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MATHEMATICAL EXPRESSION STUDY OF SOME GERMINATION PARAMETERS AND THE GROWTH BY PRESOWING WHEAT SEEDS TREATMENT WITH A STATIC MAGNETIC FIELD AND AMMONIUM MOLYBDATE

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Abstract

Magnetic fields and pre-soaking for seeds affects wheat germination, and have an impact on processes within plants. The effects of wheat seed treatments with a static magnetic field (SMF), pre-soaking and their combination, have been studied on germination parameters and growth rate under laboratory conditions. Seeds were subject to two of pre-sowing soaking treatments, with molybdenum (Mo) and distilled water (DW) used separately. Then seeds were exposed to a SMF for different periods (four times interval of exposure were selected: 0, 1, 2 and 3 hours). After soaking treatments and magnetic exposure, treated seeds compared in the following categories, final germination percentage (FGP), coefficient of velocity germination (CVG), germination rate index (GRI), germination index (GI), speed germination (SG), mean daily germination (MDG), mean germination rate (MGR) and mean germination time (MGT). The most promising results were obtained from the sample that was exposed to SMF duration of 2 h. Meanwhile, pre-sowing soaking treatments with molybdenum were better than distilled water. Average values of length of wheat seedlings increased with increasing of magnetic fields exposure time for both soaking treatments. The development growth rates were higher in 2 h of magnetic fields exposure time.So, the magnetic field and pre-soaking with molybdenum could be used to promote plant growth.

Key words : Static magnetic field, ammonium molybdate, germination parameters, wheat.

Introduction

A seed of wheat (*Triticum aestivum* L.) crop plant is one of the most important food security crops grown across a range of environments around the world due to their high nutritional quality (Poghosyan and Mukhaelyn, 2018). There are several studies about the seed germination and growth of some plants related to the seeds soaking in water or in several solutions and their interaction with various physical factors treatments such as magnetic field, ultraviolet, microwave, ultrasound and laser irradiation (Bakr Ahmed *et al*., 1977; Kouchebagh *et al*., 2014; Naeem, *et al*., 2013 and Verma *et al*., 2017). One of the most popular physical factors is a magnetic field which represented the most promising pre-sowing seed treatments. Magnetic seeds treatments used are being as the effective enhancement tools in agronomic and horticultural crops to improve the germination and rate seedling growth. Several studies of huge number crop seeds treatments with SMF has been observed enhancements effects in germination characteristics processes and seedling growth, for example, Cereal seeds (Martinez *et al*., 2017), wheat (Hamza *et al*., 2013; Gholami *et al*., 2010; Ijaz *et al*., 2012), barely (Martinez *et al*., 2000), maize (Florez *et al*., 2007), chickpea (Vashisth and Nagarajan, 2008) and sunflower (Vashisth and Nagarajan, 2010; Matwijczuk *et al*., 2012). As well as, Carbonnel *et al*. (2008) reported the application of stationary magnetic fields as a physical technique to improve the grass seeds germination. Also, Poghosyan and Mukhaelyn (2018) reported an increase in germination of treated wheat seeds with low intensity of electromagnetic irradiation.Moreover, under the magnetized water treatments, an increase in plants height was found on wheat (Kadum *et al*., 2017) and on maize

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(Taj – Al deen *et al*., 2009).

Molybdenum is known to be an essential element to the most living organisms as forms of a part of the nitrogen enzyme that stimulates various oxidation reactions, so playing an important role in the stabilization of nitrogen in plant (Tavares *et al*., 2013; Datta *et al*., 2011; Mohandas, 1985 and Bakr Ahmed *et al*., 1976). Bodi *et al*. (2015) found that molybdenum affects a positively on growths of maize and sunflower seedlings. Bakr Ahmed *et al*. (1977) found that the effect of combined corn seed treatment with gamma radiation and molybdenum solution gave the best germination results on the germination of seeds and the growth of seedlings.

There are a few studies showed the effect of physical treatments and seeds soaked in molybdenum about the germination and plant growth, especially in magnetic treatments of wheat plant seeds soaking in molybdenum. Wherefore, the aim of this work is to a describe the mathematical expressions of several indices associated with germination characteristics processes and growth rate length of seedlings under the combined effect of presowing exposure of a molybdenum soaked wheat seeds with a different periods time of a static magnetic field.

Materials and Methods

Seeds of wheat (*Triticum aestivum* L.) selected for uniform size and shape, were used in this experiment. Before treatments, seeds were divided into two parts, one part were soaked for 2 hours (h) in distilled water (DW), while the other were soaked for 2h in 500 ppm solutions of ammonium molybdate (Mo). Following soaking, seeds were exposed to a static magnetic field of 125 mT in a cylindrical plastic sample holder for ranging 0-3 h durations in steps of 1 h; 0h as non-exposed soaked seeds (control). Control and treated seeds were planted in ordinary plastic pots (12 seeds in each one) containing a soil peat-moss in three replicates per treatment. Pots were placed in laboratory conditions with natural light, and were watered with distilled water whenever required. The number of germination seed was counted every day after 2 day of cultivation, until the ninth day when there were no more germinated seeds. After the end of 9th day, some germination parameters and growth rate of length plant were recorded as follows:

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

$$FGP\% = \frac{\text{Number of germination seeds after 9 days}}{\text{Total numbe of seeds planted}} \times 100$$

Speed germination (S.G) was calculated as described in the Association of Official Seed Analysts (AOSA, 1983) by the following formula:

$$S.G. = \frac{\text{N. of germinated seed}}{\text{Days of 1st count}} + \ldots + \frac{\text{N. of germinated seed}}{\text{Days of final count}} \left(\text{seed day}^{-1}\right)$$

Mean Germination Time (MGT) was calculated according to the following formula of Ellis and Roberts (1981):

$$MGT = \frac{\Sigma nD}{n} (\text{day})$$

Where, n is the number of seeds, which were germinated correspondent to the day D observation (not the accumulated number) and D is number of days counted from the beginning of germination.

Coefficient of Velocity of Germination (CVG) was calculated according to the following formula of Scott *et al*. (1984):

$$CVG = \frac{\Sigma N_i}{N_i T_i} \times 100$$

Where, N is the number of seeds germinated on day i and T is the number of days from seeding corresponding to N.

Germination Rate Index (GRI) was calculated according to the following formula of Esechie (1994):

$$GRI = \frac{G_1}{1} + \frac{G_2}{2} + \frac{G_3}{3} + \ldots + \frac{G_n}{n} (\%/\text{day})$$

Where, G_1, G_2 … G_n are the germination percentage × 100 at the first, second and subsequent days after sowing until the 9th day; 1, 2… and n are the days of first, second … and final count, respectively.

Germination Index (GI) was calculated according to the following formula of kader (2005):

$$GI = (10 \times n_1) + (9 \times n_2) + \ldots (1 \times n100)$$

Where, n_1, n_2 . . . n_9 are the number of germinated seeds on the first, second and subsequent days until the 10th day; 10, 9 . . . and 1 are the number of germinated seeds on the first, second and subsequent days, respectively

Mean Daily Germination (MDG) was calculated according to the following formula of Scott *et al*. (1984):

$$MDG = \frac{FGP}{D}$$

Where, FGP is a final germination percent, D is day of maximum germination (experiment period).

Mean Germination Rate (MGR) is defined as reciprocal of the mean germination time and was calculated according to the following formula of Ranal and Santana (2006)

$$MGR = \frac{1}{MGT}$$

And also was calculated based on the following equation of Scott *et al*. (1984) as:

$$MGR = \frac{CVG}{100} = \frac{n}{\Sigma nd} day^{-1}$$

The lengths of the plant height (cm) were measured daily every day after 2 day of cultivation until the ninth day and the average length of plant calculated and plotted vs. time of growth.

All tests were carried out in the department of agricultural machinery and equipment, in the Laboratory of Physics, Agriculture College, University of Basrah. The statistical analyses were used in the experiment study, according to completely randomized design, with three replications, each pot represents one replicate. The results analyses were done using the SPSS 20. The data of germinating percentage were transformed to arcsin $\sqrt{\frac{x}{100}}$.

After testing the data distribution, the analysis of variance (ANOVA) was used to test the main effects of the magnetically treated on water-or molybdenum-soaked seeds and their interaction. The mean values compared according to L.S.D. test at the level 0.05 for each of the treatments and their interaction.

Results and Discussion

Exposure of wheat seeds to different magnetic field exposure time prior to germination significantly increased germination-related characters, such as final germination percentage, coefficient of velocity of germination, germination rate index, germination index, speed germination, mean daily germination and mean germination (table 1). The improvement for 1, 2 and 3 magnetic field exposure time over untreated control seeds was 3.395, 28.144 and 15.220% for final germination percentage, 6.818, 27.721 and 22.931% for velocity of germination, 10.835, 40.748 and 30.661% for germination rate index, 13.078, 52.742 and 37.129% for germination index, 10.203, 52.030 and 29.861% for speed germination,1.263, 59.343 and 51.222% for mean daily germination and 6.587, 27.545 and 24.551% for mean germination rate, respectively.

Among the various magnetic field treatments, 2 and 3hexposure time were more effective than others in increasing most of the seedling parameters. Magnetic field exposure time of 2 h significantly increased germination characteristics. However, control (0 h exposure time) was more effective compared to the others in enhancing mean germination time.

The time required for germination (mean germination time) recorded for each treatment were, in general, lower than control value, thus the rate of germination of treated seeds was higher than the untreated seeds. The time needed to germinate (the time required to the onset of the germination) decreased by 6.026, 20.865 and 18.995% for seeds exposed to 1, 2 and 3 h of magnetic field compared to control. It is remarkable that parameter 2 hexposure time was significantly lower than the control. These results might be parallel to the results of Carbonnel *et al*. (2008) where authors found that a decrease in mean germination time (MGT) when exposing the grass seeds for 10, 20 min and 6, 24 hours to both static magnetic field of 125 and 250 mT.

The stimulatory effect of the application of different time magnetic treatments on the germination rate index might be consistent with that obtained by other researchers. Florez *et al*. (2007) observed an increase for initial growth stages and in early sprouting of rice and maize seeds exposed to 125 and 250 mT stationary magnetic fields. Martinez *et al*. (2000) and Martinez *et al*. (2017) noticed similar effects on wheat and barley seeds magnetically treated. Alexander and Doijode (1995) reported that pre-germination treatment enhanced the germination and seedling. Kavi (1977) found that seeds exposed to a magnetic field gave absorbed more moisture. Carbonell *et al*. (2000) found that magnetic treatment formed a biostimulation of the germination. Gholami *et al*. (2010) found a significant increase in mean germination time (MGT) in two wheat cultivars when the time of seed exposed at magnetic field treatments increased about 3 and 2 hours respectively for Omid and BCR cultivars.

The work mechanisms of plants that exposed to a magnetic field are not obvious yet, but several theories have been suggested, with biochemical changes or adapted enzyme activities by Phirke *et al*. (1996a). Garcia

Table 1 : Effect of magnetic field exposure time of seeds on studied traits.

MFET (h)	FGP	CVG	GRI	GI	SG	MDG	MGR	MGT
Control	64.916	16.72	15.505	39.5	1.872	7.364	0.167	5.991
1	67.12	17.86	17.185	44.666	2.063	7.457	0.178	5.63
2	83.186	21.355	21.861	60.333	2.846	11.734	0.213	4.741
3	74.796	20.554	20.259	54.166	2.431	11.136	0.208	4.853
L.S.D0.05	7.42	1.761	1.546	4.694	0.3304	2.023	0.01849	0.496

$L.S.D_{0.05}$=Least significance difference at probability 5%; N.S=Non-significance
MFET magnetic field exposure time (hr.), FGP final germination percentage, CVG coefficient of velocity of germination, GRI germination rate index, GI germination index, SG speed germination, MDG mean daily germination, MGR mean germination rate, MGT mean germination time.

Table 2 : Effect of soaking in ammonium molybdate of seeds on studied traits.

Soaking	FGP	CVG	GRI	GI	SG	MDG	MGR	MGT
DW	69.24	18.373	17.652	46.83	2.207	8.771	0.1839	5.51
Mo	75.76	19.872	19.752	52.50	2.398	10.075	0.1997	5.097
L.S.D0.05	5.25	1.245	1.093	3.319	N.S	2.861	0.01308	0.35

$L.S.D_{0.05}$=Least significance difference at probability 5%; N.S=Non-significance
FGP final germination percentage, CVG coefficient of velocity of germination, GRI germination rate index, GI germination index, SG speed germination, MDG mean daily germination, MGR mean germination rate, MGT mean germination time.

Table 3: Interaction effect of magnetic field exposure time and soaking in ammonium molybdate of seeds on studied traits.

MFET (h)	Soaking	FGP	CVG	GRI	GI	SG	MDG	MGR	MGT
Control	Mo	65.9	16.763	15.925	40.33	1.912	7.322	0.167	5.966
Control	DW	63.93	16.676	15.084	38.67	1.832	7.406	0.166	6.016
1	Mo	68.34	18.568	18.204	47.67	2.185	7.593	0.184	5.426
1	DW	65.9	17.155	16.1666	41.67	1.94	7.322	0.171	5.833
2	Mo	90	23.384	24.139	68.33	3.008	14.285	0.234	4.273
2	DW	76.37	19.326	19.582	52.33	2.684	9.183	0.193	5.21
3	Mo	78.81	20.772	20.742	53.67	2.489	11.1	0.212	4.723
3	DW	70.78	20.336	19.776	54.67	2.373	11.172	0.203	4.983
	L.S.D0.05	N.S	N.S	N.S	6..638	N.S	N.S	N.S	N.S

$L.S.D_{0.05}$=Least significance difference at probability 5%; N.S=Non-significance
MFET magnetic field exposure time (hr.), FGP final germination percentage, CVG coefficient of velocity of germination, GRI germination rate index, GI germination index, SG speed germination, MDG mean daily germination, MGR mean germination rate, MGT mean germination time.

and Arza (2001) conducted a study on water absorption by lettuce seeds previously treated in a stationary magnetic field of 1-10 mT; they reported that an increase in water uptake rate due to the applied magnetic field, which might be the explanation for increase in the germination speed of treated seeds (table 1).

Pre-magnetic field treatment of seeds led to the acceleration of plants' growth, protein biosynthesis and root development (Hirota *et al.*, 1999; Penuelas *et al.*, 2004; Poghosyan and Mukhaelyan, 2018; Vashisth, 2008 and Vashisth, 2017). In addition, more accelerated plant growth is believed to be directly due to the reunion of north and south magnetic monopole and the energy that is released with their reunion.

The results show that different duration of exposure of magnetic field has an enhancing effect on the early growth of wheat seeds.

Growth data measured after soaking allow us to corroborate the effect soaking treatments observed in the studied traits. Table 2 shows that soaking treatments for a given seed population was significantly affected by applied soaking treatments. The final germination percentage, coefficient of velocity of germination, germination rate index, germination index, speed germination, mean daily germination and mean germination rate increases significantly by 9.417, 8.159, 11.897, 12.107, 8.654, 14.867 and 8.591% respectively, for soaking wheat seeds with ammonium molybdate compared to DW, in addition mean germination time decreased by 7.495% under soaking with ammonium molybdate treatment compared to DW.As molybdenum forms a part of the enzyme nitrogenase which plays key role in fixing nitrogen its enrichment has obviously increased nitrogen content in the plant (Mohandas, 1985). According to Kaiser *et al*. (2005) Mo-dependent enzyme activity impacts upon plant development, in particular, those processes involving nitrogen metabolism and the synthesis of the phytohormones abscisic acid and indole-3 butyric acid. In addition, Molybdenum has a close relationship with metabolic products of carbon and nitrogen metabolism. Molybdenum treatment may be having promoted the content of carbon assimilation products such as total soluble carbohydrates in different parts of the plant body (Datta *et al*., 2011).

The results of interaction treatment seeds with a magnetic field and molybdenum shown in table (3). With most of the magnetic field exposure duration levels and soaking treatment, significant enhancement of germination index noted for the 2 h duration with ammonium molybdate soaking treatment.

The effect of magnetic field pre-treatment on the average length of wheat seedlings is presented in figs. 1 and 2 under two soaking treatments. The effect began after 2 days of planting until the ninth day. There were significant changes in the seedlings length for both DW and Mo treatments when compared to the control seeds. These results might be parallel to the results of Răcuciu *et al*. (2017) where authors found that an increase in average length of each batch of seedlings grown from magnetic exposed barley seeds and to the result of Srikanth *et al*. (2018) from magnetic exposed Chilli seeds. The 8 and 9 days after planting seeds were longer than other germinating.

Fig. 3 shows curves of growth rate for both DW and Mo soaking treatments significantly different from each other. Mo soaking treatment indicates lesser values of their time parameter (mean germination time) and consequently higher growth rate than the DW soaking treatment. According to these results, the highest rates of growth rate were detected when seeds were subjected to 2 h continuous exposure time.

There are several possible theories reported by some authors relates to the activities of some enzymes in magnetic exposed seeds which leads to enhanced germination and seedling growth. Kataria *et al*. (2015)

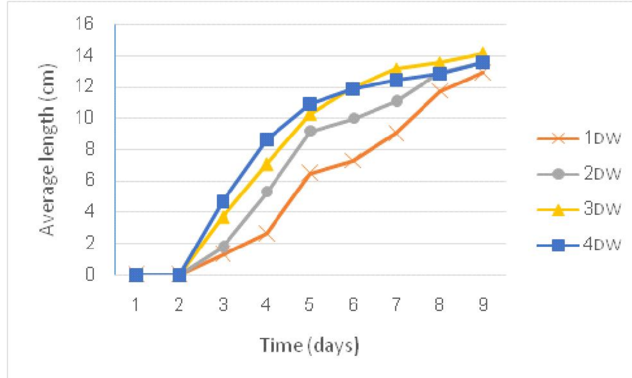

Fig. 1 : Average values of length of wheat seedlings developed from water-soaked seeds treated with magnetic field for 1h (DW2), 2h (DW3) and 3h (DW4), 0h (DW1) as non-exposed soaked seeds (control).

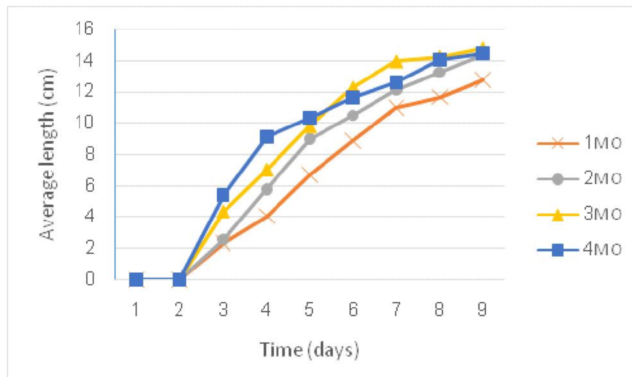

Fig. 2 : Average values of length of wheat seedlings developed from molybdenum-soaked seeds treated with magnetic field for 1h (Mo2), 2h (Mo 3) and 3h (Mo 4), 0h (Mo 1) as non-exposed soaked seeds (control).

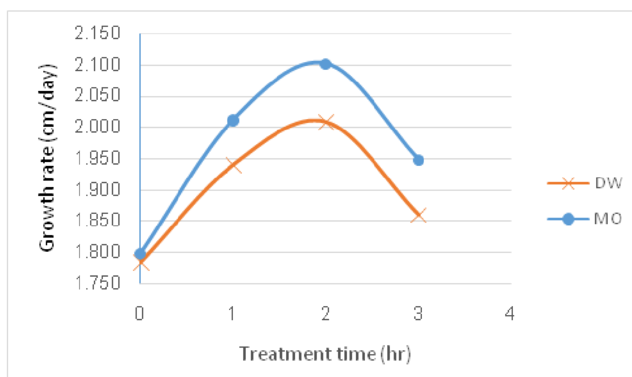

Fig. 3 : The development of growth rate versus treatment time.

have found activities of hydrolytic enzymes in magnetically soybean and maize seeds may be responsible for increased seeds germination and seedling length. Also, Samani *et al*. (2013) observed an increase in the germinating of magnetically cumin seeds as a consequence on increased activity of three enzymes, amylase, dehydrogenase and protease. While Mousavizadeh *et al*. (2013) observed an increase of peroxidase activity in Lettuce seeds exposed to a different

SMF period time, which may be lead toquick the germination seeds and growth seedling.

Conclusion

The study indicated that exposure of wheat seeds to static magnetic field durations ofexposure significantly increased laboratory germination and emergence characteristics. A 2 h exposure durations of a SMF showed an increase in final germination percentage, coefficient of velocity germination, germination rate index, germination index, speed germination, mean daily germination and mean germination rate. Soaking wheat seeds with molybdenum promoted germination and emergence characteristics. The improved germination and emergence characteristics suggested that this technique may be had suitably exploited and enhanced wheat seedling growth.

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