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Effect of Stimulating Maize Seeds with Potassium Nitrate and Licorice Extract on the Seed Viability and Vigor

M. M. KHudhair[1] and Hamza J. H.[2]

[1,2] Department of Crop Sciences, College of Agricultural Engineering Sciences, University of Baghdad, Baghdad, Iraq.

[1]E-mail: Mariam.mohsen1106a@coagri.uobaghdad.edu.iq

Abstract. Germination and field emergence are delayed and their duration is prolonged due to the declining soil temperature during the spring season, which is reflected in the subsequent stages of crop growth, therefore, this study aimed to improve germination. Under a wide range of environmental conditions, a laboratory factorial experiment was carried out to study the effect of seed stimulation with potassium nitrate (distilled water only (0), 2, 4, and 6 mg L^{-1}) and with an aqueous extract of licorice roots (distilled water only (0), 3, 6, and 9 g L^{-1}) on the seed viability and vigor. The laboratory experiment was carried out according to the Completely Randomized Design (CRD) with four repetitions. The results showed the superiority of the interaction treatment between the two concentrations 6 gm L^{-1} and 6 mg L^{-1} for each of licorice root extract and potassium nitrate by giving the highest average of the final germination 99%, the seedling vigor index reached 3846, the germination percentage at accelerating age test of 75%, and the germination percentage at the cold test of 76%. We can conclude that there was a response to soaking the seeds in licorice root extract at specific concentrations, with a clear response to potassium nitrate, and the response could be better when soaking in potassium nitrate at concentrations higher than 6 mg L^{-1}. We also recommend that the soaking duration in any of the two factors is 18 hours to improve germination under a wide range of environmental conditions.

Keywords. Seed stimulation, Germination, Accelerating age, Aqueous extract, Cold test.

1. Introduction

Growing maize (*Zea mays* L.) in Iraq coincides with a significant decrease in temperatures, especially soil temperature, and thus there will be a negative impact on the germination and field emergence processes. Appropriate solutions to these constraints can be found by using the seed stimulation technique. The effect of the treatments was not limited to stimulating germination only, but studies have tended in recent years to investigate the possibility of improving the seeds' vigor, and increasing the germination percentage and velocity by soaking them in various nutrient solutions. The technique of stimulating seeds has a major and important role in improving the seed performance and stimulating it for germination and rapid and homogeneous emergence, by partially wetting the seeds until reaching a point where the germination process begins. The stimulation is done by pre-planting soaking in a nutrient, plant extract, or natural or manufactured solutions that increase the velocity, percentage, and homogeneity of germination, and improve seedling vigor, and so on, that can be an appropriate solution to reveal the potential energy in seeds under a wide range of environmental conditions[1,2].

Stimulation is the process of treating the seeds with osmotic solutions, which allows the seeds to absorb, in addition to accelerating the production of ATP and increasing the activity and level of enzymes and the production of simple sugars that can be absorbed by the embryo during the first stage of germination [3]. For instance, soaking the seeds in potassium nitrate (KNO_3), the most widely used chemical, for the purpose of increasing seed germination, which is recommended by the International Society for Seed Testing in germination experiments for many species, as it is a soluble source of two main types of nutrients (13% N and 44-66% K_2O), and their relationship to the nucleic acids assimilation and participation in cell division and the transport of sugars and protein. Also, soaking the seeds in licorice root extract is because it contains the initiator of the biosynthesis of gibberellin, which stimulates increasing the germination velocity, helps cell division and elongation, increases seed vigor, embryo development, and improves germination.
The objective of the study was:

- Stimulating the seeds by soaking them before planting in potassium nitrate and aqueous extract of licorice roots to improve the seeds' vigor and vitality.
- Raising the germination percentage under a wide range of environmental conditions.

2. Materials and Methods

A laboratory experiment was conducted at the Seed Technology Laboratory to study the effect of stimulating maize seeds, cultivar Baghdad, with potassium nitrate and aqueous extract of licorice roots on germination and seedling vigor. The experiment was carried out according to the Completely Random Design (CRD) with four replicates as a factorial experiment order (4x4) as follows:

- Stimulating the seeds with potassium nitrate (stylized water (0), 2, 4, and 6mg.L^{-1}).
- Stimulating the seeds with aqueous extract of licorice roots (stylized water (0), 2, 3, 6, and 9g.L^{-1}).

The total number of treatments was 16. The seeds were soaked for 18 hours at a rate of 200 seeds per treatment. Licorice root extract was dissolved at 6 gm L^{-1} of and dissolved in potassium nitrate solution that was prepared from dissolving 6 mg L^{-1}. All tools used and the germinator were disinfected with ethanol at a concentration of 96%. The seeds were distributed on germination papers of 24cm diameter, at a rate of 50 seeds per each, where each treatment was replicated four times. Next, the paper was folded and placed in nylon bags, then in the germinator at a temperature of 25°C ±2 and humidity (70%) for ten days. After that, the data required for the study were taken and statistically analyzed, and compared according to the means based on the least significant error (LSD) using the software, GenStat.

2.1. Study Factors

2.1.1. Licorice Aqueous Extract Preparation

Four different concentrations of licorice root aqueous extract were prepared according to the [4] procedure in the postgraduate laboratory of the Department of Field Crops - College of Agricultural Engineering Sciences - University of Baghdad. Ten grams of dried licorice root were crushed and soaked in 200 ml of distilled water for 24 hours at room temperature and mixed with an electric blender. Next, the extract was filtered to separate solid plankton using filter paper (Whatman No.1) and Buechner funnel. The water was disposed of with a rotary device to obtain a powder and then was weighed with a sensitive scale and dissolved in water to prepare the required concentrations (3, 6, and 9 gm L^{-1}), in addition to the control treatment.

2.1.2. Potassium Nitrate Preparation

Four concentrations of potassium nitrate solution KNO_3 (2, 4, and 6mg.L^{-1}) in addition to the control treatment were prepared by dissolving the powder in distilled water.

2.2. Studied Traits

2.2.1. First Count % of the Standard Germination Test
The normal seedlings only were counted on the fourth day from putting the seeds in the germinator [5], applying the same steps followed for the standard germination test and converting the results into percentages.

2.2.2. Final Count % of the Standard Germination Test
The normal seedlings only were counted on the fourth day from putting the seeds in the germinator [5], applying the same steps followed for the standard germination test and converting the results into percentages.

2.2.3. Radical and Plumule Length at the Standard Germination Test
After the test period ended (ten days), ten normal seedlings were chosen, the radical was separated from its point of contact with the seed, and the plumule was separated from its point of contact with the epicotyl [6]. Then, the length of the radical and the plumule were measured separately using a ruler.

2.2.4. Seedling Dry Weight at the Standard Germination Test
The same ten seedlings, chosen at the radical and plumule length test, were placed in a perforated paper bag and dried at a temperature of 80°C for 24 hours [6-7]. The average dry weight of the seedlings was calculated by dividing the total weight by their number.

2.2.5. Seedling Vigor Index at the Standard Germination Test
The seedling vigor index was calculated relying on the germination percentage at the final count and on the radical and plumule length, calculated previously, according to the following equation [8] .

$$\text{Seedling vigor index} = \text{germination percentage at the final count x (radical length} + \text{plumule length)}$$

2.2.6. Germination Percentage (%) at the Accelerating Age Test
A sample of seeds was taken from each treatment and placed on a mesh inside a plastic box containing distilled water so as not to touch it. The box was closed and placed in a germinator to expose the seeds to stress under a temperature of 43 ° C ± 1 and 100% humidity for 72 hours. Then the seeds were subjected to a standard germination test after accelerating, where their moisture was in the range of 20-30%, as only one count was conducted seven days after changing the germination temperature according to the conditions of the standard germination test to determine the number of normal seedlings only, after that, the results were converted into percentages and recorded as a germination percentage at the acceleration age test.

2.2.7. Germination Percentage (%) at the Cold Test
A sample from the field soil where the experiment was conducted was taken, cleaned out of the plant residual, and mixed with sand by a ratio of 1:1 [9]for use to cover the seeds in this test. Using moisturizing paper towels, 200 seeds were planted in four replicates. They were moisturized with cold water of 10° C, covered with a thin layer of moist soil, and kept in a germinator at a temperature of 10°C ± 0.5 for seven days. After that, the temperature in the germinator was changed to 25°C ± 0.5 to remain the seeds there for four days. At the end of the test period (11 days), only normal seedlings were counted and the results were calculated as percentages according to the following law:

$$\text{Normal seedling percentage } = \frac{\text{number of the normal seedlings}}{\text{Total number of the seeds}} \times 100$$

3. Results and Discussion

3.1. First Count

Results in Table 1 showed no significant differences affected by soaking the seeds in the licorice root extract, potassium nitrate, or the interaction between them on the first count.

Table 1. Effect of stimulating maize seeds with potassium nitrate and aqueous extract of licorice roots on the first count (%) at a standard germination test.

Aqueous extract of licorice roots ($g.L^{-1}$)	Potassium nitrate ($mg.L^{-1}$)				Mean
	Distilled water	2	4	6	
Distilled water	95	98	98	97	97
3	96	97	98	98	97
6	98	99	99	97	98
9	97	97	96	94	96
$L.S.D_{0.05}$					n.s
Mean	96	98	97	97	
$L.S.D_{0.05}$	n.s				

3.2. Final Count

Table 2 demonstrates significant differences affected by soaking the seeds in the licorice root extract, with no significant difference affected by soaking in the nitrate potassium nor by the interaction between the two factors on the final count. The treatment of soaking the seeds in the licorice roots extract at the concentration of $6g.L^{-1}$ was superior giving the highest average of the final count (99%), knowing that it did not differ significantly from the concentration of 3 $g.L^{-1}$, yet it differed significantly from the other concentrations.

In general, this result is a good indicator for the pre-soaking process of seeds, as it increases the germination and its percentage, since the pre-soaking of the seeds accelerates the metabolic processes inside the seed, beginning from wetting the seeds and their absorbing with the solution in which the seeds were soaked to complete these metabolic processes and reduce the time taken from planting until the germination process initiation as a result of the transfer of decomposing materials to the developing embryo during the soaking period. Furthermore, the licorice root extract contains several compounds of saccharides and proteins to which that increase in most traits may be due to [10-11].

Table 2. Effect of stimulating the seeds with potassium nitrate and aqueous extract of licorice roots on the final count (%) at a standard germination test.

Aqueous extract of licorice roots ($g.L^{-1}$)	Potassium nitrate ($mg.L^{-1}$)				Mean
	Distilled water	2	4	6	
Distilled water	96	98	98	98	97
3	97	97	98	99	98
6	98	99	99	99	99
9	97	97	96	94	96
$L.S.D_{0.05}$		n.s			1.265
Mean	97	97	98	97	
$L.S.D_{0.05}$		n.s			

3.3. Radical Length

Table 3 reveals significant differences in radical length at standard germination test after soaking in the licorice root extract, potassium nitrate, and the interaction between them. The highest average was 18.9 cm obtained from the treatment of the concentration of $6g.L^{-1}$, while the treatment of soaking in distilled water recorded the lowest average of 16.7 cm. We also notice that the highest average for soaking in the potassium nitrate was at the concentration of $18.6L^{-1}$, differing significantly from other treatments involving the distilled water treatment recording the lowest value averaging 17.3cm (Table 3). The same table also illustrates that the highest average of the interaction between the two factors was at the combination between 6g.L^{-1} of licorice root extract and 6mg.L^{-1} of potassium nitrate, recording 22.5 cm of the radical length trait at the standard germination test whereas the lowest average was 14.4 cm recorded by the control treatment (soaking in the distilled water only). The increase in the radical length is due to the role of the licorice extract in enhancing most traits, including this one, for it contains several nutritional elements such as proteins, saccharides, and menials (e.g., K, Cu, Mg, Mn, Zn, and P).

The increase in the radical length may be a result of an increase in the seed germination velocity enhanced by potassium nitrate leading to an increase in the radical length. This result is consistent with the findings of [12]. They confirmed that potassium nitrate has a prominent role in increasing the nutritional storage amount through releasing hydrolytic enzymes that have a role in starch decomposition that its use efficiency is increased affected by potassium nitrate as well as producing energy and construction units that transfer to the growing embryo rapidly. These results are consistent with [13].

Also, the reason for the radical length is due to an increase in the germination percentage, i.e. it took a longer time to grow compared to those that did not germinate, and the reason for the decrease in the radical length may be the presence of active compounds or toxic substances which is consistent with what was found by [14].

The increase in the radical length achieved by the effect of soaking with licorice root extract and potassium nitrate was associated with an increase in the concentrations used for each factor individually, which allowed them to be superior in the interaction treatments because potassium nitrate decomposes to K+ and NO-3, which has a role in the providing N, which it is a major component of several organic compounds and essential for the construction of proteins necessary for constituting both DNA and RNA, which participate in activating the work of enzymes and increasing the protein content of cells [15].

Table 3. Effect of stimulating the seeds with potassium nitrate and aqueous extract of licorice roots on the Radical length (cm) at the standard germination test for the maize seeds.

Aqueous extract of licorice roots (g.L^{-1})	Potassium nitrate (mg.L^{-1})				Mean
	Distilled water	2	4	6	
Distilled water	14.4	16.9	17.9	17.5	16.73
3	18.5	16.4	17.4	17.0	17.24
6	19.6	16.7	16.7	22.5	18.93
9	17.3	18.3	17.4	17.4	17.62
L.S.D$_{0.05}$		2.148			n.1.074
Mean	17.3	17.1	17.4	18.6	
L.S.D$_{0.05}$		1.074			

3.4. Plumule Length

Table 4 shows significant differences related to soaking the seeds in potassium nitrate and no significant difference resulting from soaking the seeds in the licorice root extract nor the interaction between them in the plumule length at the standard germination test. The highest average plumule length was 14.4 cm from soaking the seeds in potassium nitrate at the concentration of 6mg.L^{-1} that did not differ significantly from the treatment of soaking the seeds at the concentration of 4g.L^{-1}, while it differed significantly from the treatment of soaking in the concentration of 2mg.L^{-1} as well as from the control treatment that gave the lowest length averaged 12.7 cm. The reason for the increase in the plumule length may be due to the role of potassium nitrate in the process of water absorption through the entry of water and oxygen into the seed, thus the seed absorbs oxygen, the endosperm destructed and reaches germination faster, thus increasing the length of the plumule [12]. It may also be due to absorbing the seeds soaked with the stimulus solution in an appropriate manner that does not adversely affect the vitality of the seeds, their physiological activity, and their osmotic pressure because the length of the soaking period can negatively affect the plumule length by affecting the seeds' vitality of the seeds which is consistent with [16].

Table 4. Effect of stimulating the seeds with potassium nitrate and aqueous extract of licorice roots on the plumule length (cm) at the standard germination test for the maize seeds.

Aqueous extract of licorice roots (g.L^{-1})	Potassium nitrate (mg.L^{-1})				Mean
	Distilled water	2	4	6	
Distilled water	11.5	12.8	14.0	13.8	13.0
3	12.8	13.0	14.0	13.6	13.3
6	14.1	12.4	13.6	16.1	14.0
9	12.6	14.0	14.3	14.0	13.7
L.S.D$_{0.05}$					n.s
Mean	12.7	13.0	14.0	14.4	
L.S.D$_{0.05}$	0.916				

3.5. Seedling Dry Weight

Table 5 shows significant differences in the effect of soaking with licorice extract and potassium nitrate and the interaction between them in the dry weight of the seedling in the standard germination test. The treatment of soaking seeds with licorice extract was superior at the concentration of 6 gm L^{-1} by giving the highest average of 0.042 mg, which did not differ significantly from the concentration treatment of 3 gm L^{-1}, while it differed significantly from the rest of the treatments, including the distilled water treatment only, which was 0.035 mg. For the potassium nitrate, the highest average was 0.042 mg from soaking the seeds with the concentration of 6mg.L^{-1}, knowing that it did not differ significantly from the other treatments of potassium nitrate. The lowest average was at the control treatment of 0.038mg. We notice the significant effect of the interaction between licorice extract and potassium nitrate, as the interaction treatment of 6 gm L^{-1} with 6 mg L^{-1} recorded the highest average of 0.048 mg, which did not differ significantly from the treatment of soaking in 3 gm L-1 and 6 mg L^{-1} While it differed significantly, from the rest of the interacted concentrations when soaking the seeds with the above two factors, compared to the control treatment (soaking in distilled water only), which recorded the lowest average of 0.031 mg.

The reason for the increase in the seedling dry weight may be a result of the prior increase in the traits of the radical length and plumule length affected by the treatment of soaking the seeds in potassium nitrate (Tables 3 and 4), as this increases as a result of increasing the seedling length that is related to the dry matter, because in most cases the dry weight of the seedling increases with increasing the seedling length itself [17].

Table 5. Effect of stimulating the seeds with the potassium nitrate and aqueous extract of licorice roots on the seedling dry weight (mg) at the standard germination test for the maize seeds.

Aqueous extract of licorice roots (g.L^{-1})	Potassium nitrate (mg.L^{-1})				Mean
	Distilled water	2	4	6	
Distilled water	0.031	0.033	0.038	0.040	0.035
3	0.040	0.040	0.037	0.043	0.040
6	0.040	0.039	0.042	0.048	0.042
9	0.040	0.039	0.040	0.037	0.039
L.S.D$_{0.05}$	0.005178				0.002589
Mean	0.038	0.038	0.039	0.042	
L.S.D$_{0.05}$	0.002589				

3.6. Seedling Vigor Index

Table 6 shows significant differences affected by soaking with licorice extract and potassium nitrate, and the interaction between the above two factors on the seedling vigor index at the standard germination test. The concentration treatment 6 gm L^{-1} was superior and recorded the highest average for seedling vigor index of 3267, noting that it did not differ significantly from the rest of the treatments, while the control treatment (soaking in distilled water only) recorded the lowest average for this trait, which is 2911. We also note that the treatment of soaking the seeds in the potassium nitrate at the concentration of 6 mg L^{-1} was superior by giving the highest average of the seedling vigor index of 3233, which did not differ significantly from the rest of the concentrations, including the treatment of soaking the seeds in distilled water only, which gave the lowest value for this trait in the standard germination test of 2935 (Table 6). Concerning the interaction treatment between soaking in the licorice extract and potassium nitrate, shown in the same table that the concentration treatment of 6 gm L^{-1} with 6 mg L-1 gave the highest average for the same trait amounted to 3846, which differed significantly from the treatment of soaking the seeds in distilled water only, as the last treatment recorded the less average of the seedling vigor index at the standard germination test, which was 2497. The reason is due to the significant increase in the germination percentage (Table 2) and both length of the radical and plumule at the final count (Tables 3 and 4), and thus this is reflected in the seedling vigor index. These results agree with [12]. [18] has confirmed that the seedling vigor is more closely related to its association with the plumule length than its association with the length of radical. We also observe that the plumule length or the radical length can be one of the main criteria that reflects the seedling vigor, and thus it may be that the high germination percentage does not necessarily reflect the seedling vigor, such as the length of the plumule or radical [19].

Table 6. Effect of stimulating the seeds with the potassium nitrate and aqueous extract of licorice roots on the seedling vigor index at the standard germination test for the maize seeds.

Aqueous extract of licorice roots ($g.L^{-1}$)	Potassium nitrate ($mg.L^{-1}$)				Mean
	Distilled water	2	4	6	
Distilled water	2497	2935	3136	3075	2911
3	2996	2877	3101	3040	3003
6	3328	2886	3008	3846	3267
9	2918	3149	3051	2971	3022
$L.S.D_{0.05}$					152.3
Mean	2935	3074	2962	2935	
$L.S.D_{0.05}$		152.3			

3.7. Germination Percentage at the Accelerating Age Test

Table 7 shows significant differences for the effect of soaking the seeds in the licorice extract and the interaction between the aforementioned factor and the other factor, soaking the seeds in the potassium nitrate, in the germination percentage at the accelerating age test, while the effect of soaking the seeds in potassium nitrate was not significant. The concentration treatment of 6 gm L^{-1} of licorice extract was superior by giving it the highest average germination percentage in the accelerating age test of 68%, noting that it did not differ significantly from the two soaking treatments with a concentration of 9 gm L^{-1} and 3 gm L^{-1}, as each of them gave an average of 63% and 61%, respectively, while they differed significantly from the control treatment, which gave the lowest average for this trait in the accelerating age test, which was 53%.

As for the effect of the interaction between the two factors, the two concentration treatments of 6 gm L^{-1} of licorice extract with 6 mg L^{-1} of potassium nitrate were superior by recording the highest average germination percentage in the accelerating age test of 75%, compared to the treatment of soaking in distilled water only, which gave the lowest average of 45% for this trait, knowing that it differed significantly from the aforementioned treatment (Table 8).

The evident effect of the licorice extract concentrations is due to its action, which is similar to that of gibberellin, as it contains the bio-initiator of the growth regulator, as it plays a leading role in the aleurone layer in inducing hydrolysis enzymes, thus decomposing complex molecules into simple ones in the endosperm, and then transferring them to the embryo during the germination stage which reflects positively on that process. In addition, soaking the seeds in licorice extract increases germination rates due to its contents of many compounds (e.g., p, Cu, Zn, Mn, Mg, and k), the elements are essential for inducing the germination process [11].

The possible reason could be the role of potassium nitrate in producing antioxidant compounds and enzymes that significantly increase and improve germination percentage, as well as the occurrence of some different biochemical changes that work on the seed membrane and promote various physiological activities. The effective effect of the interaction between licorice root extract and potassium nitrate may be due to the increase in the stimulating compounds in the two factors that lead to seed imbibition and the occurrence of the germination process, since the licorice root extract contains mephanolic acid, whose action is similar to the growth regulator gibberellin in stimulating seed germination, [20-21], and to the absorption of nitrates and their use in the metabolism of the embryo through the enzyme of nitrate reductase to nitrite, in addition to that soaking the seeds in potassium nitrate led to an increase in the activity of antioxidant enzymes at the start of the process of imbibition and the endosperm destruction that works to produce the energy needed for seeds [22-23].

Table 7. Effect of stimulating the seeds with the potassium nitrate and aqueous extract of licorice roots on the germination percentage (%) at the accelerating age test in maize.

Aqueous extract of licorice roots ($g.L^{-1}$)	Potassium nitrate ($mg.L^{-1}$)				Mean
	Distilled water	2	4	6	
Distilled water	45	62	57	48	53
3	59	68	53	65	61
6	67	69	64	75	68
9	70	56	68	59	63
$L.S.D_{0.05}$	n.s				4.621
Mean	60	63	60	61	
$L.S.D_{0.05}$	4.621				

3.8. Germination Percentage at the Cold Test

Table 8 shows no significant difference in the effect of soaking the seeds in licorice root extract on the germination percentage at the cold test and significant differences in soaking them in the potassium nitrate and the interaction between the two factors. The highest average percentage of germination at the cold test affected by soaking the seeds in the potassium nitrate was at a concentration of 6 mg L^{-1}, which reached 58%, noting that it did not differ significantly from the two treatments of soaking in 4 mg L^{-1} and the treatment of soaking in distilled water only, as each of them gave an average of 50%. While it differed significantly from the treatment of soaking at a concentration of 2 mg L-1, which gave the lowest average for this trait amounted to 43%.

Regarding the effect of the interaction between the two factors, the two soaking treatments of the licorice extract and potassium nitrate at the concentrations of 6 gm L^{-1} and 6 mg L^{-1} were superior in the germination percentage at the cold test by giving the highest mean of 76%, while the lowest average was from soaking the seeds in distilled water only giving 45 and the soaking treatment of 9 gm. L^{-1} and 6 mg L^{-1} that produced 34%, noting that the last two treatments differed significantly from the superior interaction treatment (Table 9). The reason is due to the superiority of germination resulting from soaking the seeds in licorice root extract, as it contains sugars, which in turn help to reduce or limit cold damage as a result of the increase of dissolved solids in plant cells, which increases the plant’s resistance to these damages [24]. As for the treatment of soaking with potassium nitrate, it can improve the ability of seeds to germinate through the synthesis and transport of carbohydrates and increase the sugar content, in addition to that it acts as a temporary storage of nitrogen and potassium, which can be used later, and this is consistent with what was found by [25]relating to soaking corn seeds in potassium nitrate.

It is believed that the role of the two factors in increasing the percentage of germination in the cold test is due to their stimulating role in seed germination and the destruction of the endosperm through the entry of water and oxygen into the seeds, the transfer of nutrients to the embryo, and faster germination.

Table 8. Effect of stimulating the seeds with the potassium nitrate and aqueous extract of licorice roots on the germination percentage (%) at the cold test in maize

Aqueous extract of licorice roots ($g.L^{-1}$)	Potassium nitrate ($mg.L^{-1}$)				Mean
	Distilled water	2	4	6	
Distilled water	34	52	53	49	47
3	51	44	49	74	54
6	54	36	49	76	53
9	63	40	52	34	47
$L.S.D_{0.05}$	16.47				n.s
Mean	50	43	50	58	
$L.S.D_{0.05}$	8.23				

Conclusions

- Seeds of maize, cultivar Baghdad 3, behaved positively towards the stimulating substances and their concentrations.
- The possibility of using licorice root extract as a substitute for the growth regulator gibberellin in laboratory and field experiments.
- The vitality and the seed vigor can be improved by the soaking process.
- There is a possibility of a biological response and seed vigor to concentrations higher than 6 mg L-1 of potassium nitrate.
- High concentrations of licorice root extract do not lead to seed stimulation

Recommendations

- The possibility of treating maize seeds before planting with licorice root extract and potassium nitrate for 18 hours to improve their ability to germinate and improve seedling vigor.
- We recommend using 6g L^{-1} of licorice extract for soaking the seeds.

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