Egypt. J. Agron. **Vol. 47**, No. 3, pp: 535 - 546 (2025)

Egyptian Journal of Agronomy

http://agro.journals.ekb.eg/

Influence of Pre-sowing Treatments on Germination, Seedling and Agronomic Traits in Lupine (*Lupinus albus* L.)

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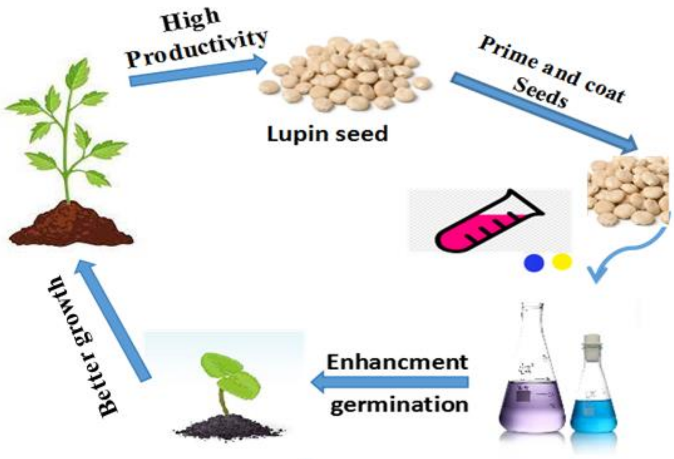
THE PAPER aimed to determine the changes that occurred in germination characteristics, agronomic traits and enzymes activity of lupine after pre-sowing treatments. The present study analyzed the influence of six seed treatments by seed priming and coating on yield of Egyptian commercial variety of lupine (Giza 2). Laboratory, greenhouse and field experiments were conducted at Agricultural Research Center (2022/2023 and 2023/2024 crop seasons) in a randomized complete blocks design with three biological replications. Aqueous solutions of K_2SO_4 (0.5 g/ml), salicylic acid (0.1 g/ml), $MgSO_4$ (0.5 g/ml) were prepared, Extra Seed Power priming (0.3 g/ml) were used to prime seeds by soaking for 8 hours, while Extra Seed Power coating was used as a powder, which was mixed with seeds before planting. Results showed that the treatments differed significantly for all the studied traits. ESP priming and ESP coating followed by $MgSO_4$ (0.5 g/ml) and K_2SO_4 (0.05 g/ml) had higher values in different germination and seedling traits under study. Data indicated that the yield characters improved by treated seed as compared with untreated seed under field conditions. The Extra Seed Power priming (0.3 g/ml) gave higher values for most yield characters followed by ESP coating, while salicylic 0.1g/ ml gave lower values. Treating seeds with ESP prime and ESP coat considerably increased the amount of peroxidase, catalyze and amylase in germinating seeds, compared to other treatments and control. Most of the evaluated parameters were had strong positive correlations among some studied traits, except, first height node and seed index which had negative correlation with all characters, according to phenotype correlation coefficient analysis. This study suggests that Extra Seed Power as priming at 0.3 (g) concentrate and Extra Seed Power as a coating were suitable treatments and highly responsive that can enhance germination of seeds, stimulate seedling development and give higher yield in lupine under Egyptian environmental conditions.

Keywords: *Lupinus albus*, seed treatments, germination, enzymes activity, crop establishment.



Graphical Abstract

Introduction

Lupine is an old leguminous crop, it has been grown and used as a food for human beings and cattle, since around 2000 years ago (Petterson and Fairbrother, 1996). Several species of lupines have

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Received: 20/06/2025; Accepted: 30/07/2025
DOI: 10.21608/agro.2025.391180.1718

been used as a food, for over 3000 years, around the Mediterranean area and for 6000 years in the Andean highland. In Egypt, the lupine is known as Termes, and it is a popular street snack after being treated by soaking in water and then treated with salt to be brined. Besides, seeds of lupine are used in traditional medicine as an anti-diabetic agent in the Middle East and Africa and used topically in the U.S.A to treat acne, it is also used for foot eczema (Quiles et al., 2010). Recently, lupine seeds have drawn attention because of their nutritional value, pharmaceutical properties, high level alkaloid amount, and richness in protein (Omer et al., 2016). Seeds of lupine have high amounts from minerals, protein and fiber. The protein percentage of white lupine seeds (33-47 %) is more higher as compared to other legumes and close to the soybean. Furthermore, the nutritional quality of the lupines seed can be similar to soybean seeds which have over 20 % fat rich in unsaturated fatty acids as reported by (Gulewicz et al., 2014; Arab et al., 2014; Khalifa et al., 2020). Although, lupine represents a rich protein source for humans and livestock in different regions of the world (Kohajdova et al., 2011). Furthermore, lupine cultivated area reached around 160 faddan in 2020 with an average yield of 6 ardab/ faddan. Most of genotypes of white lupine until about 1986 were old low-yielding landraces in Egypt (Bulletin of Statistical Cost Production, and Net Return 2021).

Increasing yield and productivity at acceptable levels has become a primary objective of plant breeding and improvement program (de Faria et al., 2013; Ahmed et al., 2023). To improve lupine seeds germination, yield and quality, the priming techniques have been employed, including solid-matrix priming, hydro-priming, osmo-priming, bio-priming, magno-priming, halo-priming and hormonal priming. It has the advantage of overcoming non-uniform germination, slow germination, low viability seedlings, low vigor, and less productivity, as well as lack product quality. Also, it enhances germination even under stresses conditions and increases yield potential, (Marthandan et al., 2020). Janeczko et al., (2015) revealed that seeds priming is one of the methods to enhance seedling vigor, overcome difficult stresses conditions, and obtain a higher yield. Far less is known about the impact of seed priming on quality of seed produced. Seed priming is a pre-cultivation method, for affecting seedling development, with modulating pre-germination metabolic and enzymes activity to emergence of the root and synhronise it with shoot development; and generally stimulate germination rate and plant response (Ahmed and El-Mahdy, 2022; Ahmed, 2023 and Ahmed 2024). Priming is seed soaking in solutions of any priming agent then drying of seed that initiate germination related processes, without root emergence (McDonald, 2000). Using priming technique, the germination process is supported by soaking seed in solutions containing varied compounds, like salts, plant extracts, metals, and phytohormones. Some of organic and chemical priming agents have positive results for yield (Hussain et al., 2016).

Seed coating makes seeds larger, rounder, softer, heavier and more uniform in shape. Seed coating increases seed germination performance and incorporate materials that prevent pests and diseases during germination and seedling stages (Taylor et al., 1998). Junges et al., (2013) and Bicakci et al., (2018) recorded that coating seeds can ensure seed health and seedling development, promoting a plant's genetic and physiological potential. Preferred method involves coating seeds with rhizobacteria and other bacteria for bio control. The seed coating optimizes the seed size for sensitive sowing machines and provide nutrients and chemical ingredients that can improve seedling development.

Therefore, the aim of this investigation was to examine and evaluate the effects of various seed treatments on agronomic traits enhancement and estimate enzyme activities of lupine as well as germination dynamics and plant emergence under the prevailing Egyptian environmental conditions.

Materials and Methods

Location and cultivation practices

A two-seasons study were carried out at Giza Research Station, Giza government, Egypt (Lat. 30°00′30″ N, Long. 31°12′43″ E, 26 m a.s.l), Agricultural Research Center (ARC), Giza Governorate, Egypt during the 2022/2023 and 2023/2024 crop seasons in a randomized complete blocks design (RCBD) with 3 replications to evaluate the lupine yield potential of commercial cultivar lupine (Giza 2) which obtained by the Legumes Research Department at ARC. Calcium super phosphate (15.5% P2O5) at the rate of 150 kg/fad was added during every season during soil preparation. Thereafter, the experimental plot had 3 rows, 60 cm apart and 3 m long (5.4 m2), with single seeded hills, 20 cm apart in one side of ridge. The seeds were sown on 23th and 27th November at crop seasons of 2022 and 2023, respectively. Mineral N fertilizer was applied at a rate of 45 kg N/fad, as ammonium nitrate (33.5% N) which parceled in three portions; before 1st, 2nd and 3rd water irrigation. Normally recommended cultural practices for growing lupine cultivar were used (http://www.arc.sci.eg/).

Laboratory experiment

To evaluate the different seed treatments at the germination stage seedling establishment were performed at the Seed Technology Dept.

Laboratory, Field Crops Research Institute (FCRI), Agricultural Research Center (ARC), Giza, Egypt. The design of the experiment was laid out in a completely randomized design (CRD) with four replications. The study aims to estimate the effect of seed treatments as follow: control (un-treated), K_2SO_4 (0.5 g/ml), $MgSO_4$ (0.5 g/ml), salicylic (0.1 g/ml), Extra Seed Power (ESP) priming (0.3 g/ml) and Extra Seed Power (ESP) coating on germination characters, seedling growth, vigor and field emergence characteristics of lupine.

Seed preparation

The seeds were disinfected with 0.1% $HgCl_2$ solution for 4-5 minutes and washed 4-6 times by distilled water to remove any infection (wash for remove metal – Hg). The treated seeds by solutions (priming) were obtained as follow; seed soaked in K_2SO_4 (0.5 g/ml), $MgSO_4$ (0.5 g/ml), salicylic (0.1 g/ml), ESP priming (0.3 g/ml) at the ratio of 1:10 (w/v) turn to 100 mm; were prepared at room temperature (20±2ºC), for 8 hours, besides Extra seed power (ESP) coating treatment (10 g of ESP coat for 100 g seeds) (Ahmed, 2024), in addition to untreated seed. This was done by dipping the 50 viable seeds of each replicate randomly, chosen into each seed priming and seed coating, after that the treated seeds were air dried at room temperature. The experiment was artificially created in the sandy soil with four replicates of each treatment, an experiment was grown in germination trays moistened with distilled water, incubated in incubator at 20 ± 2º C (ISTA, 2020). ESP priming consists from plant extracts, antioxidants and micro elements, ESP coating consists of of antioxidant, polyphenols compound, macro and micro elements (Ahmed, 2024).

Data recording:

Germination test

A total number of germinated seeds were counted daily and percentage was calculated at 10^{th} day according to ISTA (2020). Recorded data was: Germination percentage (GP %): (The germinated seeds number /The total seed number) X 100; Germination Rate (GR/ day) was defined as described the following formula of Bartlett (1937): GR= a + (a +b) + (a + b + c) ... (a + b + c + m)/ n (a + b + c + m). Where a, b, c are number of seedlings in the first, second and third count, m is number of seedlings in final count, n is, the number of counts. Mean Germination Time (MGT/ day) was calculated based on the following equation: MGT= Σ Dn/ Σn, where (n) is the number of seeds, which were germinated on day, D is number of days counted from the beginning of germination (Ellis and Roberts, 1981). Speed Germination Index (SGI) was calculated according to AOSA (2005) by formula: SGI= (number of germinated seed/ days of first count) + (.../…) + (number of germinated seed/ days of final count).

Seedling traits

Each replicate had data collected around 10 seedlings which were taken for seedling traits. The harvesting was after 10 days from the seed sowing date (ISTA, 2020). Seedling length, root length and shoot length (cm) were measured of ten normal seedlings at 10 days after growing. Seedling fresh and dry weight (g): Ten normal seedlings 10th days after planting were measured to determine fresh weight, whereas dry weight (g) was measured by drying of seedling in hot-air oven at 85o C for 12 hours (Abdul Baki and Anderson, 1973). Seedling vigor index I (SVI) = germination (%) x total seedling length (root + shoot). Seedling vigor index II (SVII)= germination (%) x total seedling dry weight (root +shoot).

Greenhouse experiment

Untreated and treated seeds were planted in 8 kg plastic pots (25 cm of diameter and 30 of depth) containing moist clay and sand (1/1, respectively), replicated four times and were placed in greenhouse for two winter seasons and laid in a Randomized Complete Block Design (RCBD). Tested traits were measured as follow; field emergence (%), seedling lengths, seedling dry weight (g) and seedling vigor II after 25 days from sowing.

Field experiment

Data of seed yield and it̓s components were recorded on plants randomly selected from the middle row. Ten guarded plants were taken randomly from each plot to measure the following traits: plant height (cm), first nod height (cm), sickness of stem (mm), no. of first branches/ plant, no. of second branches/plant, no. of pods/first node, No. of second branches/plant number of pods per plant, pods weight/ plant, number of seeds per plant and seed yield per plant (g) and 100 - seed weight (g).

Phenotypic correlation coefficient

Phenotypic variability in lupine pooled data was used to evaluate, the simple phenotypic correlation coefficient between all possible pairs of the investigated traits for lupine which collected by seed treatments and control (Steel and Torrie, 1980).

Enzymatic activity assay

50 seeds from each treatment in 3 replicates were applied in the same conditions of germination test. Germinated seeds (root emergence in length of root 2 mm) were powdered for enzymatic assay. According to the methods previously described, the enzymes activity of peroxidase enzyme was determined by Agarwal and Shaheen (2007), catalyse enzyme activity was determined according to (Kar and Mishra, 1976) and amylase enzyme was evaluated by (Elarbi et al., 2009).

Statistical analysis

Analysis of variance of investigated traits of each season was performed. The least significant differences (L.S.D) test, with a significance level of 5%.26 The measured variables were analyzed by ANOVA using the CoStat system for Windows, Version 6.311 (CoHort, software, Berkeley, CA 94701).

Results

The results of the study were determined that K_2SO_4 (0.5 g), salicylic (0.1 g), $MgSO_4$ (0.5 g), ESP priming (0.3 g) and ESP coating influenced the germination percentage (GP%), germination rate (GR/ day), mean germination time (MGT/day), speed germination index (SGI), seedling length (cm), root length (cm), shoot length (cm), seedling fresh weight (g), seedling dry weight (g), seedling vigor index I (SVI), seedling vigor index II (SVII) properties of Giza 2 lupine cultivar. Effects of treatments of pre-sowing on germination traits are illustrated in Table 1. While, effect of pre-sowing treatments on seedling parameters are illustrated in Table 2 and 3, respectively.

Germination characteristics

The GP % values of lupine cultivars varied between 94.33% and 67.00%. The lowest GP% values were determined both at the salicylic treatment (67.0%) and control (73.33%), whereas the highest GP % values were detected both at ESP priming (94.33%) and ESP coating (91.33%) then $MgSO_4$ (83.67%).

The highest values of GR /day were observed on seed treatments by ESP priming and ESP coating (46 and 44, respectively) followed by MgSO4, while salicylic and control recorded the lowest percentage compared with other treatments (32 and 35, respectively). Compared to other treated and untreated seed, control (4.80) and salicylic (4.63) had the highest value of MGT, where ESP priming and K_2SO_4 treatments gave the minimum values of MGT/ day (3.43 and 383, respectively). Whereas, the speed germination index (SGI) was significant among all treatments, the higher SGI was higher by 151.55 % for ESP priming and 146.93% for ESP coating followed by K_2SO_4 which was 102.6% (Table 1).

Table 1. Influence of different per-sowing treatments on germination traits of lupine.

Treatments	Traits							
	GP (%)	Increase %	GR/day	Increase %	MGT/ day	Increase %	SGI	Increase %
Control	73.33de		0.35d		4.80ab		1.94c	
K_2SO_4	78.33cd	6.82	0.38c	8.57	3.83cd	-20.21	3.92ab	102.06
Salicylic	67.00e	-8.63	0.32e	-8.57	4.63ab	-3.54	2.80bc	44.33
$MgSO_4$	83.67bc	14.10	0.41bc	17.14	4.20bc	-12.50	3.49abc	79.90
ESP priming	94.33a	28.64	0.46a	31.43	3.46d	-27.92	4.88a	151.55
ESP coating	91.33ab	24.55	0.44ab	25.71	4.07c	-15.21	4.78a	146.39
LSD $_{0.05}$	8.01		0.023		0.45		1.59	
F test	***		***		***		*	
CV%	5.53		4.63		6.08		24.63	

GP: germination percentage; GR: germination rate; MGT: mean germination time; SGI: speed germination index.

Seedling characteristics

The length of lupine seedling varied significantly depending on the seed treatments (Table 2). The maximum lupine seedling length (cm) were observed in the ESP coating and ESP priming treatments (14.07 and 13.76 cm, respectively), which were statistically greater than the other treatments. lupine seedlings with a minimum length of 6.40 cm were discovered in control. The present investigation revealed that all the treated seeds significantly stimulated growth of shoot and root seedlings lengths (cm). The shoot length (cm) of lupine had significant with different treatments. Treatment with ESP coating produced the longest shoot which was 8.75 cm, followed by ESP priming 8.03 cm with no significant differences between them comparing with other treatments and control.

While, the control produced the shortest shoot which was 3.83cm. The root length (cm) of lupine seedlings was significantly impacted by various seed treatments. ESP priming treatment had the longest root (5.73cm), and followed by the ESP coating treatment (5.50 cm), then the $MgSO_4$ (4.07 cm), K_2SO_4 (2.07 cm) and without treatment (2.57 cm). In contrast, the treatment with salicylic acid yielded the shortest root (2.67 cm) compare with other treatments.

The lupine seedling fresh weight (g) showed a significant difference between treated and untreated seeds. The maximum seedling fresh weight (g) was recorded under the ESP priming treatment (1.87 g), which was statistically higher than the other treatments followed by ESP coating (1.55 g). Moreover, the minimum seedling fresh weight (cm) was for salicylic and control which were 1.20 and 1.18 (g), respectively (Table 3). The dry weight (g) of the lupine seedlings varied significantly depending on the seed treatments. The maximum seedling dry weight of lupine was observed in the ESP priming treatment (0.38 g), followed by ESP coating treatment which was 0.35 g. Seedling dry weight (g) recorded non-significant variation among other treatments. Seedling vigor showed a significant difference between seed treatments. The maximum seedling vigor index I (SVI) of lupine was for ESP priming (649.4), then (642.0) for ESP coating. Salicylic and untreated seeds showed minimum SVI compared with other treated seed which recorded (261.3 and 218.0, respectively).

The maximum seedling vigor index II (SVII) of lupine was observed with ESP priming (35.6), followed by (31.83) for ESP coating. On the other hand, the other seed treatments of lupine showed non-significant differences in seedling vigor II.

Table 2. Influence of different per-sowing treatments on seedling lengths traits of lupine.

Treatments	Seedling lengths (cm)					
	Shoot length (cm)	Increase %	Root length (cm)	Increase %	Seedling length (cm)	Increase %
Control	3.83c		2.57c		6.40c	
K_2SO_4	5.53bc	44.39	2.70c	5.06	8.23bc	28.75
Salicylic	4.53bc	18.28	2.67c	3.89	7.20c	12.50
$MgSO_4$	5.93b	54.83	4.07b	58.37	10.00b	56.25
ESP priming	8.03a	109.66	5.73a	122.96	13.76a	115.00
ESP coating	8.57a	123.76	5.50a	114.01	14.07a	119.69
$LSD_{0.05}$	1.70		0.91		2.18	
F test	***		***		***	
CV%	15.78		13.26		13.39	

Table 3. Influence of different per-sowing treatments on seedling weight and seedling vigor of lupine.

Treatments	Seedling weights (g)				Seedling vigor			
	Fresh weight (g)	Increase %	Dry weight (g)	Increase %	Vigor I (SVI)	Increase %	Vigor II (SVII)	Increase %
Control	1.18b		0.20b		218.0d		17.02b	
K_2SO_4	1.46ab	23.73	0.30b	50.00	322.9bc	48.12	22.08b	29.73
Salicylic	1.20b	1.69	0.28b	40.00	261.3cd	19.86	22.02b	29.38
$MgSO_4$	1.49b	26.27	0.34b	70.00	418.7b	92.06	22.60ab	32.78
ESP priming	1.87a	58.47	0.38a	90.00	649.4a	197.89	35.56a	108.93
ESP coating	1.55b	31.36	0.35b	75.00	642.0a	194.50	31.83a	87.02
$LSD_{0.05}$	0.56		0.15		95.0		13.45	
F test	NS		NS		***		NS	
CV%	22.75		28.55		12.86		30.02	

Field Emergence Experiment

Table (4) showed that there were significant effects for seed priming, coating and untreated seed of lupine. As results, there were significant increases in field emergence % of lupine seeds were obtained due to sowing priming treated seeds with K_2SO_4 (0.5 g), $MgSO_4$ (0.5 g), salicylic (0.1 g), ESP priming (0.3 g) and ESP coating compared to untreated seeds. The increment reached to 96 % and 95% for field emergence %, 26.25 and 24.95 cm for shoot length, 15.5 and 14.5 cm for root length for ESP priming and ESP coating, respectively. In the same trend observed in seedling length which reached to 41.75 and 39.45 cm; 8.39 and 7.34 g for fresh seedling weight, 2.14 and 1.74 g for seedling dry weight, 204.5 and 165.1 for seedling vigor II for ESP priming and ESP coating, respectively. Significant differences were observed in estimated lupine parameters at field emergence due to positive effects of pre-sowing treatments as coating and priming seeds. ESP priming had the highest results to all estimated characters, then ESP coating, whereas, treating using salicylic and untreated seeds had the lowest values to tested traits compared to other treatments.

Table 4. Influence of different per-sowing treatments on field emergence parameters of lupine.

Characters	Field emergence %	Seedling lengths (cm)			Seedling weights (g)		Seedling Vigor II
		Shoot length (cm)	Root length (cm)	Seedling length (cm)	Fresh weight (g)	Dry weight (g)	
Control	81.5b	17.1b	10.25de	25.5c	4.81c	1.35b	109.7b
K_2SO_4	86.0b	19.5b	12.75bc	30.5bc	5.40c	1.45b	125.2b
Salicylic	82.0b	17.5b	8.75e	26.25bc	5.38c	1.35b	109.8b
$MgSO_4$	82.5b	21.0b	11.5cd	32.5b	6.17bc	1.54b	126.3b
ESP priming	96.0a	26.25a	15.5a	41.75a	8.39a	2.14a	204.5a
ESP coating	95.0a	24.95a	14.5ab	39.45a	7.34ab	1.74ab	165.1ab
$LSD_{0.05}$	4.73	3.81	1.76	6.35	1.35	0.47	55.24
F test	**	**	**	**	**	**	***
CV%	2.11	7.05	5.62	7.56	8.45	11.67	15.34

Yield and its components

Tables (5 and 6) show the effect of different per-sowing treatments lupine seed on the means of yield and yield components, across two crop seasons (2022/2023 and 2023/2024).

Plant height: Means of plant height show significant different response to the studied treatments. $MgSO_4$ (0.05 g) and ESP priming (0.3 g) exerted taller lupine plants comparing with other treatments as well as the control (untreated), whereas the shorter treatments were salicylic (0.1 g) and control. This reveals that the plant height was much by seed treatment of lupine, this was true in both seasons (Table 5).

First node height (cm): Data in indicated that the investigated lupine treatments exhibited significant differences in first node height, which ranged from 26.25 to 17.75 cm in Table (5). untreated seeds, salicylic and K_2SO_4 significantly surpassed than all the other treatments. On the other hand, $MgSO_4$ gave the shortest height of node (cm).

Sickness of stem(cm): Sickness of stem (cm) of lupine under investigations was significant differences. Treatment ESP coating appeared to have more sickness of stem than the other treatments, but the lowest sickness of stem was exhibited by untreated seed (Table 5).

Number of first branches/ plant: The results in Table (5), estimated that the studied lupine treatments exhibited significant increases in no. of first branches/ plant which ranged from 2.25 to 1.0. ESP priming and coating significantly surpassed compared with other treatments and un-treatment. In the contrary, salicylic and control gave the lowest No. of first branches/ plant (1.2 and 1.0), respectively.

Number of second branches/ plant: Results showed in Table (5) recorded that seed lupine treatments and control were significant different in no. of first branches/ plant. The means for this trait ranged from 4.25 to 3.25. ESP priming and coating exceeded the others. On the contrary, salicylic and untreated seeds had the lowest values in this trait.

Number of pods /first node: Results in Table (5) indicated that lupine seed treatments were significantly different in no. of pods/first node, ranging from 11.75 for ESP priming to 8.25 and 8.25 for K_2SO_4 and control, respectively. ESP priming and ESP coating were the best treatments for this trait.

Number of pods/plant: Data present in Table (6) showed the No. of pods/plant of the studied lupine seed treatments. The highest values were recorded for ESP priming and ESP coating whereas the lowest value of no. of pods/plant was found for control and salicylic treatment.

Pods weight/ plant (g): Results showed in Table (6) cleared that lupine treatments and control were highly significant different in Pods weight/ plant (g). The means for this trait ranged from 96.2 (ESP priming) to 45.0, 45.0 (salicylic 0.1 g and control). ESP priming and coating exceeded the others. On the contrary, salicylic and untreated seeds had the lowest pods weight/plant (g).

Number of seeds/plant: Results recorded in Table (6) indicated that seed treatments of lupine and un-treated seed were significantly different in number of seeds/plant. The means for this trait ranged from 175.4 (ESP priming treatment) to 85.8 and 85.8 (salicylic and control) in both growing seasons. ESP priming and ESP coating exceeded the others. On the contrary, salicylic treatment and control had the lowest number of seeds/plant. This indicates that number of seeds/plant was affected much by seed treatments and ESP priming and ESP coating are considered the best.

Table 5. Influence of different per-sowing treatments on lupine seed yield and its components characters.

Characters	Plant height (cm)	First node height (cm)	Sickness of stem (cm)	No. of first branches/ plant	No. of second branches/ plant	No. of pods/first node
Control	79.0b	26.25a	1.08c	1.0b	3.25b	8.25b
K_2SO_4	85.5ab	24.5ab	1.21b	1.25bc	4.0ab	8.25b
Salicylic	77.5b	25.0a	1.23b	1.20bc	3.5ab	8.5b
$MgSO_4$	92.5a	17.75c	1.36a	1.50b	4.0ab	9.0b
ESP priming	88.25a	20.0bc	1.33a	2.25a	4.25a	11.75a
ESP coating	86.0a	21.75b	1.56a	2.0a	4.25a	10.97a
$LSD_{0.05}$	11.06	4.86	0.25	0.37	0.82	1.80
F test	*	*	*	*	NS	**
CV%	8.66	14.11	12.99	32.35	14.49	12.76

Table 6. Influence of different per-sowing treatments on lupine seed yield and its components characters.

Characters	No. of pods/ plant	Pods weight/ plant (g)	No. of seeds/ plant	Seed yield/ plant (g)	100-Seed weight (g)	Seed yield (ardab/fad.)
Control	23.25c	45.0c	85.8c	30.4c	30.56a	5.65c
K_2SO_4	41.25b	53.4c	120.3b	55.6b	31.50a	9.02b
Salicylic	25.75c	45.0c	85.8c	30.8c	30.85a	6.26bc
$MgSO_4$	37.25b	81.6b	145.5b	57.8ab	32.14a	9.05b
ESP priming	50.5a	96.2a	175.4a	68.6a	33.50a	12.27a
ESP coating	50.25a	93.2ab	169.8ab	65.7a	33.95a	12.21a
$LSD_{0.05}$	8.91	15.47	28.27	12.25	5.33	2.25
F test	***	***	***	***	Ns.	***
CV%	15.54	18.56	20.43	19.45	9.66	16.54

Seed yield/plant (g): The data in Table (6), recorded that the studied lupine treatments exhibited significant differences in seed yield/ plant that ranged from 68.6 to 30.4 g. ESP priming and coating significantly surpassed the other treatments besides control. In the contrary, control and salicylic had the lowest values for seed yield / plant.

100-Seed weight (g): Data in Table (6) for 100-seed weight (seed index) indicated that significant variation was found among treatments in both seasons, showing the existence of a wide phenotypic variation between these seed treatments. Averaged values for this trait ranged from 30.56 to 33.95 g. ESP priming and ESP coating treatments surpassed the others followed by $MgSO_4$ and K_2SO_4, while salicylic and control gave the lowest values for seed index as compared with all studied lupine treatments.

Seed yield (ardab/fad): There were significant differences among the studied seed treatments for seed yield per fad (Table 5). Seed yield of the studied treatments ranged from 5.65 to 12.27 ardab per fad. The ESP priming and ESP coating had higher seed yield per fad (12.27 and 12.21 ardab per fad, respectively) than the other treatments. The treatments of $MgSO_4$ and K_2So_4 ranked second (9.05 and 9.02 ardab per fad, respectively). Meanwhile, the Salicyli treatment and untreated seed had lower seed yield per fad (6.26 and 5.65 ardab per fad, respectively) than the others.

Phenotypic correlation coefficients

The evaluation of correlations between different parameters revealed that some of parameters are positively associated. Whereas, others were negatively correlated (Table 7). This means, it is considered an indicator for increasing or enhancing specific traits that will have a positive or negative effect on the other traits. The phenotypic correlation recorded that germination percentage (GP) gave a high and positive significant correlation obtained with seed germination index (SGI). on the other hand, seedling length (SL) and seedling vigor II (SVII), it was negatively correlated with 100- seed weight. In addition, SGI and SVII are highly correlated with SL. Furthermore, no. of pods/ plant, pods weight/ plant, no. of seeds/ plant, weight of seeds/ plant were showed high and positive correlation between them. In addition, First node height (FNH) and SI had high and negative significant correlation achieved between all other characters. The correlation between germination traits and yield components traits were low correlation to GP then SVII, whereas, SGI and SL were medium correlation with most of yield characters.

Table 7. Phenotypic correlation coefficients of quantitative traits of lupine.

Characters	**G%**	**SGI**	**SL (cm)**	**SVII**	**PL**	**FNH**	**No. of pods/ plant**	**Pods weight/ plant**	**No. of seeds/ plant**	**Weight of seeds/ plant**
SGI	0.899*									
SL (cm)	0.94**	0.954**								
SVII	0.94**	0.856*	0.938**							
PL	0.393	0.642	0.657	0.505						
FNH	-0.243	-0.505	-0.546	-0.359	-0.898*					
No. of pods/ plant	0.216	0.497	0.422	0.3844	0.813*	-0.575				
Pods weight/ plant	0.241	0.4918	0.387	0.386	0.694	-0.398	0.976***			
No. of seeds/ plant	0.155	0.458	0.366	0.312	0.806	-0.571	0.996***	0.971**		
Weight of seeds/ plant	0.239	0.492	0.391	0.388	0.707	-0.416	0.981***	0.999***	0.975***	
SI	-0.253	-0.241	-0.188	-0.392	-0.055	-0.265	-0.552	-0.693	-0.516	-0.682

* and ** denote significance at 0.05 and 0.01levels of probability, respectively.

GP: Germination percentage SL: Seedling length SVII: Seedling vigor II SGI: Speed germination index PL: Plant height FNH: First node height SI: 100-seed weight.

Enzymes activity assay

Seed treatments have pronounced influence on enzymes activity. Results in (Figure 1) showed that the pre-sowing treatments increased enzymes activity over the control (un-treatment). Peroxidase activity was affected significantly for treatments, which gave the highest level with ESP priming (1.20 mg/g) then (1.16 mg/g) for ESP coating. While untreated seed, peroxidase activity was lower significant and amounted (0.89) compared with other seed treatments. It was affected significantly by seed priming and coating treatments. The ESP priming and ESP coating recorded the maximum levels of catalyze activity and amounted to (3.55 and 3.40 mg/g, respectively) compared with other seed treatments which were $MgSO_4$ (3.12 mg/g), K_2SO_4 (2.79 mg/g) and salicylic (2.64 mg/g). Untreated seeds gave the lowest level of catalyze enzyme which estimated to 2.39. Amylase activity was affected significantly by different seed treatments and control. Amylase activity ranged from 9.91 to 7.93 mg/g, and the best effects were achieved after treatment with ESP priming and ESP coating which gave 9.91 and 9.60 mg/g, respectively compared with other treated and untreated seeds.

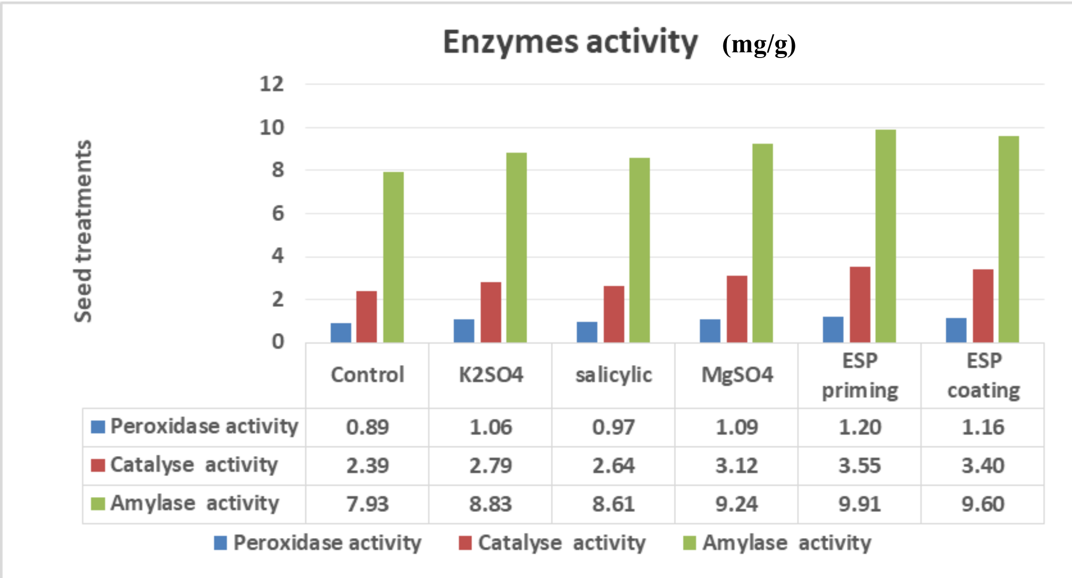

Fig. 1. Effect of different seed treatments on enzymes activity of lupine seeds germinated cultivar (Giza 2).

Discussion

Seed treatments before planting are one of the ways to improve plants vigor, increase stress resistance and obtain higher seed yield. The investigations showed that pre-sowing treatments as priming and coating techniques affected the course of the analyzed agronomic and physiological processes. Changes in germination dynamics and the growth of lupine seedlings were observed. Treated seeds expressed higher activity of enzymes, which causes an acceleration of the germination process compared to control. Then, using ESP prime and ESP coat caused an increase in all enzymes concentration in the seeds and seedlings under study. Germination and seedling growth development characteristics are important contributors to final yield. High germination rate is the main foundation that ensures development in overall seedling establishment. Thakur et al., (2023) investigated the influence of different seed soaking treatments on rate of germination and seedling vigor of okra. Investigation revealed that osmo-priming (5% PEG) optimized the okra growth, yield, and quality parameters in okra followed by halo-priming (3% $MgSO_4$). Primed seeds by hydro-priming, moringa, and garlic extracts significantly increased in all traits, germination traits, seedling vigor, field emergence, and growth (Ahmed and El-Mahdy, 2022; Ahmed, 2023). The salicylic acid is responsible for the antioxidant enzymes activation, for example guaiacol peroxidase superoxide dismutase, ascorbate peroxidase,and catalase, that act on free radicals present in cell, decreasing reactive oxygen species, (ROS) and lipid peroxidation, (Jayakannan et al., 2015). Studies have demonstrated that the exogenous application of salicylic acid stimulate physiological changes, as an increase in plant height, stem diameter and leaf area (Hussein et al 2007), induced photosynthetic pigments contents

(Hayat et al., 2005) and improved germination and seedling development, (Shakirova et al., 2003). Similarly, Fernandes et al., (2019) investigated the physiological quality of common bean seed subjected to the treatments of several salicylic concentrations. Salicylic acid concentrations up to 1,000 µM and seed imbibition (24 hours) do not affect the vigor of the two common bean varieties. However, the salicylic acid influence on germination percentage which has been controversial, as reports suggested that it may inhibit or enhance germination potential. The contradictory results may be linked to the utilized concentrations of salicylic acid and the applications mode on crops seeds (Horváth et al., 2015; Huang et al., 2016). Rajjou et al. (2006) recorded that the exogenous application of 1,000 µM of salicylic acid inhibited seed germination for Arabidopsis thaliana species. 250 µM concentration of salicylic acid had negative effects germination traits which measured in barley (Xie et al., 2007). Anaya et al., (2018) also recorded that the germination reduced with salicylic acid by 250 to 1,000 µM concentrations in the seed imbibition through eight hours for Vicia faba. However, grain wheat (Triticum aestivum) treated by 50 µM concentrate of salicylic acid showed the best vigor, obtaining seedlings with higher growth and development (Shakirova, 2007).

Ramesh and Sing (2006) said that the length of root, roots number/seedlings, length of shoot, seedlings fresh and dry weights, germination % and plant height, yield and its attributes were increased by using K_2SO_4 soaking. The seed priming by K_2SO_4 for 24h enhanced germination and seedling growth. Extra seed power (ESP) as a pre-cultivation treatment was the most effective treatment for many seed species, it can improve seed germination percentage and seedling development under normal and stress conditions as poor storage and diseases (Ahmed, 2024; Ahmed et al., 2025). Priming isn't only stimulating germination percentage and subsequent growth under optimum condition and chemical s it also helps in broadening the range of heat through the germination stage, that finally enhances plant yield (Farooq et al., 2008). Kata et al., (2014) revealed that the seed priming technique containing hydro-priming resulted in the improved activity of α-amylase which in turn had resulted in the better stored carbohydrate mobilization reserves resulting in the enhancement of rice germination and its characters under stresses condition. Response of treated seeds with magnetic field and natural extracts under salinity stress conditions (100 mM NaCl) (Kata et al., 2014; Hozayn et al., 2019; Hozayn and Ahmed, 2019; Pepescu, 2019). The study also found that glucose levels were higher for growing seedlings by coated seeds, indicating more efficient metabolism of glucose into tissue structures in young seedlings from coated seeds (Ahmed 2024). Khan et al., 2011, recorded that the Physiological and biochemical changes that took place, addition to the stimulated physiological activity of the embryo and the mobilization of food reserves, into the growing seedlings, are responsible for the development of a stronger and more effective shoot and root system as well as the effective reduction of physiological deterioration. This may have led to DNA repair, the process of imbibition generates protein membranes and enzymes. A potential reason for the observed rise in shoot length in the primed seeds is either cell division, meristematic growth, or its function in cell elongation (Kaur et al 2015). Primed seeds displayed more rapid and elongated coleoptiles with vigorous root growth. Seed germination and increased vigor during osmotic priming may be due to active food transportation and the resynthesis of specific enzymes. Furthermore, DNA and RNA synthesis, might have started. Seeds germinate more quickly when barriers are removed, and eventually, they form a strong shoot with an increase in dry weight (Adhikari and Shrestha 2020). Increased stand establishment in wheat and the maintenance of controlled but sufficient seed hydration which allows pre-germinated metabolic activity to proceed but stops actual bell pepper radicle emergence, may lead to higher seedling vigor (Yari et al., 2011).

Conclusion

Seed treatment is effective way and good option for enhancing germination and rapid; it has a positive effect on the seedling stage, produces strong and healthy seedlings; and high seed yield components in lupine compared with untreated seeds. Seeds treated with ESP prime and ESP coat as new treatments are better techniques to enhance seedling growth and crop establishment than untreated seeds. Treating lupine seeds with ESP priming and ESP coating considerably increased the enzyme activity in germinating seeds compared with other treatments and the control. Finally, results revealed that using ESP priming and ESP coating are the most effective treatments before planting for enhancing germination traits and stimulating seedling growth of lupine addition to giving higher yield.

Consent for publication:
All authors declare their consent for publication.

Author contribution:

Conceptualization and design of study: AAA, seed treatments preparation and germination tests: AAA, In greenhouse experiment: HHA, field experiment; procedure, sampling, data collection and analysis: AAA, HHA, AAMA, Enzymes analysis: HHA, First manuscript draft: AAA, HHA, AAMA. Reviewing and editing of manuscript: AAA. All authors commented on previous versions of manuscript. All authors read and approved this manuscript version.

Conflicts of Interest:
The author declares no conflict of interest.

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