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Effects of Physical and Chemical Seed Priming Techniques on Seed Germination and Seedling Growth of Maize (*Zea mays* L.)

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ABSTRACT

Experiments including both physical and chemical priming were carried out in order to examine the influence of magnetism (MF) Ultraviolet-C radiation (UV-C), microwave radiation (MW), Gibberellic acid (GA_3), Ammonium molybdate (Mo) and hydro-priming (Hydro) on the development of corn from its seedling stage. Unprimed seeds were used as a control. Specifically, seed priming with MW 10 sec and UV-C 120 min significantly increased final germination percentage (FGP), GRI, GV, peak value (PV) and seedling vigour index (SVI) compared to control. Also, results showed that seed priming with UV-C 120 min, MF 6 h and UV-C 60 min significantly increased the SVI and shoot length (SL) compared with the control. However, the highest values for mean daily germination (MDG) were observed in seed priming with MW 10 sec, MF 6 h, UV-C 120 min and UV-C 60 min than other seed priming treatments. While the seed priming with MW 20 sec showed the highest values for MGT. However, the highest value for root length (RL) was observed in seed priming with gibberellic acid (GA_3), UV-C 120 min, MF 3 h, MF 6 h and UV 60 min. This experiment suggested that physical and chemical seed priming could boost maize seed germination and seedling growth.

Key words: Ammonium molybdate, gibberellic acid, hydro-priming, microwave radiation, ultraviolet radiation

INTRODUCTION

Seed priming is the method which is done before sowing of seeds in which seeds are moisturized until pre-germination metabolic activities begin and then dried to their original moisture level before germination, preventing the actual emergence of the radicle (Ashraf *et al.*, 2019). It treats seeds quickly, cheaply and sustainably. Priming seeds has been utilized to boost the metabolic process for quick germination, reduce seedling emergence time and improve seedling growth and final yield. Several seed priming techniques broadly can be categorized into traditional and advanced methods. Traditional priming methods include hydro-priming (soaking in water), osmo-priming (soaking in solutions of organic osmotica), bio-priming (hydration using biological compounds), solid-matrix priming (treatment of seed with solid matrices), and chemical priming (soaking in chemical solutions like gibberellic acid (GA_3), ammonium molybdate (Mo), potassium nitrate (KNO_3), zinc sulfate ($ZnSO_4$), and potassium chloride (KCl). Seed priming using physical agents including X-rays, gamma, ultrasonic waves, ultraviolet, magnetic fields, microwaves and others is more advanced and laser radiation. Various studies such as germination treatment (hydro-priming) and chemical pre-treatments as priming agents of seeds have reported improved seedling growth and seed germination parameters, such as ammonium molybdate in sorghum (Lazim, 2022), cowpea (Arun *et al.*, 2020), wheat (Lazim and Ramadhan, 2019) and chickpea (Singh *et al.*, 2014), and a gibberellic acid in maize (Adhikari and Subedi, 2022), lettuce (Adhikari *et al.*, 2022), green gram (Chakraborty and Bordolui, 2021) and sorghum (Shihab and Hamza, 2020). Moreover, various researches demonstrated that hydro-priming acts as plant growth promoting, such as sorghum (Dembele *et al.*, 2021), okra (Tania *et al.*, 2020) and bean (Damalas *et al.*, 2019). Physical treatments, in contrast, are given externally without hydrating or immersing the seeds in chemical substances. Some physical priming techniques, such as magnetic fields, microwaves and UV radiation, are commonly used successfully for rapid seed germination and growth in different crop plants in pre-sowing treatments. For instance, magnetic field treatments have been observed to promote germination in numerous plant species, such as barley (Lazim, 2021) and sorghum (Lazim and Nasur, 2017). Microwave-mediated priming has also had a major impact on the growth and yield performance of plants such as wheat (Lazim and Ramadhan, 2020), maize (Danesh *et al.*, 2017) and pepper (Mohsenkhah *et al.*, 2018). Similar improvements in germination and growth have also been reported by the application of seed priming with UV-C radiation in several crops like wheat (Rupiasih and Vidyasagar, 2016; Semenov *et al.*, 2020) and soybean (Araujo *et al.*, 2020). To our knowledge, not much research had been conducted on the effect of traditional and advanced priming techniques as a comparative study in improving the germination of maize seeds. Therefore, the purpose of this study was to show how priming techniques could affect the germination and growth of maize seeds, including conventional priming techniques like hydro-priming and chemo-priming (soaking in ammonium molybdate and gibberellic acid), as well as advanced priming techniques like magnetic fields, microwaves and UV radiation.

MATERIALS AND METHODS

Maize seeds were differently treated with some physical and chemical priming methods including seed treatment with magnetic field of 125 mT for 3 h (MF 3 h) and 6 h (MF 6 h) (Lazim and Nasur, 2017), Ultraviolet-C radiation at 254 nm for 60 min (UV-C 60 min) and 120 min (UV-C 120 min) (Rupiasih and Vidyasagar, 2016), microwave radiation for 10 sec (MW 10 sec) and 20 sec (MW 20 sec) (Iuliana *et al.*, 2013), hydro-priming for 24 h (Hydro), 100 ppm solutions of gibberellic acid for 24 h (GA_3) and 500 ppm solution of ammonium molybdate for 24 h (Mo). Controls were unprimed seeds. Before each physical treatment was applied, seeds steeped in distilled water for 12 h followed by shade drying. For each physical and chemical treatment, three replications had 30 seeds. Each replicate contained 10 seeds. After the treatments, each 10 primed and unprimed seeds were placed in each 10 cm diameter plastic Petri dish with distilled water-soaked filter paper. During the experiment, when needed, Petri dishes received distilled water. Laboratory physics, agricultural machinery and equipment department, Agriculture College, University of Basrah, conducted all tests. The experiment used a completely randomized design with three replicates for statistical analyses. Each Petri dish contained 10 seeds which represented one replicate. Least Significance Difference (L. S. D.) test was used to compare variation between the treatment means at the 5% probability level. A seed was assumed to have germinated at the first sign of a radicle growth through the seed coat. Then, the number of germinated seeds was counted in every Petri dish daily at a specific hour after two days of sowing until the tenth day, when no further germination occurred. The measured parameters were recorded in respect of the observation data collected daily by count till end of experiment as below:

The cumulative number of germinated seeds with normal radicles was calculated using Final Germination Per cent FGP % = (Ng/10) ×100, where Ng was the number of seeds germinated 10 days after being sown and 10 was the total number of maize seeds sown. MGT = (nD/n) (Day), where D was the number of days measured from the start of germination and n was the number of seeds germinated on day D (not the total quantity).

Germination Rate Index: GRI = G1/D1 + G2/D2+... + Gn/Dn (% /day), where G1, G2, G3,... Gn was the number of freshly germinated seeds on the 1, 2, 3 and nth days, respectively, and D1, D2, D3, and Dn were the counts on those days.

RESULTS AND DISCUSSION

The analysis of variance of laboratory data showed that the final germination percentage (FGP) in maize seed was significantly affected by different priming techniques. Significantly higher FGP (96.76%) was recorded for seeds primed with MW-10 sec followed by 93.33, 90, 90, 86.67, 83.3 and 83.33% primed with UV-C 120 min, MF 6 h, UV-C 60 min, MF 3 h, hydro and Mo, respectively, whereas minimum FGP (43.33%) was recorded for seeds primed with MW 20 sec (Fig. 1). Physical and chemical pre-treatment promoted seed viability and germination. Seed priming in molybdate and physical priming (particularly magnetic field, microwave UV-C radiation) increased seed germination in several field crops, according to many research. As per Abu-Elsaoud (2015) microwaves improved wheat seed germination and seedling growth. A similar study reported that UV-C had stimulated the germination percentage of wheat (Rupiasih and Vidyasagar, 2016). Pre-sowing physical therapies were regarded to be microwave and UV-radiation (Araujo *et al.*, 2016). The beneficial effect of pre-treating seeds with microwave radiation may have been due activation of several germination enzymes which in turn altered the seed's internal energy (Iuliana *et al.*, 2013). Moreover, UV-C sunlight broke down seed coats and raised temperatures, which may explain its favourable effects so reducing the level of dormancy and allowing the seeds to take in more oxygen and water (Sadeghianfar *et al.*, 2019). In another study, the highest FGP was recorded by Majda *et al.* (2019) in 0.1% ammonium molybdate-soaked bean seeds. Arun *et al.* (2017) reported that molybdenum resulted in the synthesis of enzymes that might have an earlier initiation of metabolic processes and that changed the physiological and biochemical characteristics leading to enhanced germination events in cowpea seed priming.

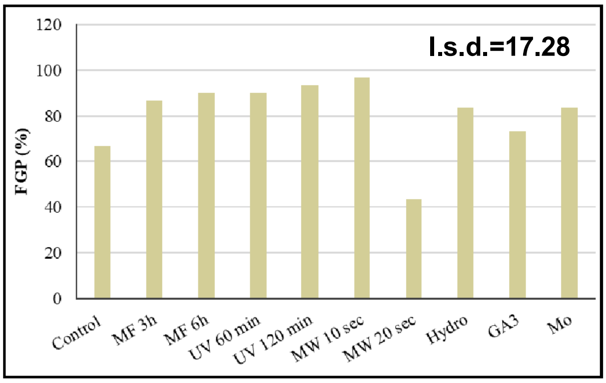

Fig. 1. Maize seed final germination percentages as affected by different priming techniques.

The MW 20 sec took a maximum time of 5.75 days for germination, while priming with UV-C 120 min, MW 10 sec and UV-C 60 min resulted in minimum germination times of 2.50, 2.55 and 2.59 days (Fig. 2). Each treatment had a shorter germination time than the controls. Thus, treated seeds germinated more than untreated seeds. Similar results found a decrease in priming soybean seeds with a microwave by Amirnia (2014). Maize seed enhancement was recorded by reducing MGT and increasing FGP. This positive influence of the MFs treatment was explained by a theory related to ionic

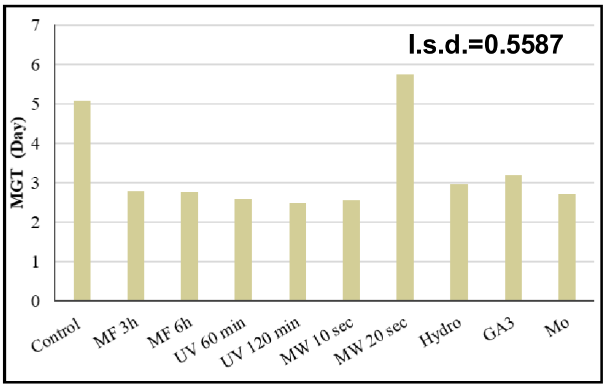

Fig. 2. Maize seed mean germination time as affected by different priming techniques.

properties. MF capacity impacted cell membrane structure. It then enhanced ion channel transit and ionic current density across the cellular membrane to promote germination and decreased MGT (Afzal *et al.*, 2015).

Priming with MW 10 sec, UV 120 min, UV 60 min and MF 6 h had the greatest and most significant effects on germination rate index (GRI), 40.49, 39.72, 37.61 and 35.77%/day, respectively (Fig. 3). Moreover, the GRI data in Fig. 3 show lowest value in MW 20 sec primed seeds (10.61%/day) and unprimed seeds (11.75%/day). Some other studies showed similar results in the exposure of soybean seeds to microwave radiation (Amirnia, 2014). Magnetic field pre-treatment also improved the GRI of spinach seeds (Alpsoy and Unal, 2019). A significantly higher seed coefficient of velocity of germination (CVG) was reported in the primed with UV-C 120 min (40.01), but it had no significant effect, as compared to MW 10 sec, UV-C 60 min, Mo, MF 6 h and MF 3 h (Fig. 4). On the other hand, the data in Fig. 4 show the lowest CVG (16.43) in unprimed control seeds. Other researched that pre-

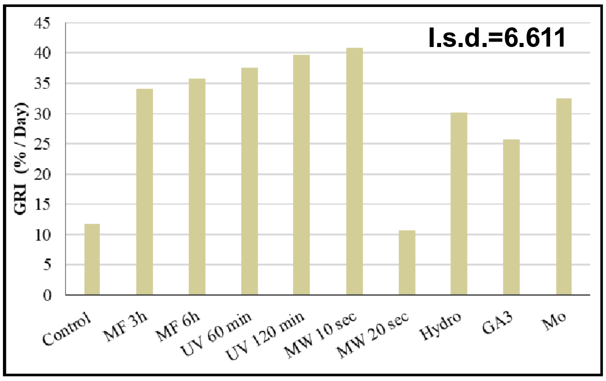

Fig. 3. Maize seed germination rate index as affected by different priming techniques.

treated spinach seeds with a magnetic field yielded comparable findings (Alpsoy and Unal, 2019). Some other studies showed similar results in the exposure of soybean seeds to microwave radiation (Danesh *et al.*, 2017). In another study, following a 60 min irradiation treatment with UV-C, Neelamegam and Sutha (2015) came to the conclusion that there was an increase in the germination rate and seedling vigour in groundnut plants.

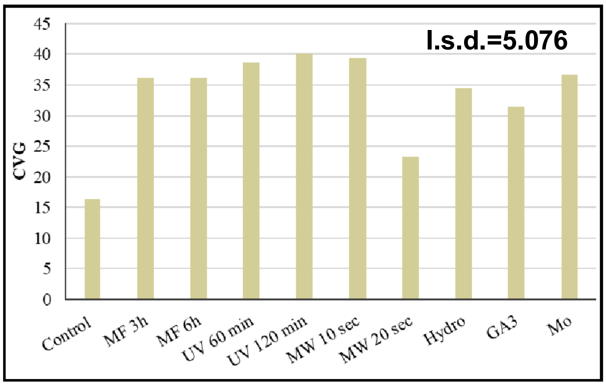

Fig. 4. Maize seed coefficient of the velocity of germination as affected by different priming techniques.

Based on analysis of variance, the priming techniques of MW 10 sec, MF 6 h, UV 120 min and UV 60 min had a significantly higher effect on mean of daily germination (MDG), 0.97,0.93, 0.93 and 0.90 seed/day, respectively, as compared to lowest MDG primed with MW 20 sec (0.43 seed/day) (Fig. 5). Studies in pre-treatment with a magnetic field showed similar results in wheat seeds (Lazim and Ramadhan, 2019) and spinach seeds (Alpsoy and Unal, 2019).

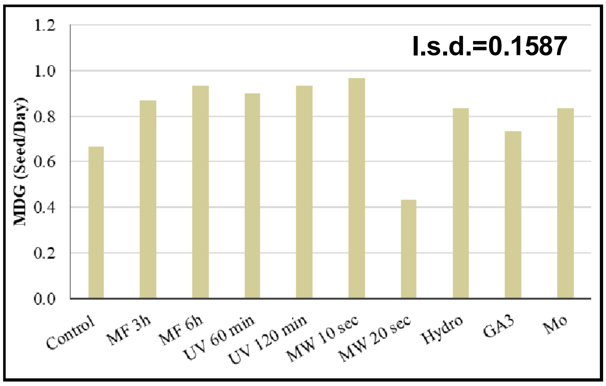

Fig. 5. Maize seed mean of daily germination as affected by different priming techniques.

The analysis of the variance data in Fig. 6 shows that peak value (PV) was significantly affected by different priming techniques and had found a highest significant value in seed priming in MW 10 sec (3) and UV 120 min (2.83) as compared with all priming treatments. Conversely, priming in MW 20 sec and unprimed seed resulted in the lowest PV, 0.73 and 0.75, respectively.

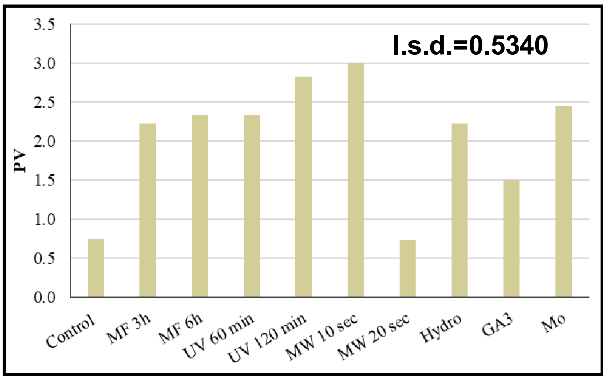

Fig. 6. Maize seed peak value as affected by different priming techniques.

According to the results of this study, all priming techniques had a major impact on maize seed GV (Fig. 7). Where significantly highest GV was obtained by MW 10 sec (2.9) and UV 120 min (2.65), while the lowest GV was reported in MW 20 sec primed seeds and unprimed seeds (0.33 and 0.50, respectively). Other studies showed similar results in pre-treatment spinach seeds in a magnetic field (Alpsoy and Unal, 2019). Depending on the radiation dose, a number of studies have found that exposure to UV-C has a beneficial effect on seedling growth rates, health seeds, germination rates and numerous physiological and biochemical processes in seeds of different types of crops (Sadeghianfar *et al.*, 2019; Semenov *et al.*, 2020).

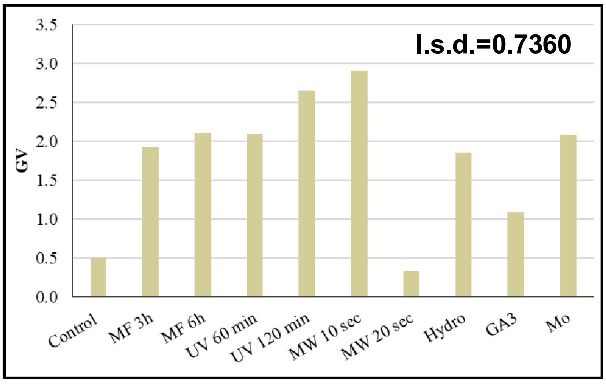

Fig. 7. Maize seed germination value as affected by different priming techniques.

The highest RL (11.6, 10.63, 10.50, 10.30 and 9.67 cm) was obtained when seeds were primed with GA3, UV 120 min, MF 3 h, MF 6h and UV 60 min, respectively, and the lowest RL was reported in priming by MW 20 sec and hydro primed seeds (4.10 and 5.33 cm, respectively; Fig. 8). Moreover, the highest SL (10.2, 9.90, 9.37, 9.27 and 8.33 cm) was obtained when seeds had primed with UV 120 min, MF 6 h, UV 60 min, GA_3 and Mo, respectively, while the lowest SL was reported in MW 20 sec primed seeds and unprimed seeds (3.8 and 5.17 cm, respectively; Fig. 9). Many researchers observed that the priming treatment of seeds by UV-C had effectively used to increase root and shoot length by Semenov *et al.* (2020) in wheat and Neelamegam and Sutha (2015) in groundnut. According to the findings of research carried out by Araujo *et al.* (2020), some biochemical responses may be responsible for the increased seedling growth that resulted from UV-C-treated soybean seeds. Research shows that magnetic fields improve germination energy and shoot length. An increase in seedling length may be due to increasing physiological activity caused by better absorption of moisture magnetically treated maize seeds (Vashisth

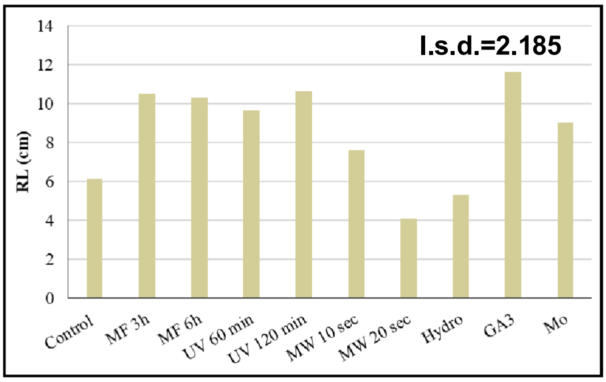

Fig. 8. Root lengths of maize seed affected by different priming techniques.

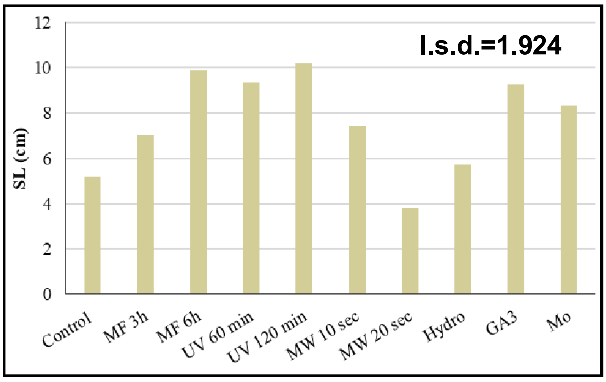

Fig. 9. Shoot lengths of maize seed affected by different priming techniques.

and Joshi, 2017). Likewise, seed priming with chemicals played a significant role in increasing plant height seedlings. Arun *et al.* (2020) recorded an improvement in the seedling lengths of cowpea seeds primed with Mo and GA_3. Similarly, Kumari *et al.* (2017) and Tsegay and Andargie (2018) found that maize treatment with GA_3 increased the root and shoot length. On the other hand, Lazim (2022) recorded an improvement in the seedling lengths of sorghum seeds primed with Mo. According to the results by Arun *et al.* (2017), in priming cowpea with GA_3 and Mo, the enzymatic action at the initiation of germination may be beneficial to advance seed vigour through sharing the expanding length of the seedling.

The analysis variance of laboratory data revealed that the priming techniques used on the maize seeds had a substantial impact on SVI. The highest SVI was recorded in primed with UV-C 120 min (19.37), MF 6 h (18.23) and UV 60 min (17.13) and lowest from MW 20 sec seed treatment (3.33; Fig. 10). Similar findings were reported by Neelamegam and Sutha (2015), who came to the conclusion that improved seedling vigour was observed in groundnut plants following a treatment with UV-C for a duration of 60 min. When exposed to the microwave, several researchers found that it improved the vigour index of barley seeds (Iuliana *et al.*, 2013).

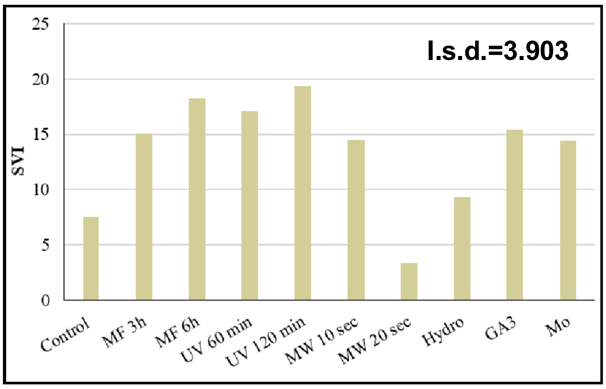

Fig. 10. Maize seed seedling vigour index as affected by different priming techniques.

Physical treatments involve magnetic fields, UV-C radiation and microwaves are well-known as physical methods used for seed priming. Stimulating various physiological processes in plants through the use of physical means can aid in the enhancement of agronomic features. Physical techniques increased the energy account by internally converting energy, regardless of its source, into electrical and increasing the membrane's electro potential. Besides increasing the energy balance, intensifying the exchange of materials, and activating the growth and yield processes, biophysical stimulation of seeds and plants had achieved. The cells received several types of energy from physical elements. It is a kind of energy treatment that promotes enzyme activity and other biochemical processes that help in early germination. The electrons in various molecules absorb imported energy. The absorbed energy may be transformed into another type of energy (most likely a chemical kind) and then used to accelerate the metabolism of the seed (Govindaraj *et al.*, 2017).

CONCLUSION

In conclusion, this study showed that seeds primed with MW 10 sec and UV-C 120 min, as well as UV-C 120 min, MF 6 h and UV-C 60 min significantly affected the parameters of maize germination and growth development, including (FGB, MGT, GRI, GV, PV, SVI and SL), respectively. The highest values for mean daily MDG and MGT was observed in seed priming (MW 10 sec, MF 6 h, UV-C 120 min and UV-C 60 min) and MW 20 sec, respectively, compared with other seed priming treatments. Likewise, the highest value for root RL was observed in seed priming with gibberellic acid (GA_3), UV-C 120 min, MF 3 h, MF 6 h and UV 60 min. Based on the results, priming maize seeds and seedlings are more effective and helpful than the control since physical and chemical primed seeds showed the highest result in all the above data.

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