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Evaluation of seed quality in Flaxseed (*Linum usitatissimum* L.) genotypes and response to salicylic acid priming on germination and seedling

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ABSTRACT
The experiment was conducted at the Khabat Technical Institute (Erbil Polytechnic University, Kurdistan, Iraq) during September of 2025. This study aims to identify the chemical composition of the six flax genotypes in terms of their oil, protein, mineral, and vitamin content. Chemical analyses revealed significant differences in chemical composition among the genotypes. The laboratory experiment was then conducted to evaluate the effect of treating flaxseed with five concentrations of salicylic acid (SA) (0, 0.5, 1, 1.5, and 2 mM) on the germination rates of six flax genotypes (Germany, Leider, Local, Poland, Syrian 1, and Syrian 2). For the germination experiment, the seeds were treated with salicylic acid (SA) for 24 hours, and parameters such as germination percentage and early growth indicators were recorded. Treatment with SA had a variable effect on germination, with a positive effect observed at concentrations of 0.5 and 1 mM in some genotypes, and a negative or negligible effect in others at concentrations of 1.5 and 2 mM. These results highlight the importance of selecting the appropriate SA concentration for each genotype to improve germination and suggest that the chemical diversity of flaxseed genotypes may be related to their physiological response to the hormone.

KEYWORDS: Flaxseed, Seed quality, Salicylic acid, Germination.

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تقييم جودة بذور تراكيب وراثية من الكتان (*Linum usitatissimum* L.) واستجابتها للنقع بحمض الساليسيليك على الإنبات ونمو البادرات

نهلة جوهر كريم
قسم تقنيات الزراعة المائية، المعهد التقني خبات، جامعة إربيل التقنية، إربيل، العراق.

الملخص
أُجريت التجربة في المعهد التقني خبات (جامعة إربيل التقنية، إقليم كردستان، العراق) خلال شهر سبتمبر من عام 2025. تهدف هذه الدراسة إلى تحديد التركيب الكيميائي لستة تراكيب وراثية من الكتان من حيث محتواها من الزيت والبروتين والمعادن والفيتامينات. وكشفت التحاليل الكيميائية عن وجود اختلافات كبيرة في التركيب الكيميائي بين التراكيب الوراثية. بعد ذلك، أُجريت التجربة المخبرية لتقييم تأثير تنشيط بذور الكتان بخمس تركيزات من حمض الساليسيليك (0، 0.5، 1، 1.5، و2 مليمول/لتر) على نسب إنبات ستة تراكيب وراثية للكتان **(Germany, Leider, Local, Poland, Syrian 1, and Syrian 2).** في تجربة الإنبات، عُوملت البذور بحمض الساليسيليك لمدة 24 ساعة، وتم تسجيل معطيات مثل نسبة الإنبات ومؤشرات النمو المبكر للبادرات. أظهر تنشيط البذور بحمض الساليسيليك تأثيرًا متغيرًا على الإنبات، حيث لوحظ تأثير إيجابي عند التركيزين 0.5 و1 مليمول/لتر في بعض التراكيب الوراثية، في حين كان التأثير سلبيًا أو ضئيلًا في تركيزات 1.5 و2 مليمول/لتر في تراكيب أخرى. وتبرز هذه النتائج أهمية اختيار التركيز المناسب من حمض الساليسيليك لكل تركيب وراثي لتحسين الإنبات، وتشير أيضًا إلى أن التنوع الكيميائي لتراكيب بذور الكتان قد يكون مرتبطًا باستجابتها الفسيولوجية لهذا الهرمون.
الكلمات المفتاحية: بذور الكتان، جودة البذور، حمض الساليسيليك، الانبات.

INTRODUCTION

Flax (*Linum usitatissimum L.*) is one of the important dual-purpose industrial crops, which is cultivated to obtain oil or fiber or both. The percentage of oil in its seed's ranges from 33 - 47 % and 11 - 25 % protein (Rahimi, 2014). Their seeds are widely used because its oil contains a high percentage of antioxidants, such as ascorbic acid, and unsaturated fatty acids such as linoleic acid, which belongs to the omega-3 group, and linolenic acid, which belongs to the omega-6 group in

addition to oleic acid, which belongs to the omega-9 group (Berti, *et al* 2009; Abdulazeez & Salih, 2025). Different genotypes can lead to genotypes in the amount of oil or fatty acids they contain (Pali and Mehta, 2014; Alizawee *et al*., 2025). They are also a valuable source of dietary fiber and omega-3 fatty acids. Many nutrients and active ingredients, such as vitamins, minerals, and healthy fats, can be found in flax seeds (Shinde *et al*., 2023). Eighty percent of the oil consumed globally is used for human consumption, while the remaining 6% is used as animal feed. Flax ranks third among plants used for fiber and oil production (Ahmed *et al*., 2019). Seed production and quality are influenced by flax genotypes practices, particularly irrigation and suitable soil (Ahmed *et al*., 2024). Seed germination and seedling formation are critical stages in the plant's growth cycle, (Shatpathy *et al*., 2018). The numerous health benefits of oilseeds are attributed to their antifungal (Kalam *et al*., 2024), anti-inflammatory, and antioxidant (Karkosh *et al*., 2024) properties. Global climate change and environmental pollution are causing significant problems, and plants possess numerous mechanisms to mitigate these damages. One effective protective compound produced by plants is SA. Recent research has also highlighted that SA plays a key role in certain subprocesses of plant development (Kavulych *et al*., 2023). Some researchers have tested SA on plant growth. They found that plants grown from seeds treated with SA exhibited increased seedling weight, root and shoot length, and shorter germination times compared to untreated seeds. Therefore, its positive effect on seed germination has also been demonstrated (Decsi *et al*., 2025). Salicylic acid is also involved in the defense response and secondary metabolism (Li *et al*., 2019; Li and Ahmed, 2023). For example, seed preparation with SA has been shown to induce various physiological and biochemical processes to mitigate the effects of different stresses (Rahman *et al*., 2021). Furthermore, the application of SA to seeds stimulates the activation of secondary metabolic pathways, promoting the synthesis of therapeutic nutrients (Gao *et al*., 2021) and the breakdown of anti-nutritional compounds. The application of SA during germination has also been observed to improve the nutritional content of seeds and seedlings (Escobedo *et al*., 2024). The external application of SA during the cultivation of various plants can be an alternative to increase their economic value. A study by Barwal *et al*. (2023) demonstrated that seed preparation with SA protects plant growth and development processes during early growth stages. Islam *et al*. (2022) found that externally applied SA seed treatment mitigated the detrimental effects of salinity on young maize plants. A 1 mM concentration yielded the best results in terms of root dry matter, ear production, and relative leaf water content. Kulak *et al*. (2021) treated basil plants with SA and subjected them to water stress. The treatment effectively increased the plant's physiological parameters and its phenolic and flavonoid content. However, the treatment did not significantly affect the percentage of essential oil components in the basil plants.

Therefore, this study aimed to determine the chemical composition of the seeds content of oil, protein, fats, elemental estimation and vitamins percentage %. Then, a laboratory experiment was carried out

by treating flax seeds with five concentrations of salicylic acid (0, 0.5, 1, 1.5 and 2 mM) to study germination rates and seedling parameters of six different genotypes of flax seeds (Germany, Leider, Local, Poland, Syrian 1 and Syrian 2).

MATERIAL AND METHOD

The six flax seed genotypes were sent to laboratories to determine the chemical composition of the seeds content of oil, protein, fats, elemental estimation and vitamins percentage %.

Then, the effect of SA treatment at five concentrations (0, 0.5, 1, 1.5, and 2 mM) on germination rates and seedling parameters was evaluated. Solutions were prepared in the laboratory, and flax seeds were treated with the concentrations SA for 24 hours before being placed in Petri dishes. Germination rates and seedling parameters were then measured (Apon *et al*., 2023). The experimental setup used a completely randomized design (CRD) and included the following parameters: SA concentrations (0, 0.5, 1, 1.5, and 2 mM) and six flax seed genotypes (Germany, Leider, Local, Poland, Syrian 1, and Syrian 2). Ninety experimental units were used, based on the preparation method employed, with three replicates. The following parameters, particularly those related to seedlings and germination, were examined (Germination %, Root length cm, Root fresh weight g, Root dry weight g, Shoot length cm, Shoot fresh weight g, Shoot dry weight g) and the seed genotypes were obtained from the Salahaddin University Research Center.

The data were statistically analyzed for each of the assessed characteristics (Al-Rawi *et al*., 2011), and Duncan's multiscale test (DMRT) was used to compare means at a 5% significance level, according to analyses of variance performed using the Statistical Analysis System (SAS Institute, 2016).

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 10 days. Germination percentage = seeds germinated/total seeds × 100 **.**
2. Root length (cm): The root length was measured after it reached the seedling stage**.**
3. Radicle length (c): The radicle length was measured after it reached the seedling stage**.**
4. Root fresh weight
5. Shoot fresh weight
6. 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**.**
7. 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.

Extraction of oil percentage %

A weight of (10 grams) was taken from the ground seeds samples and placed in the thimble of the fat

extraction device (Soxhlet), and the weight of the beaker of the device was then added to it (250 ml) of hexane, and the extraction process continued for about (5) hours. Then the solvent was collected from the device and the beaker was taken out and placed in the beaker. In an electric oven for half an hour at a temperature of (60°C) to ensure that the solvent residue evaporates from the beaker and that the fatty materials remain. Then remove from the oven and leave until it cools, then weigh the beaker (Majnooni *et al*, 2016).

Protein percentage %:

The Kjeldahl method was used to estimate protein content following (Dijk and Houba, 2000). A known weight of the ground seeds samples (about 5 g) was placed in a beaker, then 25 ml of concentrated sulfuric acid was added along with a mixture of potassium sulfate and copper sulfate. The sample was digested by heating until a clear pale-blue solution was obtained. The digest was transferred to the Kjeldahl distillation flask containing 40% sodium hydroxide and connected to a condenser ending in a receiving flask with a known volume of 20% boric acid and mixed indicators (methyl red and bromocresol blue). The mixture was distilled until about 25 ml of distillate was collected. The obtained distillate was titrated with 0.1 N hydrochloric acid, and a blank was prepared using the same reagents without the sample. Protein content was then calculated using the following equation**:**

Protein % = (Volume of HCl × Standard × 0.014 × 6.25) / Sample weight × 100.

Fat percentage %:

Fat content was estimated according to the AOAC (1995) method. A 10 g portion of the dried and grounded seeds samples were wrapped in filter paper and placed inside the Soxhlet extractor thimble. The extraction flask was weighed, and then filled with 250 ml of hexane. The extraction process continued for about five hours. After completion, the solvent was collected and the flask was transferred to an electric oven at 80°C for 30 minutes to evaporate any remaining solvent. The flask was then cooled and re-weighed. Fat percentage in the sample was calculated using the following formula**:**

Fat (%) = (Weight of flask before extraction – Weight of flask after extraction) / Sample weight × 100.

Elemental estimation percentage %

Elemental analysis was performed on the collected, dried, and ground seeds samples using the APHA (2017) wet digestion method. A 3 g portion of the powdered sample was placed in a 25 ml Griffin beaker and mixed with 3 ml of concentrated perchloric acid. The beaker was covered and gently heated on a hot plate, with temperature gradually increased to promote digestion. After reaching near dryness, the mixture was cooled and treated with 3 ml of concentrated nitric acid, then reheated until a clear, light-colored digestate was obtained. The solution was again evaporated close to dryness,

followed by the addition of 5 ml of diluted hydrochloric acid (1:1) to dissolve remaining residues. Distilled water was added and the mixture was filtered to remove undigested particles. The final volume was adjusted to 50 ml according to expected element concentrations. The absorbance of the digested samples was subsequently measured using a SHEMADZU AA-7000 atomic absorption spectrometer.

Determination of water – fat soluble vitamins:

Water- and fat-soluble vitamins were determined according to Kozhanova *et al*. (2002). A 2 g seeds sample was mixed with 20 mL of an extracting solution consisting of 0.4 M lithium perchlorate (pH 2.4) and 0.1% butylhydroxytoluene in methanol at a 19:1 ratio. The mixture was stirred in the dark for 10 minutes at 30–35°C and pH 5–5.5. If needed, pH was adjusted using lithium hydroxide. After dissolution, the pH was lowered to 2.4 and stirring continued for another 10 minutes. All added volumes were considered when calculating vitamin concentrations.

RESULTS AND DISCUSSION:

The results in table (1), clearly demonstrate that both flaxseed genotypes and SA concentration exert significant effects on all measured germination and seedling growth parameters. Overall, low to moderate concentrations of SA promoted seedling performance, whereas higher concentrations produced inhibitory effects, highlighting a typical dose-dependent response.

For germination percentage, among genotypes, Syrian 1 (87%) and Germany (84%) showed the highest germination, indicating their strong inherent vigor. In contrast, the local genotype exhibited extremely low germination (24%), followed by the Poland genotype (27%), showing a markedly weaker physiological response and greater sensitivity.

Regarding SA treatments, 0.5 mM resulted in the highest germination percentage (75%), followed closely by 1 mM (71.67%), both exceeding the untreated control (62.5%). This suggests that low SA concentrations stimulated germination, likely by enhancing antioxidant defense. However, 2 mM sharply reduced germination (35.83%), indicating toxicity at higher concentrations.

For root length parameters, the 0.5 mM SA treatment achieved the longest roots (5.876 cm), clearly surpassing all genotypes and treatments, confirming its stimulatory role. High SA concentration (2 mM) drastically reduced root length (2.293 cm), similar to the weak performance of the Syrian 2 genotype (2.365 cm). Among genotypes, Syrian 1 and Local recorded the longest roots (4.991 and 4.743 cm, respectively), reflecting superior root vigor, and root fresh and dry weight, 0.5 mM produced the highest root fresh weight (0.0661 g), while the Syrian 2 genotypes showed the lowest (0.0293 g) .

And shoot length parameters, 0.5 mM SA yielded the longest shoots (5.168 cm), significantly compared with control (4.472 cm). The 2 mM treatment produced the shortest shoots (2.822 cm), showing clear growth inhibition. Among genotypes, Germany and Syrian 1 performed best (4.905

and 4.835 cm), consistent with their high germination rates. for shoot fresh and dry weight, the highest fresh weights were recorded by Syrian 1 (0.0814 g) and 0.5 mM SA (0.0811 g). High SA concentration (2 mM) resulted in the lowest biomass values (0.0256 g fresh; 0.00115 g dry).

High SA concentrations may disrupt cellular respiration, water uptake, and hormonal balance abscisic acid (ABA)– Indole acetic acid (IAA) interaction, leading to growth suppression (Escobedo *et al*., 2024), (Gao *et al*., 2021).

Also, genotype differences, Syrian 1 consistently exhibited superior performance across most traits, while the local genotype and Poland genotype showed poor germination and weak seedling vigor. These differences indicate strong genetic variation in physiological response to SA (Liqing *et al*., 2024)

Table 1. Effect of flax seed varieties to seed priming with SA on germination and seedling parameters

Treatment	Germination %	Root length cm	Root fresh weight g	Root dry weight g	Shoot length cm	Shoot fresh weight g	Shoot dry weight g
Germany	84 a	3.886 c	0.0447 b	0.00148 a	4.905 a	0.0720 b	0.00163 ab
Leider	81 a	3.78 c	0.0567 a	0.00143 a	4.144 b	0.0753 ab	0.00176 a
Local	24 c	4.743 ab	0.0400 b	0.00174 a	3.295 c	0.0307 d	0.00137 bc
Poland	27 c	4.083 bc	0.0380 b	0.00180 a	3.4.56 ab	0.0413 c	0.00193 a
Syrian 1	87 a	4.991 a	0.0567 a	0.00207 a	4.835 a	0.0814 a	0.00177 a
Syrian 2	65 b	2.365 d	0.0293 c	0.00207 a	3.053 c	0.0340 cd	0.00115 c
control	62.5 b	3.959 c	0.0417 c	0.00165 a	4.472 b	0.0589 b	0.00171 ab
0.5 mM	75 a	5.876 a	0.0661 a	0.00228 a	5.168 a	0.0811 a	0.00195 a
1 mM	71.67 a	4.867 b	0.0417 b	0.00191 a	4.523 b	0.0656 b	0.00160 b
1.5 mM	61.67 b	2.880 d	0.0389 c	0.00162 a	3.661 c	0.0478 c	0.00158 b
2 mM	35.83 c	2.293 d	0.0233 d	0.00137 a	2.822 d	0.0256 d	0.00115 c

The results in table (2) refer to interaction between flax genotypes and SA, showed that low SA concentrations (especially 0.5–1 mM) significantly enhanced germination and seedling vigor across most genotypes, while high concentrations (1.5–2 mM) had inhibitory effects. The genotypes Germany, Leider, and Syrian 1 responded most positively, showing higher germination (up to 100%) and greater root/shoot biomass under 0.5 mM SA. In contrast, the Local and Poland genotypes exhibited low baseline germination but still showed noticeable improvement at 0.5 mM SA, consistent with SA's role in boosting antioxidant activity and cell metabolism. At 2 mM SA, all genotypes showed reduced root length and biomass, indicating phytotoxicity. These results align with previous studies showing that SA at low doses improves germination and stress tolerance (Shatpathy *et al*., 2018), (Ben *et al*., 2025), while higher doses suppress growth due to oxidative imbalance (Fang

et al., 2025). Overall, the findings confirm a dose-dependent (hormetic) effect of SA and highlight variety -specific variability in responsiveness.

Table 2. Effect of interaction between some flax seed genotypes to seed treatment with SA on germination and seedling parameters

genotypes	Concentration of SA	Germination %	Root length cm	Root fresh weight g	Root dry weight g	Shoot length cm	Shoot fresh weight g	Shoot dry weight g
	control	85 ab	2.833 h-l	0.0333 f-j	0.00161 bc	5.0123 a-f	0.0700 d-g	0.00150 b-g
	0.5 mM	100 a	5.510 bcd	0.0600 b-e	0.00168 bc	5.8100 abc	0.1133 a	0.00197 a-e
Germany	**1 mM**	90 ab	4.647 d-h	0.0500 c-f	0.0017 bc	5.1767 a-e	0.0733 def	0.00172 a-f
	1.5 mM	90 ab	4.577 d-h	0.0500 c-f	0.0010 c	4.5900 b-g	0.0633 e-f	0.000159 a-f
	2mM	55 d	1.863 j-n	0.0300 f-j	0.00133 c	3.9333 e-i	0.0400 j-m	0.00136 c-h
	control	85 ab	4.277 d-1	0.0600 b-e	0.00169 bc	4.680 a-g	0.0833 cde	0.00166 a-f
	0.5 mM	95 ab	5.670 bcd	0.0833 a	0.00193 bc	5.210 a-e	0.1067 ab	0.00209 abc
Leider	**1 mM**	90 ab	5.547 bcd	0.0800 ab	0.00175 bc	4.690 a-g	0.0900 bcd	0.00192 a-e
	1.5 mM	80 bc	1.857 j-n	0.0367 f-i	0.00111 c	3.410 g-j	0.0667 e-h	0.00158 a-g
	2mM	55 d	1.567 k-n	0.0233 hij	0.00084 c	2.730 h-l	0.0300 k-o	0.00153 a-g
	control	25 ef	2.55 i-n	0.0267 g-j	0.00130 c	2.6667 i-l	0.0300 k-o	0.00148 b-g
	0.5 mM	30 e	8.557 a	0.0700 abc	0.00237 bc	5.2500 a-d	0.0667 e-h	0.00208 abc
Local	**1 mM**	30 e	5.483 b-e	0.0467 d-g	0.00203 bc	3.8767 f-i	0.0300 k-o	0.00165 a-f
	1.5 mM	25 ef	5.123 c-g	0.0367 f-i	0.00193 bc	2.9500 h-l	0.0133 o	0.00113 d-h
	2mM	10 f	2.053 j-n	0.0200 ij	0.00112 c	1.7333 l	0.0133 o	0.00050 h
	control	30 e	4.333 d-i	0.0400 e-i	0.00213 bc	4.627 b-g	0.0467 h-k	0.00220 ab
	0.5 mM	35 e	6.850 bc	0.0633 a-d	0.00260 abc	5.950 a	0.0567 f-j	0.00247 a
Poland	**1 mM**	35 e	5.203 c-f	0.0500 c-f	0.00236 bc	5.847 ab	0.0500 g-k	0.00233 ab
	1.5 mM	25 ef	2.693 i-m	0.0233 hij	0.00108 c	4.010 d-h	0.0367 j-n	0.00197 a-e
	2mM	10 f	1.333 lmn	0.0133 j	0.00083 c	2.34 jkl	0.0167 no	0.00067 gh
	control	85 ab	5.567 cd	0.0633 a-d	0.00165 bc	5.367 abc	0.0967 abc	0.00181 a-f
	0.5 mM	100 a	5.327 b-e	0.0767 ab	0.00421 ab	5.490 abc	0.1600 abc	0.00198 a-d
Syrian 1	**1 mM**	95 ab	7.043 ab	0.0733 ab	0.00176 bc	5.627 abc	0.1033 abc	0.00191 a-f
	1.5 mM	90 ab	3.643 e-j	0.0400 e-j	0.00143 c	4.537 c-g	0.0733 def	0.00173 a-f
	2mM	65 cd	3.377 f-k	0.0300 f-j	0.00128 c	3.157 h-k	0.0333 k-o	0.00142 b-g
	control	65 cd	2.550 i-n	0.0233 hij	0.00117 c	2.250 jkl	0.0233 k-o	0.00103 e-h
	0.5 mM	95 ab	4.223 d-i	0.0433 d-h	0.00487 a	3.827 f-i	0.0500 g-k	0.00137 c-h
Syrian 2	**1 mM**	90 ab	3.343 g-k	0.0367 f-i	0.00176 bc	3.683 ghi	0.0433 i-l	0.00134 c-h
	1.5 mM	55 d	0.917 mn	0.0300 f-j	0.00172 bc	3.400 g-j	0.0333 k-o	0.00104 e-h
	2mM	20 ef	0.790 n	0.0133 j	0.00087 c	2.107 kl	0.0200 mno	0.00098 fgh

The data presented in Table (3) inducted significant differences between genotypes; it was found that

the Syrian 2 genotype recorded the highest oil content (43.66%), while Leider genotype gave the lowest oil percentage (37.89%). The analysis of variance results shows significant differences in saturated and unsaturated fatty acids composition between genotypes, the oil seeds for plants Syrian 2 genotype was recorded high percentage of saturated fatty acid as palmitic and Stearic acids (5.51% and 4.15%) respectively, but Leider genotype gave the lowest palmitic and Stearic acids percentage (4.33% and 3.22%) respectively. Also, from unsaturated fatty acids composition between genotypes; Syrian 2 genotype was giving high percentage of oleic%, lenolic%, lenolinic% and arachidonic% (19.90%, 14.58%, 50.14% and 0.35%) respectively, and the lowest oleic%, lenolic%, lenolinic% and arachidonic% acids percentage was given of Leider genotype (17.15%, 12.35%, 45.11% and 0.17 %) respectively. The increase of oleic acid percentage is due to rise of temperature degrees which decrease of oxygen rate which in turn reduce the activity of Desaturase as it is responsible for the converting of oleic acid to linoleic acid (Canven, 1965). The results explain that the Leider genotype produced the highest percentage of Myristic acid (0.08%), while Local genotype gave the lowest rate for this trait (0.012 %).

Table 3. Flaxseed oil content and composition of saturated and unsaturated fatty acids.

genotypes	Oil %	Palmatic %	Stearic %	Oleic %	Lenolic %	a-Lenolinic %	Arachidonic %	Myristic %
Germany	41.25 b	5.11 b	4.00 b	18.98b	13.74 b	48.00 b	0.30 ab	0.020 bc
Leider	37.89 f	4.33 f	3.22 f	17.15f	12.35 f	45.11 f	0.17 c	0.08 a
Local	38.98 e	4.58 e	3.50 e	17.90e	13.00 d	46.25 e	0.20 c	0.012 c
Poland	40.69 c	5.00 c	3.85 c	18.22c	13.24 c	47.15 c	0.26 bc	0.018 bc
Syrian 1	39.08 d	4.78 d	3.66 d	18.04d	13.11 d	46.88 d	0.22 bc	0.014 c
Syrian 2	43.66 a	5.51 a	4.15 a	19.90a	14.58 a	50.14 a	0.35 a	0.025 b

It is clear from Table (4) that the protein percentage in the Leider genotype is higher than the rest of the genotypes, as the protein percentage in it reached (23.08) %, while the rest of the genotypes Local, Syrian 1, Poland, Germany and Syrian 2 were (22.55, 21.89, 20.74, 20.23, 19.80) % respectively.

As for minerals, the best results were for the German genotype, where the percentage of minerals Ca, K, Mg, Fe reached to (0.277, 0.836, 0.385, 0.062) %. As for the Syrian 2 genotype, its results were also good, where the percentage of Ca and Fe reached (0.289, 0.070) %. As for the other genotypes, there are differences in the percentages of minerals present in them, and the reason may be that the difference in genotypes leads to a difference in the percentage of protein and minerals. Also, environmental conditions may control the characteristics of the plant and thus the seeds, as well as the conditions and type of soil in terms of salinity and the amount of water, which leads to changing the characteristics (Kaur *et al*., 2017), (Kauser *et al*, 2024).

Table 4. Flaxseed contains protein and mineral composition.

genotypes	Protein %	Ca %	K %	Mg %	Fe %
Germany	20.23 e	0.277 b	0.836 a	0.385 a	0.062 ab
Leider	23.08 a	0.209 f	0.815 b	0.369 b	0.033 e
Local	22.55 b	0.225 e	0.778 e	0.338 d	0.042 d
Poland	20.74 d	0.250 c	0.783 d	0.352 c	0.055 bc
Syrian 1	21.89 c	0.239 d	0.745 f	0.325 e	0.050 cd
Syrian 2	19.80 f	0.289 a	0.799 c	0.352 c	0.070 a

In table (5) The chemical analysis results revealed significant differences among the six flaxseed genotypes in terms of their vitamin content (A, D, E, K). For Vitamin A, the Germany genotype showed the highest significant concentration (3.11 ppm), followed by the local genotype (2.89 ppm). The Poland genotypes recorded the lowest concentration (1.58 ppm), indicating potential genetic variability in the biosynthesis of this vitamin among genotypes. Regarding Vitamin D, the Germany genotype again recorded the highest value (12.90 ppm), with the local genotype close behind (12.42 ppm). Although the differences among genotypes were relatively small, they were statistically significant. For Vitamin E, the local genotype had the highest concentration (33.78 ppm), followed by the Germany genotype (33.00 ppm), while the Leider genotype showed the lowest (30.25 ppm). This suggests that the local flaxseed may be a rich source of antioxidant compounds such as Vitamin E. In terms of Vitamin K, the local genotype also ranked first (4.79 ppm), followed by the Germany one (4.55 ppm), while the Leider genotype again had the lowest concentration (3.44 ppm). Overall, the data suggest that the local and Germany genotype possess superior vitamin profiles compared to the other genotypes, which may make them more suitable for nutritional or industrial applications aiming to enhance the final product's dietary value. (Lobanov *et al*., 2024), (Wu *et al*., 2023)

Table 5. Vitamin content in flax varieties

varieties	VIT A (ppm)	VIT D (ppm)	VIT E (ppm)	VIT K (ppm)
Germany	3.11 a	12.90 a	33.00 b	4.55 b
Leider	1.80 e	11.77 e	30.25 f	3.44 f
Local	2.89 b	12.42 b	33.78 a	4.79 a
Poland	1.58 f	11.58 f	32.25 c	4.32 c
Syrian 1	2.00 d	11.90 d	30.98 e	3.89 e
Syrian 2	2.15 c	12.05 c	31.25 d	4.00 d

CONCLUSIONS

Laboratory results for oil content shoed that the Syrian 1, Germany and Leider genotypes recorded

the highest percentage. And for the Leider genotype recorded the highest protein percentage. And low concentrations of SA (especially 0.5 mM) significantly improved germination percentage, root and shoot lengths, and biomass accumulation across most flax genotypes. In contrast, 2 mM resulted in severe inhibition. genotypes such as Syrian 1, Germany, and Leider demonstrated superior performance and stronger positive response to SA, while local and Poland varieties were more sensitive and showed poorer vigor.

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