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Response of black seed (*Nigella sativa* L.) varieties to seed priming with zinc on germination and seedling parameters

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ABSTRACT

A study was carried out at the Scientific Research Center of Erbil Polytechnic University in Erbil city during the fall of 2024. Three parameters were included in the experiment, which used a completely randomized design (CRD): zinc concentrations (0, 1, 2, and 3 g l^{-1}), seed soaking times (0, 6, 9, and 12 hours), and black seed varieties (Russian, Syrian, and Locally). In terms of germination percentage, germination speed, root length, shoot length, root and shoot dry weight, the Syrian variety treated with 2 g l^{-1} zinc had the greatest results. Syrian seeds immersed for 12 hours produced the best outcomes, indicating a strong interaction between seed variety and soaking period. The best results were obtained after soaking with 2 g l^{-1} zinc for 12 hours, according to the relationship between zinc concentration and soaking period. The Syrian variety produced the highest values for germination %, germination speed, root length, shoot length, and dry weights of both the root and the shoot after being soaked for 12 hours and treated with 2 g l^{-1} zinc. However, the Russian variety treated with 2 g l^{-1} zinc and immersed for 12 hours showed the highest fresh root and shoot weights. However, the Russian variety treated with 2 g l^{-1} zinc and immersed for 12 hours showed the highest fresh root and shoot weights. It's interesting to note that the Syrian variety had the highest seedling value at 1 g l^{-1} zinc with soaking duration (12 hours).

KEYWORDS: Black seed; varieties; zinc; seed priming; seedling.

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استجابة بعض أصناف حبة السوداء لمعاملة البذور بالزنك وتأثيره على قياسات الانبات والبادرات

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الملخص

اجريت الدراسة خلال موسم الخريف لعام (2024) في مختبر مركز البحوث العلمية / جامعة أربيل التقنية بمدينة أربيل. اتبعت التجربة تصميمًا عشوائيًا كاملاً (**CRD**) بثلاثة عوامل: يتكون العامل الرئيسي من ثلاثة أصناف من الحبة السوداء (روسي، سوري، ومحلي)، ووقت نقع البذور (0، 6، 9، و12 ساعة)، وتركيزات الزنك (0، 1، 2، و3 غم/لتر). سجل الصنف السوري المعالج بـــ 2 غم/لتر من الزنك أعلى القيم عبر العديد من الصفات بما في ذلك نسبة الإنبات وسرعة الإنبات وطول الجذر وطول البراعم والوزن الجاف للجذور والوزن الجاف للبراعم. كان التفاعل بين صنف البذور ووقت النقع مهمًا، مع ملاحظة النتائج المثلى عند نقع البذور السورية لمدة 12 ساعة. وبالمثل، أظهر التفاعل بين تركيز الزنك ووقت النقع أن النقع لمدة 12 ساعة مع 2 غم/لتر من الزنك أعطى أفضل النتائج. علاوة على ذلك، أثر التفاعل الثلاثي (الصنف × تركيز الزنك × مدة النقع) بشكل كبير على نسبة الإنبات والصفات ذات الصلة. نتج عن الصنف السوري، مع إضافة 2 غم/لتر زنك و12 ساعة من النقع، أعلى قيم لنسبة الإنبات وســـرعة الإنبات وطول الجذر وطول البراعم والوزن الجاف لكل من الجذر والبراعم. ومع ذلك، لوحظت أعلى أوزان للجذور والبراعم الطازجة في الصنف الروسي المعالج بـ 2 غم/لتر زنك ونقع لمدة 12 ساعة. ومن المثير للاهتمام، أن أعلى قيمة للشتلات سُجلت للصنف السوري عند 1 غم/لتر زنك مع مدة نقع (12 ساعة). تؤكد هذه النتائج على أهمية الصنف الأمثل ومدة التحضير وتركيز الزنك لتحسين نمو الشتلات.
الكلمات المفتاحية: الحبة السوداء؛ الأصناف؛ الزنك؛ تحضير البذور؛ الشتلات.

INTRODUCTION

Black seed (*Nigella sativa* L.), a spice crop widely used worldwide and a member of the Ranunculaceae family, it is particularly noteworthy for its many culinary and therapeutic applications (Mohamed et al., 2014). It is said to have originated in western Asia, where it grows both wild and under cultivation. Among the nations that cultivate it widely are those in Southwest Asia, South Europe, Syria, Egypt, Pakistan, India, Iran, Japan, China, and Turkey (Nemtinov et al., 2022). The use of *Nigella sativa* L. medicinal plants, particularly those with a diversity of biological activities, has attracted interest from all over the world due to its capacity to effectively treat a wide range of diseases (Kiralan et al., 2016). Historical narratives have contributed to this curiosity, especially the sayings attributed to the Prophet Muhammad that claim black seeds are a panacea for all ailments except death (Islam et al., 2019). Ustun et al. (2014) state that the seed, appropriately called the seed of blessing (habbatul barakah), has multiple uses in the medicinal and culinary industries and contains 30–35% oil. Due to the presence of numerous active components, *Nigella sativa* seed oil showed a wide range of pharmacological actions, including antiparasitic, antihypertensive, analgesic, antineoplastic, and antibacterial qualities against hepatotoxicity and nephrotoxicity (Abedi et al., 2017, Ketenoglu et al., 2020). Numerous biochemical and nutritional parameters are altered during seed germination, improving the nutritional state of the seed and having a favorable impact on human health. It is inexpensive and effective to use seed reserves to increase digestibility, increase nutritional values, and supply energy during respiration and the synthesis of new cells during embryo development. These actions reduce the quantity of phytic acid and tannin in the seed (Kumar & Anand, 2021). Although early plant development frequently contributes to the production of stronger and healthier plants, it may not always be correct to say that it directly raises yields. According to Tan Ugor (2024), early growth enables plants to develop more quickly and efficiently, which may increase productivity. The great growth and output of black seed are hindered by the development of seedlings and the germination of black seeds (Papastylianou et al., 2018). Cereals' dormant embryos can be managed chemically; for example, soaking the seeds in strong acids or specific organic solvents for a while can assist break the dormant phase (Gowthami and Vijaya, 2020). The current approach to cultivating medicinal plants emphasizes the use of modern, safe technologies to minimize pollution risks associated with traditional farming practices (Al-Qadi et al., 2024). Seed priming is an economical and effective way to encourage early crop growth and more consistent emergence in a range of field crops, including oilseeds. It treats seeds using a variety of osmotic, each with unique characteristics and degrees of effectiveness. The physiological status of the plant and the viability of the seeds are affected by priming and another hydration priming (Afzal, 2023; Thakur et al., 2024). Strong root development, emergence, and cumin seed germination are all improved by halopriming. Several priming methods have been found to positively affect seed germination and seedling growth in numerous studies (Paparella et al., 2015; Sharma et al., 2014; Khalaki et al., 2020). Due to the significant role that excessive use of chemical fertilizers plays in soil and environmental degradation (Muhammad & Al-Falahi, 2023), the concept of using zinc supplements emerged as a way to nourish crops with essential nutrients and minerals. Among many other benefits, priming seeds encourages improved stand development and faster, more reliable germination. Applying ZnCl2 and ZnSO4 in particular has been shown to increase stand establishment and seedling growth. (Rehman ,2015). Given its increasing importance in crop productivity in recent years, zinc is believed to be the element that most restricts agricultural yields. Since zinc is a necessary component of photosynthesis, a lack of it may contribute to lower plant vigor and, in turn, lower levels of photosynthesis in higher plants. A common occurrence in cases of severe zinc deficiency is the death of shoot tips. Young leaves that are poisoned with zinc turn yellow. Enhancing cereals with zinc via genetic and agricultural biofortification is a top research objective that will help lessen the health issues linked to zinc deficiency in both plant and human populations. (Dasm, 2018). The structural and functional components of several enzymes, such as RNA polymerase, alkaline phosphatase, phospholipase, carboxypeptidase, carbonic anhydrase, and alcohol dehydrase, generally contain zinc. Among zinc's functional activities include cytochrome synthesis, enzyme activity, auxin metabolism, and nitrogen metabolism (Aparna, 2021).

MATERIALS AND METHODS

This study was conducted at the Scientific Research Center/Erbil Polytechnic University in Erbil during the fall of 2024. The experimental setup used a completely randomized design (CRD) and included three factors: zinc concentrations (0,1,2,3 g l-1), priming time (0,6,9, and 12 hours), and three types of black seed (Russian, Syria, and locally). Using 144 experimental units based on the applied priming and three replications, the solutions are made in the lab in accordance with the zinc concentrations previously indicated. On January 11, 2024, the seeds were sown for a fifteen-day period. The following metrics, particularly those pertaining to seedling and germination, will be examined .

The data was statistically examined for each of the assessed characteristics (AL-Rawi et al., 2011), and Duncan's multiple range test (DMRT) was employed to compare the means at a significance level of 5%, in accordance with analyses of variance carried out using the Statistical Analysis System (SAS Institute, 2016). The three varieties of black seed were sent to laboratories to determine some qualitative characteristics such as the percentage of oil, protein and vitamins.

Study and measurements of characteristics:

1. Germination (%): It is measured by dividing the total number of seeds used by the number of germinated seeds, expressed as a percentage after 15 days. Germination percentage = seeds germinated/total seeds × 100 .
2. Germination time (day): The following formula, was used to determine Germination Time (MGT): GT= $\sum nD/n$ (day). where D is the number of days measured from the start of germination

and n is the number of seeds that germinated according to the day D observation (not the total number).

3. Speed of germination (seeds per day): The number of seeds that germinate daily from planting for up to 15 days is used to calculate the germination speed rate. Speed germination (S.G.) was computed using the formula below: Germination speed is calculated as the ratio of germination time (seeds per day) to germination percentage.
4. Root length (cm): The root length was measured after it reached the seedling stage.
5. Radicle length (c): The radicle length was measured after it reached the seedling stage.
6. Seedlings: When the plant reaches the seedling stage and shows the first true leaf after the cotyledons, the seedling is determined by summing the length of the radicle and the length of the shoot. Seedling = Root length + Radical length
7. Dry weight of the radicle: After measuring the radicle length, it was cut and dried by using an oven for 24 hours at a temperature of 80°C.
8. Dry weight of the shoot: After measuring the shoot length, it was cut and dried for 24 hours by using an oven at a temperature of 80°C.
9. Seedling vigor: After completing all measurements from germination to the seedling stage, seedling vigor was measured by multiplying the germination percentage by the sum of the radicle and shoot lengths. (Maaroof et al., 2025).

RESULTS AND DISCUSSION

Table No. 1 shows that the local variety outperformed the other varieties in terms of the presence of the substance (Palmatic, Stearic, Oleic, Lonoleic, Lenoleinic) %, reaching (16.757, 0.820, 13.910, 63.623, 1.610) %. This result is agreed with (Al-Doori, 2024) who showed different black seed varieties affected to content of fatty acids (Palmatic, Stearic, Oleic, Lonoleic) %. The same applies to the presence of vitamins, with the percentage of vitamins E, D, K, and A reaching (465.600, 426.920, 145.433, 109.243) ppm, respectively. This was followed by the Russian variety, where the percentage of the substance (Oleic, Lonoleic) % was high, reaching (13.553, 63.403) %, respectively. While the percentage of oil and protein was high in the Syrian variety, reaching (41.952, 24.216) %, respectively. This may be due to the genetic characteristics of the three varieties. The response of black seed (*Nigella sativa*) varieties to chemical composition refers to how different cultivars or genotypes of black seed vary in the type and concentration of bioactive compounds they produce; this variability can be influenced by genetics, environmental factors, and agronomic practices (Tawfik, et al., 2020)

Table No. 2 illustrates how three different *Nigella sativa* kinds differ in how they perceive germination and the time of day. The local variety was superior to the Syrian variety, and the Syrian variety was more important than the Russian and local variety. The germination percentage, time germination, speed germination, root length, shoot length, root fresh weight, root dry weight, shoot fresh weight, shoot dry weight, and seedling respective rates were 80.77%, 11.70 days, 7.25 seed days^{-1}, 4.77 cm, 4.95 cm, 0.030 g, 0.095 g, 0.087 g, 0.00058 g, and 9.73 cm. Black seed grows best in cool regions, in ordinary, well-drained soil with a moderate pH. Fertilize it, remove its withered flowers regularly, and water it during prolonged dry spells. Black seed is easy to grow from seed; this is consistent with research on the appropriate conditions for seed growth. (Alshammari, 2017). The concentration of zinc (2 g l^{-1}) was found to be superior to the concentrations of 1 g l^{-1} and 3 g l^{-1}. The corresponding rates of germination, time germination, speed germination, root length, shoot length, root fresh weight, root dry weight, shoot fresh weight, shoot dry weight, and seedling were 85.77 %, 10.33 days, 5.404 seed day^{-1}, 4.104 cm, 4.86 cm, 0.024 g, 0.084 g, 0.025 g, 0.00051 g, and 9.25 cm, respectively. This is in line with the findings of researcher (Ambreen et al., 2024), who found that adding 60 mg l-1 of zinc oxide nanoparticles (ZnO-NPs) increases secondary metabolites and callus growth, and (Javed et al., 2018) found that adding zinc oxide (ZnO) affects the renewal of callus leaves and the increase of important secondary metabolites like phenols, flavonoids, and antioxidants at a concentration of 10 mg l-1. For varying lengths of time, *Nigella sativa* seeds were soaked (0, 6, 9, and 12 hours).Then we noticed the best result from 12-hour soaking: germination percentage 83.47%, time to germination 11.25 days, speed of germination 7.54 seed days-1, root length 4.25 cm, shoot length 4.807cm, root fresh weight 0.026g, root dry weight 0.088g, shoot fresh weight 0.028g, shoot dry weight 0.0019 g, and seedling 9.057 cm. Black seed's physicochemical and phytochemical characteristics were greatly impacted by soaking and sprouting. During and after soaking and germination, there was unquestionably a large decrease in antinutritional components like tannins and phytic acid, as well as a significant decrease in a number of other metrics like antioxidant activity, total phenolics, and flavonoids. This will increase the usage of black seed flour in the food business by improving the quality of its processing. It is possible to increase the soaking period to 18 hours (Suri et al., 2019).

Table 1. Effect of black seed varieties on seed quality.

Varieties	Oil%	Palmatic %	Stearic%	Oleic%	Lonoleic %	Lenoleinic %	Protein%	Vit E ppm	Vit D ppm	Vit K ppm	Vit A ppm
Russian	37.04 c	16.326 b	0.746 b	13.55 a	63.403 a	1.290 b	19.516 b	459.433 a	422.847 b	142.486 b	105.633 b
Syrian	41.95 a	15.532 c	0.693 b	12.62 b	62.523 b	0.976 c	24.216 a	451.000 b	413.443 c	140.553 b	102.567 c
Locally	39.11 b	16.757 a	0.820 a	13.91 a	63.623 a	1.610 a	18.550 c	465.600 a	426.920 a	145.433 a	109.243 a

Table 2. Effect of black seed varieties to seed priming with zinc on germination and seedling parameters

Priming	Germination %	Time Germination Day	Speed germination-seed day^{-1}	Root length cm	Shoot length cm	Root fresh weight g	Root dry weight g	Shoot fresh weight g	Shoot dry weight g	Seedling cm
Russian	79.27 b	11.45 a	7.00 b	3.85 c	4.63 b	0.019 c	0.055 b	0.020 b	0.00064a	8.58 b
Syrian	80.77 a	11.70 a	7.25 a	4.77 a	4.95 a	0.030 a	0.095 a	0.087 a	0.00058 a	9.73 a
Locally	80.66 a	11.66 a	7.13 ab	4.32 b	4.73 b	0.026 b	0.063 b	0.019 b	0.0021 a	8.96 b
Zn 0	78.27 c	11.000 c	6.83 c	4.33 a	4.709 b	0.023 b	0.069 a	0.018 b	0.00049 a	9.047 a
Zn 1	84.0000 b	11.55 b	7.74 b	4.52 a	4.79 ab	0.022 b	0.066 a	0.016 b	0.00050 a	9.17 a
Zn 2	85.77 a	10.33 d	5.404 d	4.104 a	4.86 a	0.024 b	0.084 a	0.025 b	0.00051 a	9.25 a
Zn 3	72.88 d	13.55 a	8.53 a	4.301 a	4.72 b	0.031 a	0.064 a	0.010 a	0.0029 a	8.9 a
Soaking 0	77.41 d	12.36 a	6.602 c	4.45 a	4.81 a	0.025 a	0.0707 b	0.017 a	0.00051 a	9.27 a
Soaking 6	79.41 c	11.305 b	6.93 b	4.17 a	4.74 a	0.024 a	0.056 b	0.049 a	0.000502 a	8.92 a
Soaking 9	80.63 b	11.52 b	7.402 a	4.38 a	4.72 a	0.025 a	0.0807 ab	0.073 a	0.0014 a	9.11 a
Soaking 12	83.47 a	11.25 b	7.54 a	4.25 a	4.807 a	0.026 a	0.088 a	0.028 a	0.0019 a	9.057 a

According to the data in **Table 3**, there is a substantial interaction between the variety and concentration priming. The maximum value of the priming under study was obtained for the Syrian variety utilizing the second concentration of zinc (2 g l^{-1}), where the rate of each of the germination %, time germination, speed germination, root length, shoot length, root fresh weight, root dry weight, shoot fresh weight, shoot dry weight, and seedling was 87.75 %, 9.91 days , 8.84 seed-days^{-1}, 5.28 cm, 5.033 cm, 0.0405 g, 0.12 g, 0.27 g, 0.0075 g, and 10.11cm, respectively. When the Syrian variety's seeds were soaked for 12 hours, the interaction between the varieties and the soaking time was at its peak, with the rate of each of the following: Germination %, time germination, speed germination, root length, shoot length, root fresh weight, root dry weight, shoot fresh weight, shoot dry weight, Seedling was 84.58%, 11.0000 days, 7.78 seed-days^{-1}, 4.78 cm, 4.99 cm , 0.033 g, 0.13 g, 0.022 g, 0.00059, and 10.078 cm, respectively. As for the interaction between the concentration priming and the soaking method, it is significant, and the best results were when using the concentration of 2 g l-1 and the soaking period for 12 hours, and the results for the characteristics reached 90.55%, 8.77 days, 9.92 seed-days-1, 4.62 cm, 4.98 cm, 0.035 g, 0.15 g, 0.24 g, 0.0064 g, and 9.52cm. These findings are in line with those of (Ekren et al.,2023), who found that using plant growth stimulants improves seed quality, speeds up germination, and lowers disease infection. To solve the issues brought on by the seed, numerous researchers have been focusing on enhancing seed quality in recent years. To address these issues and get the required level of seed quality, it is consistent with what the researcher (Davoodi, 2020) found that applying zinc in the form of nanoparticles will have a positive effect on the quantitative performance of black seed. When applied to black seed under salt stress, hydropriming and $ZnSO_4$ had a greater impact than the control (Ahmadian et al., 2015).

The results are shown in **Table 4.** It was found that the Syrian variety with 2 g zinc concentration and 12 hours of seed soaking gave the highest germination percentage and speed of germination (92.66 % and 10.72) respectively, compared with seeds primed by Russian variety with 2 g zinc concentration and 12 hours of seed soaking (68.33% and 4.90). The long day formed to germinate the seeds was recorded at priming the seeds by interactions between 3 g zinc concentration and 12 hours of seed soaking from local variety (14.66 days), but the short day formed to germinate the seeds was recorded at priming the seeds by interactions between 1 g zinc concentration and 12 hours of seed soaking from Russian variety (8.66 days). This might be due to the synthesis of some metabolites on these days of germination, which could act by inhibiting cell wall synthesis or by inducing changes in membrane structure (Kamal et al., 2010). Root length and shoot length are the longest when the Syrian variety is primed with a 2 g zinc concentration and 12 hours of seed soaking (6.33 and 5.40 cm) respectively, and the shortest root length and shoot length (2.8 and 4.25 cm) respectively are recorded from the Local variety with 0 g zinc concentration and 0 hours of seed soaking .

The results from the triple interaction between Russian variety with 2 g zinc concentration and seed soaking for about 12 hours have significantly affected the highest root fresh weight and shoot fresh weight recorded (0.053 and 0.70 g) respectively, and the lowest root fresh weight and shoot fresh weight recorded (0.011 and 0.010 g) respectively for priming the Local variety with 3 g zinc concentration and 0 hours of seed soaking. As well as the highest weight of root dry weight and shoot dry weight was recorded at priming the seeds by interactions between 2 g zinc concentration and 12 hours of seed soaking from the Syrian variety (0.29 and 0.018 g) respectively but the lowest weight formed to root dry weight and shoot dry weight was recorded at priming the seeds by interactions between 3 g zinc concentration and 12 hours of seed soaking from Russian variety (0.0223 and 0.00010 g). The length of the seedling is the longest when primed with the Syrian variety with a 1 g zinc concentration and 12 hours of seed soaking (11.51 cm), and the shortest length is recorded from the Local variety with a 1 g zinc concentration and 0 hours of seed soaking (7.21 cm). Ghassemi-Golezani et al. (2010) evaluate the effect of different types of seed priming on seed priming, decreased mean germination time, and increased seedling compared with unprimed seeds.

Table 3. Effect of interaction between black seed varieties to seed priming with zinc on germination and seedling parameters

Priming		Germin ation %	Time day	Speed seed/day	Root length cm	Shoot length cm	Root fresh whieght g	Root dry whieght g	Shoot fresh whieght g	Shoot dry whieght g	Seedling cm
Russian	Zn 0	77.33 e	12.16 b	6.38 d	4.507 bcd	4.402 f	0.0304 b	0.032 b	0.0205 b	0.00067 b	8.909 b-e
	Zn 1	83.41 c	10.33 e	7.95 b	4.95 abc	4.74 b-e	0.025 bc	0.057 b	0.013 b	0.00060 b	9.48 abc
	Zn 2	84.25 bc	10.91 d	8.17 b	3.64 ef	4.95 ab	0.026 bc	0.063 b	0.038 b	0.00064 b	9.704 ab
	Zn 3	72.083 g	13.25 a	5.48 e	4.18 cde	4.88 abc	0.026 bc	0.068 b	0.022 b	0.00065 b	9.069 bcd
Syrian	Zn 0	78.91 d	11.33 cd	7.005 c	4.45 bcd	4.51 ef	0.026 bc	0.0741 b	0.018 b	0.00052 b	8.15 ef
	Zn 1	84.75 bc	11.0000 d	7.75 b	5.055 ab	4.99 a	0.029 b	0.12 a	0.021 b	0.00055 b	10.050 a
	Zn 2	87.75 a	9.91 e	8.84 a	5.28 a	5.033 a	0.0405 a	0.12 a	0.27 a	0.0075 a	10.11 a
	Zn 3	73.66 f	13.58 a	5.43 e	4.32 b-e	4.82 a-d	0.022 c	0.056 b	0.018 b	0.00058 b	9.27 abc
Locally	Zn 0	78.58 d	11.16 cd	7.098 c	4.052 def	4.69 cde	0.016 d	0.051 b	0.015 b	0.00028 b	8.74 c-f
	Zn 1	83.83 c	11.66 bc	7.29 c	3.34 f	4.72 b-e	0.014 d	0.066 b	0.017 b	0.00033 b	7.94 f
	Zn 2	85.33 b	10.16 e	8.81 a	4.35 b-e	4.91 abc	0.025 bc	0.074 b	0.031 b	0.00068 b	9.26 abc
	Zn 3	72.91 fg	13.83 a	5.29 e	3.66 ef	4.600 def	0.022 c	0.063 b	0.013 b	0.00021 b	8.39 def
Russian	Soaking 0	77.083 e	12.16 ab	6.74 def	3.95 cd	4.54 d	0.029 ab	0.042 b	0.015 b	0.00056 a	8.57 bc
	Soaking 6	78.33 e	11.41 cd	6.89 cde	4.057 bcd	4.62 cd	0.028 abc	0.057 b	0.11 ab	0.00065 a	8.602 bc
	Soaking 9	79.66 d	11.83 bc	7.12 bcd	4.61 abc	4.64 cd	0.031 ab	0.058 b	0.18 a	0.00065 a	9.31 ab

Priming		Germin ation %	Time day	Speed seed/day	Root length cm	Shoot length cm	Root fresh whieght g	Root dry whieght g	Shoot fresh whieght g	Shoot dry whieght g	Seedling cm
	Soaking 12	82.0000 b	11.25 cd	7.23 bc	4.66 abc	4.73 cd	0.027 a	0.063 b	0.036 b	0.000708 a	9.34 ab
Syrian	Soaking 0	77.83 e	12.16 ab	6.63 ef	4.62 abc	5.14 a	0.022cde	0.063 b	0.17 b	0.00065 a	9.29 ab
	Soaking 6	79.6 d	11.33 cd	7.19 bcd	4.47 abc	4.82 bc	0.026 bcd	0.065 b	0.019 b	0.00052 a	9.76 a
	Soaking 9	81.33 bc	11.33 cd	7.45 ab	5.23 a	4.84 bc	0.027a-d	0.11 a	0.021 b	0.00057 a	9.78 a
	Soaking 12	84.58 a	11.0000 d	7.78 a	4.78 ab	4.99 ab	0.033 a-d	0.13 a	0.022 b	0.00059 a	10.078 a
Locally	Soaking 0	77.33 e	12.75 a	6.805c-f	3.35 d	4.66 cd	0.018 e	0.058 b	0.016 b	0.00018 a	8.0400 c
	Soaking 6	80.25 cd	11.5000 cd	6.42 f	3.87 cd	4.69 cd	0.017 e	0.061 b	0.016 b	0.00026 a	8.65 bc
	Soaking 9	80.91 bcd	11.41 cd	7.52 ab	4.085 bcd	4.78 bcd	0.021 de	0.065 b	0.14 b	0.0032 a	8.75 bc
	Soaking 12	83.83 a	11.16 cd	7.72 a	4.1008 bcd	4.79 bc	0.022 de	0.0701 b	0.0305 b	0.0047 a	8.89 bc
Zn 0	Soaking 0	74.77 fg	11.44 cd	6.55 f	4.47 a	4.804 abc	0.027 b-e	0.043 b	0.016 b	0.00046 b	9.41 a
	Soaking 6	78.55 e	11.77 bc	6.69 f	4.32 a	4.69 abc	0.019 g	0.037 b	0.025 b	0.00056 b	9.020 a
	Soaking 9	80.77 d	11.55 cd	7.076 def	4.309 a	4.63 bc	0.024 c-g	0.042 b	0.015 b	0.00039 b	8.94 a
	Soaking 12	79.000 e	11.44 cd	6.99 ef	4.104 a	4.802 abc	0.026 b-g	0.058 b	0.015 b	0.00055 b	9.24 a

Priming		Germin ation %	Time day	Speed seed/day	Root length cm	Shoot length cm	Root fresh whieght g	Root dry whieght g	Shoot fresh whieght g	Shoot dry whieght g	Seedling cm
Zn 1	Soaking 0	82.66 c	10.33 e	6.91 f	4.73 a	4.91 ab	0.027 b-e	0.076 b	0.015 b	0.00042 b	9.65 a
	Soaking 6	84.0000c	11.0000de	7.65 bc	4.28 a	4.63 bc	0.019 g	0.063 b	0.016 b	0.00047 b	8.91 a
	Soaking 9	82.88 c	11.22 cd	7.77 bc	4.61 a	4.55 c	0.0201 efg	0.057 b	0.020 b	0.00052 b	9.16 a
	Soaking 12	86.44 b	9.22 f	9.85 a	4.61 a	4.69 abc	0.032 ab	0.142 a	0.13 ab	0.0043 ab	9.27 a
Zn 2	Soaking 0	80.55 d	10.88 de	7.45 cde	4.46 a	4.78 abc	0.028 a-d	0.068 b	0.020 b	0.00070 b	8.62 a
	Soaking 6	86.33 b	12.44 b	7.51 bcd	4.010 a	4.84 abc	0.021 d-g	0.058 b	0.022 b	0.00045 b	8.85 a
	Soaking 9	85.66 b	11.44 cd	8.016 b	4.15 a	4.72 abc	0.031 abc	0.077 b	0.015 b	0.00046 b	8.87 a
	Soaking 12	90.55 a	8.77 e	9.92 a	4.62 a	4.98 a	0.035 a	0.15 a	0.24 a	0.0064 a	9.52 a
Zn 3	Soaking 0	71.66 h	12.33 b	5.82 g	4.02 a	4.77 abc	0.019 efg	0.067 b	0.0202 b	0.00047 b	8.79 a
	Soaking 6	73.66 g	13.66 a	5.39 gh	4.076 a	4.82 abc	0.024 c-g	0.065 b	0.014 b	0.00051 b	8.902 a
	Soaking 9	76.11 f	14.11 a	5.41 gh	4.48 a	4.83 abc	0.026 b-f	0.065 b	0.045 b	0.00043 b	9.46 a
	Soaking 12	70.11 i	14.11 a	4.98 h	3.79 a	4.89 ab	0.024c-g	0.066 b	0.037 b	0.00058b	8.804a

Table 4. Effect of triple interaction between black seed varieties to seed priming with zinc on germination and seedling parameters

Varieties * Zinc concentration* Seed soaking			Germination %	Time day	Speed seed/day	Root length cm	Shoot length cm	Root fresh weight g	Root dry weight g	Shoot fresh weight g	Shoot dry weight g	Seedling cm
Russian	Zn 0	Soaking 0	75.33 r-u	11.33 e-i	6.65 i-n	4.20 e-n	4.80a-f	0.034 b-e	0.028 b	0.01 c	0.0007 b	8.45 g-o
		Soaking 6	77.33 o-r	12.33 c-f	6.28 l-q	3.98 e-n	4.31 no	0.020 f-n	0.028 b	0.04 c	0.0007 b	8.30 h-o
		Soaking 9	79.33 nop	12.33 c-f	6.47 j-o	3.65 g-n	4.38 l-o	0.030 b-i	0.022 b	0.01 c	0.0003 b	8.04 j-o
		Soaking 12	77.33 o-r	12.66 b-e	6.14 m-r	6.18ab	4.65 d-o	0.036 bcd	0.052 b	0.01 c	0.0007 b	10.83 abc
	Zn 1	Soaking 0	81.33 j-n	10.33 h-k	7.88 efg	6.05 a-d	5.10 a-e	0.031 b-h	0.026 b	0.01 c	0.0006 b	11.15 ab
		Soaking 6	84 f-j	11.33 e-i	7.42 f-i	4.40 e-n	4.89 a-l	0.017 i-n	0.054 b	0.01 c	0.0005 b	9.29 b-m
		Soaking 9	85.66 d-g	11 f-j	7.83 e-h	4.83 a-j	4.51 h-o	0.022 e-n	0.058 b	0.01 c	0.0005 b	9.34 b-l
		Soaking 12	82.66 h-l	13.33 a-d	9.56 bc	4.53 b-l	4.49 i-o	0.029 b-i	0.078b	0.01 c	0.0006 b	9.03 c-o
	Zn 2	Soaking 0	80 l-o	11.66 e-h	6.87 h-m	4.99 a-j	4.39 l-o	0.029 b-i	0.068 b	0.01 c	0.0008 b	9.38 b-l
		Soaking 6	84 f-j	8.66 l	9.72 b	3.56 g-n	4.46 j-o	0.037 b	0.069 b	0.01 c	0.0001 b	8.03 j-o
		Soaking 9	88 cd	10 i-l	8.85 cd	3 k-n	4.33 mno	0.041 b	0.083 b	0.02 b	0.0006 b	7.33 no
		Soaking 12	68.33 y	8.66 l	4.90 s	3.01k-n	4.87 b-l	0.053 a	0.053 b	0.70 a	0.0005 b	7.88 l-o

Varieties * Zinc concentration* Seed soaking			Germination %	Time day	Speed seed/day	Root length cm	Shoot length cm	Root fresh weight g	Root dry weight g	Shoot fresh weight g	Shoot dry weight g	Seedling cm
	Zn 3	Soaking 0	71.66 wx	11.66 e-h	6.15 m-r	3.43 g-n	4.83 b-n	0.021 e-n	0.069 b	0.01 c	0.0005 b	8.26 h-o
		Soaking 6	73.33 s-w	13.33 a-d	5.50 o-s	3.85 f-n	4.82 b-n	0.024 c-n	0.065 b	0.36 b	0.0006 b	8.67 e-o
		Soaking 9	75 r-v	14 ab	5.36 qrs	4.74 a-j	4.95 a-j	0.032 b-g	0.069 b	0.10 c	0.0006 b	9.69 a-l
		Soaking 12	85.00e-i	14 ab	6.38k-p	4.72 a-j	4.92 a-k	0.029 b-i	0.022 b	0.02 c	0.0007 b	9.64 b-l
Syrian	Zn 0	Soaking 0	76 qrs	11.33 e-i	6.72 i-k	4.86 a-j	5.07 a-g	0.029 b-i	0.036 b	0.01 c	0.0004 b	9.93 a-j
		Soaking 6	78.66 n-q	11.33 e-i	6.95 g-m	4.51 b-m	5 a-i	0.024 c-n	0.041 b	0.02 c	0.0005 b	9.51 b-l
		Soaking 9	80.33 k-n	12 d-g	6.73 i-m	5.10 a-h	5.02 a-h	0.029 b-i	0.062 b	0.02 c	0.0005 b	10.13 a-h
		Soaking 12	80.66 k-n	10.66 g-j	7.61 e-i	3.33 i-n	5.03 a-h	0.023 d-n	0.055 b	0.01 c	0.0006 b	8.36 h-o
	Zn 1	Soaking 0	84 f-j	10.33 h-k	8.14 def	4.76 a-g	5.22 ab	0.027 c-k	0.069 b	0.1 c	0.0004 b	9.99 a-i
		Soaking 6	85.33 d-h	11.33 e-i	7.54 e-i	4.66 a-k	4.32 no	0.026 c-l	0.069 b	0.02 c	0.0006 b	8.98 c-o
		Soaking 9	87.33 cde	10.33 h-k	8.47 de	6.13 abc	4.59 e-o	0.026 c-l	0.064 b	0.03 c	0.0005 b	10.74 a-d
		Soaking 12	82.33 i-m	12 d-g	6.68 h-l	5.59 a-e	5.15 a-d	0.023 c-n	0.081 b	0.01 c	0.0006 b	11.74 a

Varieties * Zinc concentration* Seed soaking			Germination %	Time day	Speed seed/day	Root length cm	Shoot length cm	Root fresh weight g	Root dry weight g	Shoot fresh weight g	Shoot dry weight g	Seedling cm
	Zn 2	Soaking 0	78.66 n-q	9.66 jkl	8.16 def	5.02 a-i	5.40 a	0.032 b-f	0.083b	0.02 c	0.001 b	10.42 a-f
		Soaking 6	85.66 d-g	9 l	9.91 ab	4.04 e-n	5.20 abc	0.030 b-i	0.081 b	0.02 c	0.0006 b	9.24 c-n
		Soaking 9	86 def	9 kl	6.98 g-m	4.31 e-n	4.61 e-o	0.028 c-j	0.075 b	0.01 c	0.0006 b	8.91 d-o
		Soaking 12	92.66a	12.33 c-f	10.72 a	6.33 a	5.40 a	0.027 c-k	0.29 a	0.01 c	0.018 a	8.52 f-o
	Zn 3	Soaking 0	72.66 uvw	12.66 b-e	5.74 n-s	3.90 f-n	4.87 b-l	0.018 h-n	0.044 b	0.02 c	0.0016 b	8.71 e-o
		Soaking 6	75.66 rst	14 ab	5.40 p-s	4.66 a-k	4.78 b-n	0.028 b-j	0.063 b	0.01 c	0.0006 b	10.74 a-d
		Soaking 9	79.66 pqr	14 ab	5.50 o-s	4.74 a-j	5.14 a-d	0.025 c-m	0.060 b	0.01 c	0.0006 b	10.53 a-e
		Soaking 12	69.66 xy	13.66 abc	5.10 s	3.90f-n	4.62d-o	0.016 i-n	0.075 b	0.01 c	0.0003 b	10.74 a-d
Locally	Zn 0	Soaking 0	73 t-w	11.66 e-h	6.27 l-q	2.8 a-j	4.25 o	0.020 f-n	0.065 b	0.01 c	0.0002 b	9.86 a-k
		Soaking 6	79.66 mno	11.66 e-h	6.86 h-m	4.46 c-n	4.77 b-o	0.014 k-n	0.041 b	0.01 c	0.0004 b	9.24 c-n
		Soaking 9	82.66 h-l	10.33 h-k	8,02 def	4.16 e-n	4.50 h-o	0.015 j-n	0.044 b	0.03 c	0.0002 b	8.67 e-o
		Soaking 12	79 nop	11 f-j	7.23 f-l	2.80 n	4.41 k-o	0.018 g-n	0.055 b	0.01 c	0.0002 b	7.21 o

Varieties * Zinc concentration* Seed soaking			Germination %	Time day	Speed seed/day	Root length cm	Shoot length cm	Root fresh weight g	Root dry weight g	Shoot fresh weight g	Shoot dry weight g	Seedling cm
	Zn 1	Soaking 0	82.66 g-k	10.33 h-k	8.02 def	3.40 h-n	4.41 k-o	0.023 d-n	0.069 b	0.01c	0.0006 b	7.81 l-o
		Soaking 6	82.66 h-l	10.33 h-k	8.01 def	3.80 f-n	4.67 c-o	0.013 lmn	0.067 b	0.01 c	0.0002 b	8.47 g-o
		Soaking 9	86.33 def	12.33 c-f	7.01 g-m	2.86 lnm	4.54 g-o	0.018g-n	0.049 b	0.01 c	0.0004 b	7.41 mno
		Soaking 12	83.66 f-j	13.66 abc	6.13 m-r	3.30 j-n	4.76 b-o	0.012 mn	0.068 b	0.01 c	0.0004 b	8.06 i-o
	Zn 2	Soaking 0	83 g-k	11.33 e-i	7.34 f-l	3.36 i-n	4.56 f-o	0.024 c-n	0.054 b	0.01 c	0.0002 b	7.93 k-o
		Soaking 6	89.33 bc	9 kl	9.92 ab	4.42 d-n	4.86 b-l	0.022 e-n	0.070 b	0.01 c	0.0001 b	9.28 b-m
		Soaking 9	91ab	8.66 l	10.19ab	5.14 a-g	5.23 ab	0.023 c-n	0.072 b	0.01 c	0.0001 b	10.37 a-g
		Soaking 12	86 def	11.66 e-h	7.38 f-j	4.48 c-n	5 a-i	0.032 b-f	0.067 b	0.01 c	0.0003 b	9.48 b-l
	Zn 3	Soaking 0	70.66 wxy	12.66 b-e	5.58 o-s	4.79 a-j	4.60 e-o	0.011 n	0.09 b	0.01 c	0.0001 b	9.4 b-l
		Soaking 6	72 wx	13.66 abc	5.27 rs	3.71 f-n	4.86 b-l	0.021 e-n	0.068 b	0.02 c	0.0002 b	8.58 f-o
		Soaking 9	79.66 pqr	14.33 a	5.37 qrs	3.33 i-n	4.85 b-m	0.022 e-n	0.66 b	0.01 c	0.0002 b	8.18 i-o
		Soaking 12	72.33 vwx	14.66 a	4.49 s	2.82 mn	5.58 e-o	0.025 c-m	0.071 b	0.07 c	0.0011 b	7.40 mno

CONCLUSION:

The Syrian variety combined with 2 g l^{-1} zinc recorded the highest values for germination percentage, seedling length, root and shoot lengths, root fresh and dry weights, shoot fresh weight, and germination speed. The triple interaction of variety, zinc concentration, and soaking time significantly affected these traits. Maximum values for germination percentage, speed, root and shoot lengths, and dry weights were achieved with the Syrian variety at 2 g l^{-1} zinc and 12 hours of soaking. In contrast, the highest fresh weights of root and shoot were found in the Russian variety under the same zinc level and soaking time. Notably, the greatest seedling value appeared in the Syrian variety with 1 g l^{-1} zinc and no soaking.

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