwave radiation exposure time (sec)			Mean
	0 (Control)	10	20	
NP	3.93^{d}	7.44^{c}	1.82^{d}	4.39
6	7.46^{c}	15.13^{a}	2.42^{d}	8.17
12	12.21^{b}	21.23^{a}	3.15^{d}	12.19
Mean	7.86	14.6	2.46	

Note: NP= Non-primed (control); Different superscript letters across each column indicate significant differences at $P< 0.05$ level; L.S.D$_{0.05}$ (Microwave) =1.733, L.S.D$_{0.05}$ (hydropriming) =1.733, L.S.D$_{0.05}$ (interaction) =3.0; L.S.D$_{0.05}$: Least significant difference at a probability of 5%.

CONCLUSION

In conclusion, this study shows that seed priming treatments with hydro and MW significantly affected maize germination development traits, including FGB, MGT, GRI, CVG, MDG, PV, and GV. The best values for all germination characteristics of maize seeds were recorded in the priming alone with 10 s MW or in the 12 h hydro. Moreover, hydropriming in combination with MW caused a significant effect on all traits, except FGP and MDG. However, the highest values of FGP and MDG have been reported in combination with MW priming of seeds for time exposure for 10 s and hydropriming for 12 h. Thus, based on these findings, microwaves alone or in combination with hydropriming may be a promising and useful tool because of their positive effects on some physiological parameters of maize seeds.

ACKNOWLEDGMENTS

The author gratefully acknowledge the comfort of the College of Agriculture, University of Basrah-Iraq, for their scientific research encouragement.

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