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Response of some black seed (*Nigella sativa* L.) varieties to foliar application by zinc on growth, yield and seed quality planting in two locations

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ABSTRACT

Black seed (*Nigella sativa* L.) is an internationally important oil crop, field experiment was carried out at two locations in Erbil province, Kurdistan region-Iraq, at Grdarasha Research Field, Collage of Agricultural Engineering Sciences, is locating at 36. 40° N, 44.10° E and at an elevation 470m above sea level and at Khabat Technical Institute, and Khabat field is locating at 36. 27° N, 43.65° E and at an elevation 250m above sea level, during growing season of 2024-2025 to investigate the impact of spraying of different Zinc concentration were arranged with 4 levels (0, 100, 200 and 300ppm) on growth and yield component, fixed oil and protein seed content traits of three black seed varieties (Russian, Syrian and Local). The result of the study revealed that in both locations, the greater rates of most of growth parameters were found with Syrian and locally varieties at 300ppm. Yield contributing characters like No. of capsules plant^{-1}, No. of seeds capsule^{-1}, 1000 seed weight and seed yield, findings show that in grdarasha field Russian and local varieties occupy first position, but in khabat field Syrian was surpassed. In both locations the maximum production of yield parameters was obtained with zinc foliar application at 200 and 300ppm. For interaction, Syrian and local varieties with all Zinc spray was recorded the highest values. Fixed oil content (31.43%) recorded the maximum amount in Syrian variety and protein (22.66%) in local variety in Grdarsha field, while in khabat field Russian variety increased the oil to (30.21%) and protein for local to (24.33%), in both locations oil and protein content and their yield, 200 and 300 ppm selected the greater data. For interaction between treatments, all varieties had significant positive with all zinc spray. T-test analysis was used to compare between the field locations, results show on No. of branches and oil content had significant differences between the two fields.

KEYWORDS: Black seed, *Nigella sativa* L., Varieties, Fixed Oil, Zinc spraying.

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استجابة بعض أصناف حبة البركة (*Nigella sativa* L.) للرش الورقي بالزنك من حيث النمووالإنتاجية وجودة البذور المزروعة في موقعين

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الملخص

الحبة السوداء(*Nigella sativa* L) هو محصول زيتي ذو أهمية دولية أجريت تجربة حقلية في موقعين،في محافظة اربيل-اقليم كردستان العراق, هما حقل كردارشا البحثي التابع لكلية علوم الهندسة الزراعية، ومعهد خبات التقني، خلال موسم النمو 2024-2025، لدراسة تأثير رش تراكيز مختلفة من الزنك (0، 100، 200، و300 جزء في المليون) على نمو ومكونات المحصول، ومحتوى الزيت والبروتين في بذور ثلاثة أصناف من حبة البركة (روسية، سورية، ومحلية). أظهرت نتائج الدراسة أن معظم معايير النمو كانت أعلى في كلا الموقعين للصنفين السوري والمحلي. أدى رش الزنك الورقي إلى زيادة معنوية في جميع سمات النمو المدروسة، وخاصة عند تركيز 300 جزء في المليون. وسجل التفاعل بين المعاملات أعلى إنتاجية للصنفين السوري والمحلي عند تركيز 300 جزء في المليون. وشملت سمات المحصول المؤثرة عدد الكبسولات في النبات، أظهرت نتائج تحليل وزن 1000 بذرة وإنتاجية البذور، باستخدام كبسولة بذور واحدة، أن الأصناف الروسية والمحلية احتلت المرتبة الأولى في حقل جردارشا، بينما تفوقت عليها الأصناف السورية في حقل خابات. في كلا الموقعين، تم الحصول على أعلى إنتاجية للمعايير

الإنتاجية باستخدام رش الزنك الورقي بتركيز 200 و300 جزء في المليون. بالنسبة للتفاعل بين المعاملات، سجلت الأصناف السورية والمحلية أعلى القيم مع جميع أنواع رش الزنك. سجل محتوى الزيت (31.43%) أعلى نسبة في الصنف السوري، بينما سجل محتوى البروتين (22.66%) أعلى نسبة في الصنف المحلي في حقل جردارشا. أما في حقل خابات، فقد زاد محتوى الزيت في الصنف الروسي إلى 30.21%، ومحتوى البروتين في الصنف المحلي إلى 24.33%. في كلا الموقعين، سجل تركيزا 200 و300 جزء في المليون أعلى القيم لمحتوى الزيت والبروتين وإنتاجيتهما. بالنسبة للتفاعل بين المعاملات، أظهرت جميع الأصناف تأثيرًا إيجابيًا معنويًا مع جميع أنواع رش الزنك. تم استخدام اختبار **T** للمقارنة بين موقعي الحقلين، وأظهرت النتائج وجود فروق معنوية في عدد الفروع ومحتوى الزيت بين الحقلين.
الكلمات المفتاحية: حبة البركة، أصناف، زيت، رش الزنك.

INTRODUCTION

Nigella sativa L. (black seed or black cumin), which belongs to the Ranunculacea family, which grows in west Asia and Mediterranean region, is an annual herb plants studied due to its importance in phytochemical and pharmaceutical aspects (Tavakkoli et al., 2017). More than 2000 years ago, *Nigella sativa* seeds and oil were used in traditional medicine, a variety of active substances found in this plant, including thymoquinone, alkaloids (nigellicines and nigelledine), saponins (alpha-hederin), flavonoids, proteins, fatty acids, and many more, have been shown to be effective in the treatment of patients with a variety of disorders (Prajapati et al., 2023). *Nigella sativa* has been used since ancient times, black seeds and its oil have been used for centuries in the treatment of various diseases worldwide for the treatment of human illnesses and alleviation of their sufferings was yet to be developed, also seeds of this plant shows a wide range of antibacterial, antitumor, anti-inflammatory, hypoglycemic, muscle relaxant and immune stimulant activities (Ahmad et al., 2021 and Ferizi et al., 2023).

Zinc (Zn) is an essential element for plant that act as a metal component of various enzymes or as a functional structural or regulatory cofactor and for protein synthesis, photosynthesis, the synthesis of auxin, cell division, the maintains of membrane structure and function, metabolic processes, sexual fertilization and many physiological functions its inadequate supply will reduce crop yields (Rudani et al., 2018). Zinc deficiencies can affect plant by stunting its growth, decreasing number of tillers, chlorosis and smaller leaves, increasing crop maturity period, spikelet sterility and inferior quality of harvested products. Besides its role in crop production (Hafeez et al., 2013).

The primary determinants of plant growth and development, physiological growth, active substance synthesis, and the quantity and quality of extracted essential oil are climate and soil conditions. In particular, compared to other plants, the impact of ecological conditions on the production and essential oil of medicinal plants is greater. Even if a plant has a very large output, it cannot be cultivated if its quality is below a specific level since the quality of medicinal and aromatic herbs is just as important as its yield. As a result, they should only be grown in areas that are suitable for these plants' ecologies (Kara et al., 2015).

In the field experiment was take place to show the influence of fertilizer foliar application treatments (Zinc 1.5%) on the growth, fixed oil and fatty acids contents of two species of (*Nigella* *sativa* and *Nigella damascene*) plants. Results revealed that the foliar application, show a significant impact on the growth characters, fixed oil and fatty acids contents of both *Nigella sativa* and *Nigella damascene* (Hendawy et al., 2012). Ali et al. (2015) in their study on the effect of foliar spray of zinc application (50, 75, 100, 150 and 200 ppm) on growth, yield, yield components and oil percentage of black cumin crop plants. Results observed significant differences on capsules per plant, seeds per capsule, 1000 seeds weight, oil percentage and oil yield. where the lowest levels recorded with control and the maximum levels obtained with 200 ppm Zn foliar application which increased oil yield to 237.04 (Kg ha^{-1}). In field experiments were carried out to study the response of two species, *Nigella sativa* L. and *Nigella arvensis* L. within different sowing dates. Results showed that, due to the favorable environmental condition and the longer period of growth at autumn cultivation, most of the yield traits were gained significant values as the average of both species and different sowing dates of autumn compared to that occurred at spring cultivations. Some chemical contents of both species under the different environment conditions showed significant differences. Generally, N. sativa compared to N. arvensis contained more significant chemical compounds in the term of carbohydrates and protein at autumn, fixed and volatile oils at spring (Al-Zubaidy et al., 2020). In the study about of the effects of foliar application of urea and zinc solutions on crop performance and on seed and essential oil yield of black cumin (*Nigella sativa* L.) under different planting dates remains underexplored. Among foliar treatments, zinc (3 kg ha^{-1}) enhanced 1000-seed weight, seed yield, and oil yield relative to the control, with the highest seed oil content (26.4%) (Shafagh-Kolvanagh et al., 2024).

The aim of this study to evaluate the appropriate varieties, due the lack of studies on these varieties and uses in our region, however there a few researches on their growth and development. To determinate the suitable location for the plant growth and development, with selecting the best level of zinc with respect to growth and yield performance.

MATERIALS AND METHODS

Study Site

This experiment was conducted in two locations at Grdarasha Research Field, Collage of Agricultural Engineering Sciences, Salahaddin University – Erbil and at Khabat Technical Institute /Erbil- Polytechnic University, during November 15th, 2024 to May 14th, 2025 to study the effect of foliar application of zinc on some growth and yield traits of black seed varieties (Nigella sativa L.), Grdarasha Research Field is locating at 36. 40^{o} N, 44.10^{o} E and at an elevation 470m above sea level and Khabat field is locating at 36. 27^{o} N, 43.65^{o} E and at an elevation 250m above sea level. Representative air – dried soil sample was taken from both fields at the depth (0-30cm), then sieved with 2mm mesh and analyzed for some physical and chemical properties as shown in Table (1 and 2). Minimum and maximum temperature, the relative moisture and the amount of rain fall of both fields in planting season are shown in Table (3).

Table 1. Some chemical and physical properties of the field soil of Grdarasha

Depth	Particle size distribution (%) Sand	Silt	Clay	Texture Class	pH	EC ds m^{-1}	Organic Matter (%)	N (ppm)	P (ppm)	K (ppm)
	g kg^{-1} (soil)									
0-30	12.5	42.5	45	clay Silty loam	7.5	0.38	0.91	89.17	5.36	64.10

Table 2. Some chemical and physical properties of the field soil of Khabat

Depth	Particle size distribution (%) Sand	Silt	Clay	Texture Class	pH	EC ds m^{-1}	Organic Matter (%)	N (ppm)	Available (P) (ppm)	K+ (ppm)
	g kg^{-1} (soil)									
0-30	6	50	44	Silty clay	7.5	1.3	1.1	2700	3.76	8.6

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Table 3. Maximum and Minimum temperature, relative moisture and the amount of rain fall during the growing season

Months (2024-2025)	**Grdarasha Field**				**Khabat Field**			
	Air Temp. C° Minimum	**Maximum**	**Relative moisture %**	**Rainfall (mm)**	**Air Temp. C° Minimum**	**Maximum**	**Relative moisture %**	**Rainfall (mm)**
November	10.2	19.9	54.4	25.6	10.5	18.7	70.3	45.5
December	7.9	17.1	69.4	20.3	8.3	14.2	72.7	15
January	4.9	15.5	45.7	26.1	6.3	12.2	73.5	34
February	4.0	12.6	41.6	31.7	7.2	15.3	72.2	40.5
March	11.2	22.0	35.8	26.6	9.4	18.6	71.2	10
April	15.9	26.2	33.7	34.4	12.4	26.1	57.8	20
May	22.6	34.7	18.6	15.1	22.2	32.7	45.1	6
June	26.7	39.3	10.7		26.2	37.8	40.7	

*Data source: Meteorological Directory- Erbil province

The land was ploughed with two perpendicular lines and the soil was well softened with

Rotavator plow to erosion control and conservation of soil moisture. land divided in to plots with dimensions (1m × 1m) area and 25cm distance between rows and 20cm between plants, 20plants for each plot, with three replications resulting, 36 experimental unit, for each site.

Experiment Factors

Three black seed varieties (Russian, Syrian and Locally) were chosen for this study. Pure zinc was used with different levels (0, 100, 200 and 300 ppm) by foliar application. Seeds were sown in on November 15th, 2024 at depth of 3cm. Through the experimental period plants watered manually and depending on rainfall and manual weed control repeated more than once. Zinc solution was prepared by dissolving 1 g of zinc in 1000 ml distilled water, then diluted to required concentrations (0, 100, 200and 300 ppm) for foliar application, a surfactant agent-Tween was added at concentration of 0.1% to the solutions. Spraying was carried out at beginning of the flowering. The spray was carried out early in the morning till run-off.

Studied Parameters

Three plants were selected randomly from each experimental unit to study the plant height (cm), leaf area (cm2), leaf area index (Abdullah et al., 2022), dry matter (gm), crop growth rate (CGR) (g m-2 day-1) (Abdullah *et al.*, 2022), net assimilation rate (NAR) (g cm2 day-1) (Abdullah et al., 2022), no. of primary branch, , no. of capsules plant-1, no. of seed capsule-1, 1000 seed weight (g), seed yield (kg ha-1). Seeds ground by electrical grinder for each experimental unit. A 0.3g of ground samples were digested by adding 10ml of concentrated H_2SO_4 and 10ml of H_2O_2 with heating for digestion as described by Ryan et al., (2001). The percentage of protein and protein yield (kg ha-1) in seeds were estimated from digested samples by kjeldahl method (Rizvi *et al.*, 2022) and the percentage of oil and oil yield (kg ha-1) in seeds by Soxhlet method (Rasha *et al.*, 2017).

$$\text{LAI} = \frac{\text{plant total leaf area per plant (cm2)}}{\text{land area occupied by plant (cm2)}}$$

$$\text{Crop Growth Rate (CGR) (g m}^{-2}\text{ day}^{-1}) = \frac{1}{GA} \times \frac{W2-W1}{T2-T1}$$

$$\text{Net assimilation rate (NAR) (g cm}^{2}\text{ day}^{-1}) = \frac{DW2-DW1}{T2-T1} \times \frac{LnLA2-LnLA21}{LA2-LA1}$$

W (g): Weight

DW (g): Dry matter

GA: ground area

T: time

Statistical Analysis and Experimental Design

The experiment was designed according to factorial randomized complete block design (RCBD) with three replicates, comparisons between means were made using Duncan's Multiple Range Test at 5% level. The statistical analysis was carried out by using SPSS (Statistical Package for Social Sciences) Program, version (22.0) in 2019 (Field, 2009).

RESULT AND DISCUSSION

Growth parameters

Data presented in Table (4) indicates that growth parameters in black seed plant significantly affected by different varieties, foliar application of zinc and their interaction at Grdarasha field. Findings show that plant height and no. of branches plant^{-1} significantly increased with Russian variety to (26.17cm and 9.60). While, leaf area, LAI and N.A.R recorded the highest values (275.58cm2, 1.10 and 1.10cm^{2} day^{-1}) with local variety, as well as, Dry matter and C.G.R produced the maximum rates by (210.41 g m^{-2} and 1.40 g m^{-2} day^{-1}) with Syrian variety and the lowest values of these parameters were obtained Syrian and local varieties. Zn foliar application significantly raised the rates of all parameters and registered the maximum values with 300ppm as compared with control and other concentrations, excepting plant height had no significant differences with Zn treatment. The interaction between treatments shows in the same table, Syrian and local varieties with 300ppm Zn spray recorded the highest data for growth parameters when compare with other treatments while, lowest numbers were recorded by Syrian variety with control and local variety with 100 and 200ppm Zn foliar application.

According to the results that presented in Table (5) in khabat field the Syrian variety recorded the highest values for all growth parameters and lowest values were found by local variety except that, N.A.R significantly increases to (1.17cm2 day-1) with Russian variety. Also, like grdarasha field growth parameters significantly increased with increasing the concentration of Zn spray and decreased with those plant that not take any Zn treatment. With interaction between varieties and Zn foliar application, the maximum data were obtained by Syrian variety and 300ppm of Zn spray, exception N.A.R increased with Russian and 300ppm. Meanwhile, the minimum rate of these parameters significantly decreased with Russian and local varieties with control.

The variation between varieties may be related to the difference of the genetic formation between varieties. Plant morphology is a trait linked to plant genotype that is easily impacted by ecological variations in growth conditions and agricultural techniques. Consequently, it makes sense to anticipate differences in plant morphology under different soil and ecological situations with different fertilizer administrations. (Ahmed et *al.*, 2024). Furthermore, zinc functions as a structural, functional, or regulatory cofactor or as a metal component of several enzymes. As a result, they are connected to protein synthesis, photosynthesis, and saccharide metabolism. For cell division, auxin synthesis, and the preservation of membrane structure and function, zinc is a crucial micronutrient (Hendawy *et al.*, 2012).

Table 4. Response of some growth parameters in different varieties of black seed to foliar application of zinc at Grdarasha field

Varieties	**Plant height (cm)**	**Leaf Area (cm^2)**	**LAI**	**No. of primary branches $plant^{-1}$**	**Dry matter g m^{-2}**	**C.G.R (g m^{-2} day^{-1})**	**N.A.R (g cm^2 day^{-1})**
Russian	26.17 a	266.83 b	1.06 b	9.60 a	193.55 b	1.29 b	1.08 b
Syrian	23.91 ab	255.08 c	1.01 c	9.41 a	210.41 a	1.40 a	1.16 a
Locally	19.84 b	275.58 a	1.10 a	5.63 b	194.00 b	1.29 b	1.07 b
Zn concentration (ppm)	**Plant height (cm)**	**Leaf Area (cm^2)**	**LAI**	**No. of primary branches $plant^{-1}$**	**Dry matter g m^{-2}**	**C.G.R (g m^{-2} day^{-1})**	**N.A.R (g cm^2 day^{-1})**
Control	23.25 a	235.66 d	0.94 d	8.69 a	168.62 d	1.12 d	0.94 d
100	24.77 a	244.55 c	0.97 c	8.21 a	197.11 c	1.31 c	1.09 c
200	22.71 a	276.11 b	1.10 b	7.55 a	212.00 b	1.41 b	1.17 b
300	22.50 a	307.00 a	1.22 a	8.40 a	219.55 a	1.46 a	1.22 a
Varieties× Zn concentration	**Plant height (cm)**	**Leaf Area (cm^2)**	**LAI**	**No. of primary branches $plant^{-1}$**	**Dry matter g m^{-2}**	**C.G.R (g m^{-2} day^{-1})**	**N.A.R (g cm^2 day^{-1})**
Russian, control	14.22 ab	239.00 g	0.95 g	11.99 a	166.86 f	1.11 f	0.92 g
Russian, 100	13.88 ab	242.66 fg	0.97 fg	10.44 ab	183.66 de	1.22 e	1.02 ef
Russian, 200	9.99 a-d	281.33 c	1.12 c	8.10 abc	208.33 c	1.38 c	1.15 cd
Russian, 300	11.66 a-d	304.33 b	1.21 b	7.88 abc	215.33 bc	1.43 bc	1.19 bcd
Syrian, control	8.22 a-d	220.00 i	0.88 i	6.66 bc	177.33 e	1.18 de	0.98 f
Syrian, 100	13.55 abc	231.66 h	0.92 h	9.32 abc	215.66 bc	1.43 bc	1.19 bcd
Syrian, 200	12.33 a-d	267.00 d	1.06 d	9.44 abc	221.33 ab	1.47 ab	1.22 ab
Syrian, 300	14.77 a	301.66 b	1.20 b	12.22 a	227.33 a	1.43 bc	1.26 a

Locally, control	8.22 a-d	248.00 f	0.99 f	7.44 abc	161.66 f	1.07 f	0.89 g
Locally, 100	6.77 cd	259.33 e	1.03 e	4.88 c	192.00 d	1.28 d	1.06 e
Locally, 200	6.32 d	280.00 c	1.12 c	5.10 c	206.33 c	1.37 c	1.14 d
Locally, 300	7.33 bcd	315.00 a	1.25 a	5.10 c	216.00 bc	1.51 a	1.20 bc

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 5% level.

Table 5. Response of growth parameters in different varieties of black seed to foliar application of zinc at Kabat field

Varieties	**Plant height (cm)**	**Leaf Area (cm^2)**	**LAI**	**No. of primary branches $plant^{-1}$**	**Dry matter g m^{-2}**	**C.G.R (g m^{-2} day^{-1})**	**N.A.R (g cm^2 day^{-1})**
Russian	49.91 b	264.91 b	1.05 b	10.91 b	214.33 b	1.92 b	1.17 a
Syrian	65.91 a	299.91 a	1.20 a	12.16 a	227.00 a	2.29 a	1.01 b
Locally	45.16 c	261.91 c	1.04 c	10.00 c	209.41 c	1.89 b	1.00 b
Zn concentration (ppm)	**Plant height (cm)**	**Leaf Area (cm^2)**	**LAI**	**No. of primary branches $plant^{-1}$**	**Dry matter g m^{-2}**	**C.G.R (g m^{-2} day^{-1})**	**N.A.R (g cm^2 day^{-1})**
Control	47.22 d	232.22 d	0.92 d	7.22 d	184.88 d	1.61 d	0.71 d
100	50.66 c	250.22 c	1.00 c	9.44 c	216.77 c	1.94 c	0.91 c
200	56.11 b	291.55 b	1.16 b	12.55 b	225.22 b	2.19 b	1.19 b
300	60.66 a	328.33 a	1.31 a	14.88 a	240.77 a	2.39 a	1.43 a
Varieties× Zn concentration	**Plant height (cm)**	**Leaf Area (cm^2)**	**LAI**	**No. of primary branches $plant^{-1}$**	**Dry matter g m^{-2}**	**C.G.R (g m^{-2} day^{-1})**	**N.A.R (g cm^2 day^{-1})**
Russian, control	43.00 h	221.33 h	0.88 h	6.66 g	189.33 g	1.64 f	0.84 e
Russian, 100	48.00 fg	237.00 g	0.94 g	9.66 e	214.66 ef	1.80 e	1.11 d
Russian, 200	51.00 e	283.33 d	1.13 d	12.66 cd	218.66 de	2.05 d	1.24 c
Russian, 300	57.66 d	318.00 b	1.27 b	14.66 b	234.66 b	2.20 c	1.49 a

Syrian, control	59.00 cd	252.33 f	1.01 f	8.33 f	193.66 g	1.78 e	0.72 f
Syrian, 100	60.33 c	275.66 e	1.10 e	10.33 e	224.66 c	2.20 c	0.81 e
Syrian, 200	70.33 b	316.33 b	1.26 b	13.33 c	234.66 b	2.39 b	1.11 d
Syrian, 300	74.00 a	355.33 a	1.42 a	16.66 a	255.00 a	2.79 a	1.41 ab
Locally, control	39.66 i	223.00 h	0.89 h	6.66 g	171.66 h	1.41 g	0.57 g
Locally, 100	43.66 h	238.00 g	0.95 g	8.33 f	211.00 f	1.81 e	0.81 e
Locally, 200	47.00 g	275.00 e	1.10 e	11.66 d	222.33 cd	2.14 c	1.23 c
Locally, 300	50.33 ef	311.66 bc	1.24 c	13.33 c	232.66 b	2.20 c	1.40 b

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 5% level.

Yield and yield components

Results in table (6) for grdarasha field indicated significant differences between cultivars in no. of capsules per plant and no. of seeds per capsule, and recorded the highest rate with Russian variety by (12.44 and 72.13), while 1000 seed weight and seed yield significantly increased with local variety by (2.92g and 11.66g plant^{-1}), as well as, the lowest data (7.16, 56.66, 127g and 3.44 g plant^{-1}) respectively recorded for no. of capsules plant^{-1} with local, no. of seeds per capsule with Syrian variety 1000 seed weight and seed yield with Russian variety. No significant variation was observed for all yield components characteristics by zinc foliar application excepting, no. of seeds per capsule significantly escalated with Zn spray and recorded the maximum produce (69.21) with 200ppm and minimum value (51.92) with 100ppm. The interaction between treatments shows no significant differences of no. of seeds per capsule, meanwhile for other parameters the first position was occupy by Syrian with 300ppm for no. of capsules per plant by (14.77) and by local and 100ppm by (3.20g and 19.65g plant^{-1}) for 1000 seed weight and seed yield. The lowest record of these parameters was found with Russian and local variety that treated with zinc foliar application.

Table (7) clarifies the Response of yield and yield components in different varieties of black seed plant to foliar application of zinc in khabat field. Findings show that the greater numbers of all yield parameters were recorded by Syrian variety and lowest values with Russian variety. With increasing the level of Zn spray production of yield and yield component significantly increased. In interaction between varieties and Zn spray significantly affected on yield characteristics and the maximum values (67.33, 83.66, 2.32g and 12.77g plant^{-1}) was observed for all parameter respectively by Syrian with 200ppm and 300ppm. On the other hand, the decline in these parameters were observed for Russian variety for those plant that did not spraying by Zn, and recorded the lowest rates to (23.33, 43.66, 1.72g and 3.06g plant^{-1}).

According to the results obtained, the variation in yield characteristics of varieties may be connected to the genetic formations and their response to environmental conditions and we can conclude that varieties are adaptable to Kurdistan climate. Related to the availability of environmental conditions, particularly favorable temperature and soil fertility (Mustatfa and Ahmed, 2023).

Zinc is an important nutrient that plants absorb and transfer in the form of Zn2+. Zinc application which may be due to the important role in physiological functions in all living systems, including the structural and functional integrity, in enhancing metabolic processes, preservation of biological membranes, the facilitation of protein synthesis and gene expression, the production of energy, the structure of enzymes and the Krebs cycle, Zinc also positively affects crop yield, meaning that both the quantitative and qualitative yield of crops is heavily dependent on it Zn (Hosamani *et al.*, 2020).

Table 6. Response of yield and yield components in different varieties of black seed to foliar application of zinc at Grdarasha field

Varieties	**No. of capsules plant^{-1}**	**No. of seeds capsule^{-1}**	**1000 seed weight (g)**	**Seeds yield (g plant^{-1})**
Russian	12.44 a	72.13 a	1.27 b	3.44 b
Syrian	12.21 a	56.66 b	1.54 b	5.47 b
Locally	7.16 b	59.64 ab	2.92 a	11.66 a
Zn concentration (ppm)	**No. of capsule plant^{-1}**	**No. of seed capsule^{-1}**	**1000 seed weight (g)**	**Seed yield (g plant^{-1})**
Control	10.22 a	66.57 ab	1.84 a	5.38 a
100	11.40 a	51.92 b	2.15 a	10.49 a
200	9.55 a	69.21 a	1.82 a	6.03 a
300	11.25 a	63.55 ab	1.83 a	5.53 a
Varieties× Zn concentration	**No. of capsules plant^{-1}**	**No. of seeds capsule^{-1}**	**1000 seed weight (g)**	**Seeds yield (g plant^{-1})**
Russian, control	14.22 ab	73.88 a	1.36 c	3.54 b
Russian, 100	13.88 ab	79.55 a	1.26 c	2.52 b
Russian, 200	9.99 a-d	56.66 a	1.20 c	3.58 b
Russian, 300	11.66 a-d	78.44 a	1.26 c	4.11 b
Syrian, control	8.22 a-d	67.77 a	1.56 c	3.78 b
Syrian, 100	13.55 abc	58.10 a	2.00 bc	9.32 ab

Syrian, 200	12.33 a-d	48.33 a	1.33 c	4.17 b
Syrian, 300	14.77 a	52.44 a	1.26 c	4.62 b
Locally, control	8.22 a-d	58.05 a	2.60 ab	8.80 ab
Locally, 100	6.77 cd	69.99 a	3.20 a	19.65 a
Locally, 200	6.32 d	50.77 a	2.93 a	10.34 ab
Locally, 300	7.33 bcd	59.77 a	2.96 a	7.87 ab

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 5% level.

Table 7. Response of yield and yield components in different varieties of black seed to foliar application of zinc at Khabat field

Varieties	**No. of capsules plant^{-1}**	**No. of seeds capsule^{-1}**	**1000 seed weight (g)**	**Seeds yield (g plant^{-1})**
Russian	40.83 c	58.66 c	1.89 c	6.48 c
Syrian	49.41 a	68.16 a	2.05 a	8.53 a
Locally	41.66 b	61.66 b	2.00 b	7.24 b
Zn concentration (ppm)	**No. of capsules plant^{-1}**	**No. of seeds capsule^{-1}**	**1000 seed weight (g)**	**Seeds yield (g plant^{-1})**
Control	27.44 d	47.44 d	1.76 d	3.54 d
100	37.11 c	58.22 c	1.90 c	6.51 c
200	49.11 b	77.11 a	2.05 b	8.87 b
300	62.22 a	68.55 b	2.22 a	10.74 a
Varieties× Zn concentration	**No. of capsules plant^{-1}**	**No. of seeds capsule^{-1}**	**1000 seed weight (g)**	**Seeds yield (g plant^{-1})**
Russian, control	23.33 j	43.66 i	1.72 f	3.06 i
Russian, 100	33.66 h	52.00 g	1.82 e	5.66 g
Russian, 200	45.33 e	75.00 b	1.91 d	7.63 e
Russian, 300	61.00 b	64.00 e	2.11 c	9.56 c
Syrian, control	33.66 h	52.33 g	1.81 e	3.75 h
Syrian, 100	40.33 f	61.66 f	1.92 d	7.15 ef
Syrian, 200	56.33 d	83.66 a	2.15 c	10.46 b
Syrian, 300	67.33 a	75.00 b	2.32 a	12.77 a
Locally, control	25.33 i	46.33 h	1.74 f	3.83 h

Locally, 100	37.33 g	61.00 f	1.96 d	6.73 f
Locally, 200	45.66 e	72.66 c	2.10 c	8.53 d
Locally, 300	58.33 c	66.66 d	2.22 b	9.89 c

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 5% level.

Fixed oil and protein content in the seeds

The data presented in Table (8) indicated that in grdarash field the ratio of fixed oil significantly progressed to 31.43% in Syrian variety and the other contents was increased with local variety by (364.42g plant-1, 22.66% and 270.80g plant-1) respectively for oil yield, protein and protein yield. While the lowest ration (30.59%, 104.26g plant-1 and 77.55g plant-1) of theses parameters was obtained by Russian for oil, oil yield and protein yield and (22.24%) of protein by Syrian cultivar. No significant effect was found between all Zn concentration for oil and protein yield. Zn foliar application at 100 and 200ppm recorded the greater produce of fixed oil and protein when compared with other treatments. Fluctuation in results was obtained by combination between cultivars and Zn sparing, the results indicate that both oil and protein percentage significantly raised with local and 100ppm, while the yield of these seed contents significantly escalated in the Russian with 200ppm and local with control. As well as, these contents significantly declined with Russian and local spraying by 100ppm and 200ppm.

The results in the Table (9) show the oil and protein seed content in khabat field. The percentage of oil had significant produce with Russian variety by (30.21%) and protein ratio with local by (24.33%). Meanwhile, oil and protein yield significantly increased to (247.53 and 184.71g plant-1) with Syrian variety. The greater produce of all seed contents was obtained with 300ppm excepting that, protein ration increased with 200ppm, but the lowest proportions were observed wit 100 and 200ppm. Interaction between varieties and Zn foliar application presented that the maximum rates (32.40% and 25.71%) of oil and protein were recorded by Russian and 300ppm for oil ratio and with local and 100ppm for protein percentage. On the other hand, the oil and protein yield significantly progressed by (362.76 and 289.44g plant-1) for Syrian and 300ppm. While the minimum values of these parameters were recorded with Russian and control excepting oil percentage with Syrian and 300ppm.

This variation among genotypes might be due to differences in physiological traits that might be responsible for production potential (Al-Zubaidy et al. 2020). Numerous researchers have noted that an increase in the percentage of seed oil and protein might result from providing plants with the micronutrient components they require. Microelements effectively improved photosynthesis and assimilate translocation to the seed due to the augmentation of enzymatic activity. Zn plays an important role in increasing the amount of plant growth, contributing to the metabolism of different substances, participating in the division of meristem cells, and the production of carbohydrates, proteins and their translocation. This rise seems to be due to increased flower and essential oil percentage as a result of the promotive effects of Zn. Since the essential oil yield is directly associated with the flower yield and essential oil percentage, any increase in these two traits led to the increase of essential oil yield. (Ali et al., 2015 and Rezaei-Chiyaneh et al., 2018). In the same time the fixed oil decline at 300ppm of zinc spray may be due to zinc toxicity induced by excessive concentration, which disrupts metabolic processes, reduces photosynthesis and interferes with lipid biosynthesis.

Table (8): Response of fixed oil and protein content of seeds in different varieties of black seed to foliar application of zinc at Grdarasha field

Varieties	Oil %	Oil yield (g plant^{-1})	Protein %	Protein (g plant^{-1})
Russian	30.59 c	104.26 b	22.42 b	77.55 b
Syrian	31.43 a	170.68 b	22.20 c	124.28 b
Locally	31.02 b	364.42 a	22.66 a	270.80 a
Zn concentration (ppm)	**Oil %**	**Oil yield (g plant^{-1})**	**Protein %**	**Protein (g plant^{-1})**
Control	29.48 d	160.19 a	23.06 b	128.63 a
100	31.24 b	328.62 a	23.58 a	258.23 a
200	32.95 a	193.93 a	22.24 c	129.74 a
300	30.39 c	169.74 a	20.82 d	113.57 a
Varieties× Zn concentration	**Oil %**	**Oil yield (g plant^{-1})**	**Protein %**	**Protein (g plant^{-1})**
Russian, control	106.04 b	29.90 i	75.97 b	21.42 h
Russian, 100	80.85 b	32.04 d	53.00 b	21.15 h
Russian, 200	124.69 b	34.80 a	85.54 b	23.87 d
Russian, 300	105.45 b	25.64 l	95.69 b	23.27 e
Syrian, control	106.39 b	28.10 k	83.45 b	22.04 g
Syrian, 100	277.15 ab	29.74 j	228.32 ab	22.66 f
Syrian, 200	139.07 b	33.30 c	94.64 b	24.50 c
Syrian, 300	160.09 b	34.60 b	90.69 b	19.60 j
Locally, control	268.13 ab	30.45 h	226.47 ab	25.72 a
Locally, 100	627.86 a	31.95 e	493.36 a	25.11 b
Locally, 200	318.03 ab	30.75 g	209.04 ab	20.21 i
Locally, 300	243.68 ab	30.95 f	154.31 b	19.60 j

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 5% level

Table 9. Response of oil and protein content of seed in different varieties of black seed to foliar application of zinc at Khabat field

Varieties	Oil %	Oil yield (g plant^{-1})	Protein %	Protein (g plant^{-1})
Russian	30.21 a	197.93 c	22.19 b	146.95 c
Syrian	29.32 b	247.53 a	21.33 c	184.71 a
Locally	28.72 c	209.69 b	24.33 a	175.188 b
Zn concentration (ppm)	**Oil %**	**Oil yield (g plant^{-1})**	**Protein %**	**Protein (g plant^{-1})**
Control	29.66 b	105.20 d	21.22 d	75.93 d
100	28.31 d	184.57 c	22.73 c	153.90 c
200	29.48 c	261.16 b	23.67 a	200.57 b
300	30.21 a	322.61 a	22.86 b	245.39 a
Varieties× Zn concentration	**Oil %**	**Oil yield (g plant^{-1})**	**Protein %**	**Protein (g plant^{-1})**
Russian, control	29.90 d	91.69 i	18.97 j	58.17 j
Russian, 100	28.80 h	163.19 g	23.28 d	135.32 g
Russian, 200	29.75 f	226.99 d	21.05 h	177.62 e
Russian, 300	32.40 a	309.85 b	23.88 c	216.70 c
Syrian, control	30.50 b	114.37 h	20.21 i	75.78 l
Syrian, 100	29.65 g	212.09 e	21.43 g	153.29 f
Syrian, 200	28.75 i	300.92 b	22.66 f	220.32 bc
Syrian, 300	28.40 k	362.76 a	22.66 f	289.44 a
Locally, control	28.60 j	109.53 h	24.50 b	93.83 h
Locally, 100	26.50 l	178.43 f	25.71 a	173.11 e
Locally, 200	29.94 c	255.58 c	23.87 c	203.76 d
Locally, 300	29.85 e	295.21 b	23.26 e	230.04 b

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 5% level.

Comparison Between the Two Locations Grdarasha Field Station and Khabat Field Trial

T-test analysis in Tables (10) shows the differences of growth characteristics of different varieties under effect of Zn foliar application between the two locations Grdarasha and Khabat. No significant difference was observed between the two fields trial for all growth parameter, exception of the no. of primary branches per plant significantly increased in khabat field to (11.02). Regarding to the results that presented in the Table (11), no significant effect was found between Grdarasha and khabat field of yield and yield components. In the same table show the differences between both locations of seed content, data analysis show that the highest oil content selected by Grdarasha field, and no significant positive was observed between two locations for and no for two locations for other traits.

Measurements parameters are extremely sensitive to environmental factors like, light intensity, growing season, day length, rainfall and temperature, soil properties and soil water elevation and slope (rainfall and temperature that presented in Tables 3 and soil properties in Tables 1 and 2 for the two locations), may be due to the similar in climate conditions of the two (fields) regions, therefore there are no significant differences between most of studied parameters, in addition to that agronomic factor like plant density, fertility of the soil and weeds (Ceyhan et al., 2012 and Al-Zubaidy et al., 2020).

The increase in fixed oil content may be due to their response of black seed plant to the condition in Grdarasha field station as compared with Khabat field. If unfavorable environmental conditions are sensed and trigger signals that reduce growth rate directly and to achieve a profitable yield and obtain high quality essential oil from black seed, it is advantageous to have a warm, sunny, and dry autumn season and the soil pH should be slightly alkaline to neutral, ranging from 7.0 to 8.5, (Lamber et al., 2008, Hendawy et al., 2012 and Mustatfa and Ahmed, 2023).

Table 10. Comparison Between Grdarasha and Khabat under effect of different Plant varieties of black seed plant to foliar application of zinc of some growth parameters

Location / Parameters	Grdarasha	Khabat	Calculated -t	Tabled-t
Plant height (cm)	23.31	53.66	-15.12	
Leaf Area (cm^2)	265.83	275.58	-1.13	
LAI	1.06	1.10	-1.15	
No. of primary branches plant^{-1}	8.21	11.02	3.75	2.00
Dry matter g m^{-2}	199.32	216.91	-3.35	
C.G.R (g m^{-2} day^{-1})	1.32	2.03	-10.90	
N.A.R (g cm^2 day^{-1})	1.06	1.06	-0.04	

*If calculated-t less than table-t means there are no significant differences between the locations.

Table 11. Comparison Between Grdarasha and Khabat under effect of different Plant varieties of black seed to foliar application of zinc of yield and yield components and seed oil and protein content

Location / Parameters	Grdarasha	Khabat	Calculated -t	Tabled-t
No. of capsule plant^{-1}	10.60	43.97	-13.78	2.00
No. of seed capsule^{-1}	62.81	62.83	-0.00	
1000 seed weight (g)	1.91	1.98	-0.49	
Seed yield (g plant^{-1})	6.86	7.42	-0.43	
Oil %	31.01	29.42	3.32	
Oil yield (g plant^{-1})	213.12	218.38	-0.13	
Protein %	22.42	22.62	-0.42	
Protein (g plant^{-1})	157.54	168.95	-0.36	

*If calculated-t less than table-t means there are no significant differences between the locations.

CONCLUSION

The results concluded that this study highlights the importance of variety selection and Zn foliar application strategies in optimizing black seed growth, yield and quality. It is concluded that Syrian and local varieties surpassed Russian in most of studied parameters. Also, with increasing the level of zinc foliar application increased the production of all characteristics. From interactions between treatments for all characteristics selected the highest amount by Syrian and local varieties with all levels of zinc spray. In general, the local variety recorded the highest data in both location for most studied parameters and 300ppm of zinc level. Due to the availability of environmental conditions, particularly favourable temperature and soil fertility, no significant differences between both location excepting location recorded better value of no. of branches in Kabat field and oil content in Grdarasha field. We recommended that farmers in Kurdistan region and Iraq using local and Syrian varieties and 200 to 300ppm of zinc foliar application to enhance growth and development of black seed plant.

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