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The Impact of Seed Priming Silver Nanoparticles on Germination Indicators of Durum Wheat (*Triticum durum L.*, var. Sham 7)

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Abstract. Laboratory experiment was conducted in the College of Agricultural Engineering at Al-Furat University in Deir Ez-Zor. The seeds of durum wheat (Triticum durum L., var. Sham 7) were soaked before planting in Petri dishes with two solutions: silver nanoparticles (Ag NPs) and regular silver nitrate ($AgNO_3$) at four concentrations (10-20-40-80 ppm) in addition to soaking in distilled water (control treatment) for a duration soaking of 1,2 and 3 hours. Silver nanoparticles were synthesized by green methods from extract of dried Eucalyptus camaldulensis leaves and the resulting silver nanoparticles exhibit a spherical shape with dimensions of 12 nanometers as described by scanning electron microscopy (SEM). The surface plasmon resonance peak at a wavelength of 450 nm is based on UV-Vis spectroscopy. The results of seed soaking experiment indicated that the seed soaking of durum wheat before planting in silver nanoparticles (Ag NPs) or regular silver nitrate ($AgNO_3$) for two hours had a significant effect on the studied germination indicators (germination rate, germination percentage, shoot length, root length, dry weight of shoots and roots) .The values were higher when seeds were soaked in a 20 and 40 ppm of silver nanoparticles. The study recommends to soaking wheat seeds in a solution of silver nanoparticles at a concentration of 20-40 ppm for two hours before planting, also recommends to conducting several seed priming experiments with different nanomaterials for other varieties and crops.

Keywords. Wheat, Germination indicators, Seed priming, Silver Nanoparticles.

1. Introduction

Cultivation of wheat is highly significant for the Syrian Arab Republic, covering approximately 50% of the major grain crops cultivated in the region Wheat is primarily used in human nutrition, and the by-products of wheat harvesting are utilized in the composition of animal feed. The agricultural sector faces numerous challenges, including climate change, increased consumption of agricultural products, and a reduction in cultivated land. This necessitates the advancement of agricultural development to achieve economic stability. Nanotechnology provides scientific solutions to enhance agricultural production, both quantitatively and qualitatively, to meet human nutritional requirements. It has been found that the formation of nanoparticles of gold (Au), silver (Ag), and others has applications in agriculture [1]. Nanotechnology may offer enormous potential to enhance agricultural production to meet human nutritional requirements [2]. Grain germination is a crucial stage in the growth of plants, ensuring their survival [3]. Therefore, many researches were conducted to determine the effect of silver nanoparticles on the germination stage. Treating wheat grains with different concentrations of silver nanoparticles encouraged grain germination and seedling growth compared to control, the highest increase in root wet and dry weight was recorded at a concentration of 100 ppm [4]. Plant absorption and accumulation of particles was greater in plants treated with (75 and 100 ppm) [5]. The results of one experiment showed that (50-75) mg/ml Ag Nanoparticles had a positive effect on wheat plants, as they led to a noticeable increase in root length and root wet and dry weight [6]. Silver nanoparticles have a stimulating effect on the germination and growth of wheat plants. Low concentrations of them clearly enhanced grain germination and root length of seedlings compared to the control. In contrast, high concentrations (100-150) ppm led to a noticeable decrease in grain germination and root length of seedlings of treated plants [7&8] were able to form silver nanoparticles with a spherical shape and an average size of (10) nanometers. He studied the effect of these particles on grain germination and wheat seedling growth. The results showed that the concentration of (0.001-0.5) mg/L has no Effect on grain germination, while it was found that these particles have the ability to increase the wet mass of seedlings and roots at (1-0.06) and (0.1-0.03) mg/L, respectively, while the concentration (0.06) mg/L caused an increase in the length of the roots. While (5) mg/L led to inhibition of root length, it was also noted that (0.7) mg/L was the best concentration for the wet mass of the plant .Silver nanoparticles have a clear effect on the number of roots of wheat plants, as Ag NPs were formed at several concentrations with an average size of 13 nm, and an increase in the number of roots was observed at (2.5 and 5) mg/L [9]. While (7.5 and 10) mg/L caused a decrease in the number of roots in wheat seedlings, analyzes indicated that these particles have the ability to stimulate the formation of proteins [10]. The surface properties of silver nanoparticles also play an important role in many physiological characteristics of wheat plants [11]. Immersing wheat grains in low concentrations of silver nanoparticles (Ag NPs) with a size of (10-20) nanometers did not affect the germination of wheat grains, while concentrations higher than (75) ppm had a negative effect on the germination index. On the other hand, this Particles played a positive role by increasing the number of embryonic roots at (25 and 50) ppm. Their results also showed that a concentration of (25) ppm increased leaf area, wet and dry weight and root biomass during the first week, but it gradually decreased in the second and third weeks. Compared to the control, exposure to silver nanoparticles for a long period negatively affected the growth indicators of wheat seedlings, while all concentrations enhanced the wet and dry weight and plant chlorophyll content, but the best of them was at (25) ppm of Ag NPs compared to the control [12]. One study showed that silver nanoparticles led to a decrease in water absorption by wheat plants, and thus to a decrease in the accumulation of nutrients in the plant. In return, they had a negative impact on the biomass of roots and seedlings [13].

In this study, we aim to investigate the effect of *priming(*soaking) wheat seeds in silver nanoparticles (Ag NPs) and silver nitrate ($AgNO_3$) on germination indicators (germination rate, germination percentage, plant length, root length, shoot dry weight, and root dry weight) of durum wheat (Sham 7).

2. Materials and Methods

Laboratory experiment was conducted in the College of Agricultural Engineering at Al-Furat University in Deir Ez-Zor. The seeds of durum wheat (*Triticum durum L*., var. Sham 7) were soaked before planting in Petri dishes with two solutions: silver nanoparticles (Ag NPs) and regular silver nitrate ($AgNO_3$) at four concentrations (10-20-40-80 ppm) in addition to soaking in distilled water (control treatment) for a duration soaking of 1,2 and 3 hours. Silver nanoparticles were synthesized at NanoLab within the Physics Department of Damascus University, following the methodology outlined in the previous research [14]. In brief, an aqueous extract of dried *Eucalyptus camaldulensis* leaves was added to a solution of silver nitrate ($AgNO_3$) at room temperature. The color of the mixture changed from yellow to dark brown, signifying the formation of silver nanoparticles. The reaction mixture was left in the dark at a constant room temperature of 25°C for 24 hours to ensure the completion of the reaction. Subsequently, the nanoparticles were separated through centrifugation at 10411 × g for 5 minutes. The residue obtained was washed four times with deionized water (DI) and

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then with ethanol via centrifugation to eliminate silver ions and biological materials. The silver nanoparticles were characterized by scanning electron microscopy (SEM), UV-Vis spectroscopy and dynamic light scattering technique (DLS). The colloidal suspension of silver nanoparticles was prepared by adding distilled water to the washed silver nanoparticles. They were thoroughly dispersed using an ultrasonic bath for 15 min and then stored for further use. Subsequently, the soaked seeds were planted in Petri dishes, with a rate of 10 seeds in each Petri dish. Various indicators (germination percentage and germination rate) were measured in all replications. At ten days of age for seedlings, plants from each Petri dish were taken for germination measurements, including plant length, root length, shoot dry weight, and root dry weight.

The laboratory experiment was conducted following a factorial experimental design with three factors (type of soaking material, concentration of soaking material, and soaking duration) with four replications for each treatment. The collected data were statistically analyzed using the M-Stat-C statistical analysis program to calculate the Least Significant Difference (LSD) values at a significance level of 0.05.

3. Results and Discussion

3.1. Characterization of Ag NPs

This study investigates the impact of green-synthesized silver nanoparticles on the germination indicators of durum wheat. The nanoparticles exhibit a spherical shape with dimensions of 12 nanometers as described by scanning electron microscopy (SEM). The surface plasmon resonance peak at a wavelength of 450 nm is based on UV-Vis spectroscopy. Additionally, a narrow size distribution of silver nanoparticles was confirmed using a dynamic light scattering technique (DLS) which depicts that the nanoparticles are well dispersed, as shown in figure (1).

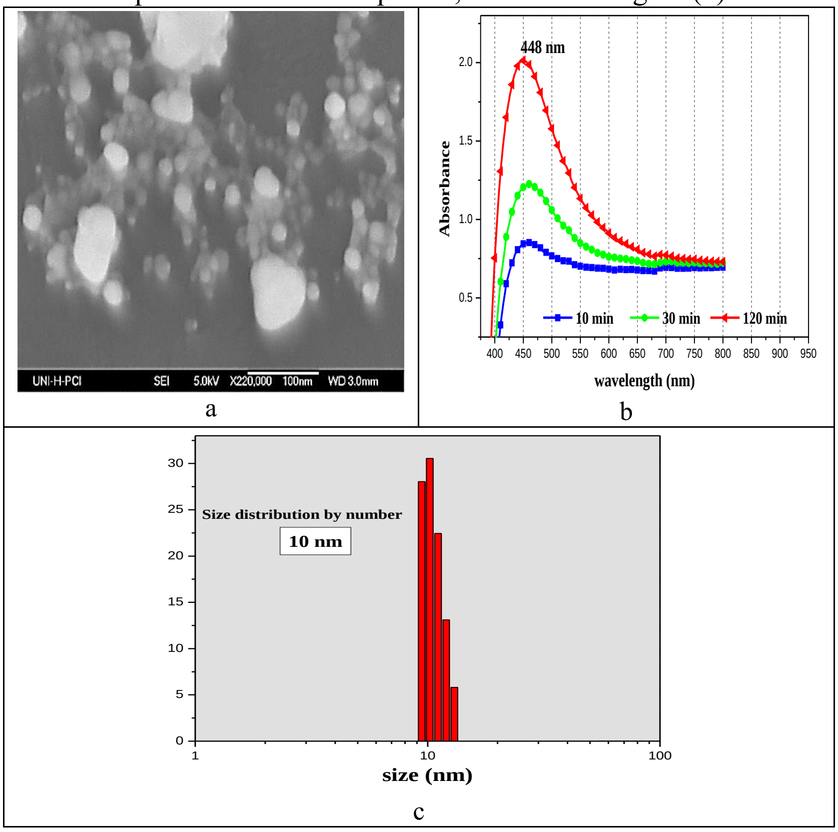

Figure 1. (a: Scanning electron microscope SEM image, b: UV-Vis optical absorbance spectrum of colloidal silver nanoparticles prepared at different times "10, 30, 120 minutes", c: Dimensional distribution curve as a function of number) according to the dynamic light scattering "DLS" technique for the colloidal silver nanoparticles used).

From the previous figure, we notice the appearance of the surface plasmon response (SPR) peak characteristic of silver nanoparticles. The intensity of this peak increases with increasing time, and this indicates an increase in the concentration of the prepared particles. We also note the narrow width of this peak, which indicates homogeneity in the sizes of the particles formed**.**

3.2. Germination Indictors

The effect of the type of soaking material is shown in Table (1), the results reveal significant differences between two soaking materials)AgNO3 and Ag NPs) with all tested germination indicators (germination rate, germination percentage, plant length, root length, shoot dry weight, and root dry weight) that were being higher when seeds were soaked in a solution of silver nanoparticles (30.51, 90, 8.23, 8.98, 0.36 and 0.77) compared to seeds soaked in regular silver nitrate (6.84 , 85 , 6.28 , 6.70 ,0.30 and 0.63)for germination rate, germination percentage, plant length, root length, shoot dry weight, and root dry weight, respectively. This suggests the absorption of silver nanoparticles by the seeds can influence the germination rate and length of the root, as observed by [15-17].

Table 1. The effect of soaking material type on tested germination indicators.

Materials	Germination rate (%)	Germination percentage (%)	Shoot length (cm.)	Root Length (cm.)	Shoot dry weight (g/dish)	Root dry weight (g/dish)
AgNO3	6.84^{b}	85.00 ^{b}	6.28^{b}	6.70^{b}	0.30 ^{b}	0.63 ^{b}
Ag NPs	30.51^{a}	90.00 ^{a}	8.23^{a}	8.98^{a}	0.36 ^{a}	0.77 ^{a}
LSD 0.05	*2.481*	*2.367*	*0.656*	*0.0995*	*0.0006*	*0.006*

As show in table (2), there were significant differences between treatments when using different concentrations of silver nanoparticles and silver nitrate (10-20-40-80 ppm) compared to the control treatment (distilled water). According to statistical analysis, the germination rate, germination percentage, plant length, root length, shoot dry weight, and root dry weight indicators were higher at concentrations (20 and 40) ppm, compared to the other concentrations in two tested materials. This results Aligns with [4], who found that the application of 25ppm, 50ppm, 75ppm and 100ppm concentrations of Silver nanoparticles promoted seed germination and seedling growth in wheat as compared to control. However significant results were observed at 100ppm Ag NPs as compared to control. Also, a significant increase in root fresh weight, root dry weight, root length, and root elongation was recorded at 100ppm concentration of Ag NPs as compared to the control. On the other hand, [7] who mentioned that The lower concentration (25 mg L^{-1}) of the synthesized Ag NPs significantly enhanced the seed germination and early seedling growth of wheat in comparison to the control on the 4th and 8th day.

Table 2. The effect of soaking material concentration on tested germination indicators.

	Germination rate (%)	Germination percentage (%)	Shoot length (cm.)	Root length (cm.)	Shoot dry weight (g/dish)	Root dry weight (g/dish)
Distilled water	2.510^{c}	85.00^{b}	6.08^{d}	6.72^{d}	0.29^{e}	0.62^{d}
10 ppm	12.76^{b}	89.72^{a}	7.08^{a}	7.64^{b}	0.32^{c}	0.69^{b}
20.ppm	20.57^{a}	88.33^{a}	7.36^{a}	8.01^{a}	0.34^{b}	0.72^{a}
40 ppm	21.40 ^{a}	89.44^{a}	7.42^{a}	7.98^{a}	0.34^{a}	0.72^{a}
80 ppm	10.84^{b}	80.28^{c}	6.58^{c}	6.94^{c}	0.31^{d}	0.63^{c}
LSD 0.05	3.023	3.055	0.847	0.046	0.0007	0.0029

According to the results of statistical analysis (table 3), there were significant differences among the three soaking periods (1, 2 and 3 hours), the seed soaking for two hours outperformed soaking for 1and 3 hours in terms of germination rate, germination percentage, plant length, root length, shoot dry weight, and root dry weight. This aligns with [18] they found from the formation of silver nanoparticles with a size of (13) nanometers and knowing their effect on the germination of millet grains and the growth of its seedlings by soaking the grains in (20,50) mg/L for two hours, where Ag

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NPs encouraged the germination of grains compared to the control, and the highest percentage was at (50) mg/L.

Table 3. The effect of soaking duration soaking on tested germination indicators.

Soaking duration	Germination rate (%)	Germination percentage (%)	Shoot length (cm.)	Root length (cm.)	Shoot dry weight (g/dish)	Root dry weight (g/dish)
1 hour	11.18^{b}	84.83^{b}	6.71^{c}	7.03^{c}	0.30^{c}	0.63^{c}
2 hours	15.84^{a}	88.83^{a}	7.05^{a}	7.79^{a}	0.33^{a}	0.70^{a}
3 hours	13.84^{a}	86.00^{b}	6.91^{b}	7.55^{b}	0.33^{b}	0.67^{b}
LSD 0.05	2.481	2.367	0.066	0.099	0.0016	0.0022

Soaking seeds before planting for a short period, without reaching the germination stage, has positive effects on improving the germination characteristics of these seeds and the emerging plants. Seed soaking here refers to hydrating the seeds either with water or nutrient solutions for a short period (before the onset of germination), followed by drying them to their initial moisture before replanting [19].

Form the results of statistical analysis, significant differences were observed between the previous soaking treatments based on the type and concentration of the soaking materials in terms of germination rate and percentage (table 4). The best germination rate was recorded when seeds were soaked in silver nanoparticles (20 ppm) compared to the control treatment, but for the germination percentage, it was highest when seeds were treated with silver nanoparticles at concentration 40 ppm compared to the control treatment. This is consistent with [16 &18].

Table 4. The effect of type and concentration of soaking materials on germination rate and germination percentage.

	Germination percentage (%)		Germination rate (%)	
	Ag NPs	$AgNO_3$	Ag NPs	$AgNO_3$
Distilled water	2.50^{d}	2.50^{d}	85.00^{b}	85.00^{b}
10 ppm	28.34^{b}	7.50^{d}	85.00^{b}	85.00^{b}
20.ppm	51.68^{a}	7.50^{d}	95.83^{a}	85.83^{b}
40 ppm	50.84^{a}	8.34^{d}	98.33^{a}	85.83^{b}
80 ppm	19.18^{c}	8.34^{d}	99.17^{a}	84.17^{b}
LSD 0.05	5.29		5.55	

As show in table (5), there was an increase the length of the root and shoot of treated seeds with silver nanoparticles and the highest length of the root and shoot (9.78,10.73 cm, respectively) was at concentration of (20ppm) compared to control treatment, this results are consistent with [7,8].

Table 5. The effect of type and concentration of soaking materials on Shoot length and Root length.

	Shoot length (cm)		Root length (cm)	
	Ag NPs	$AgNO_3$	Ag NPs	$AgNO_3$
Distilled water	6.08^{f}	6.08^{f}	6.72^{e}	6.72^{e}
10 ppm	8.60^{b}	6.34^{d}	9.63^{c}	6.62^{e}
20.ppm	9.78^{a}	6.23^{def}	10.73^{a}	6.68^{e}
40 ppm	9.63^{a}	6.37^{d}	10.45^{b}	6.75^{e}
80 ppm	7.11^{c}	6.36^{d}	7.39^{d}	6.74^{e}
LSD 0.05	0.147		0.223	

According to the results of statistical analysis in the table (6), there were significant differences observed among the previous soaking treatments based on the type and concentration of the soaking materials in terms of seedling dry weight and root dry weight. In the general, the soaking in the Ag NPs had higher values compared with soaking in $AgNO_3$. It is evident that the dry weight of the shoot increased when the seeds were soaked in silver nanoparticles especially at a concentration of 20 ppm (0.91 g) compared to the other concentration and control sample (0.62 g). On the other hand, soaking the seeds in silver nanoparticles led to an increase in the dry weight of the root, with the best result obtained at a concentration of 20 ppm (0.41 g) compared to the other concentration and control sample

(0.29 g). These Nano particles played a positive role by increasing the number of roots, leaf area, wet weight, dry weight, and biomass of the root [9], nanoparticles also play a crucial role in various physiological characteristics of wheat plants [11]. The nanoparticles played a positive role by increasing the number of seedling roots when soaking at (25 and 50) ppm of Ag NPs. The results were by [12] also indicated that a concentration of (25) ppm increased leaf area, fresh and dry weight, and root biomass during the first week, but gradually decreased in the second and third weeks compared to the control treatment. Prolonged exposure to silver nanoparticles negatively affects growth indicators for wheat seedlings, while all concentrations enhanced wet and dry weight and plant chlorophyll content. The most favorable concentration was at (25) ppm of Ag NPs compared to the control.

Table 6. The effect of the type and concentration of soaking materials on root and shoot dry weight.

	Root dry weight (g/dish)		**Shoot dry weight(g/dish)**	
	Ag NPs	**$AgNO_3$**	**Ag NPs**	**$AgNO_3$**
Distilled water	0.29^{h}	0.29^{h}	0.62^{f}	0.62^{f}
10 ppm	0.37^{c}	0.31^{f}	0.82^{f}	0.64^{de}
20.ppm	0.41^{a}	0.31^{f}	0.91^{a}	0.63^{def}
40 ppm	0.40^{b}	0.32^{e}	0.89^{b}	0.64^{de}
80 ppm	0.33^{d}	0.31^{f}	0.63^{def}	0.64^{d}
LSD 0.05	0.0140		0.0036	

Farghaly et. al. [20] indicated that the nanoparticles are adsorbed to plant surfaces and taken up through natural Nano or micrometre scale plant openings. Further, when growing, plants absorb relatively large amounts of essential and non-essential elements, which at certain concentration may be toxic. Once stored within the plants, beneficial or toxic elements can be transferred along the food chain to consumers.

Conclusions and Recommendations

We conclude that the bio-method using Eucalyptus leaves in the preparation of silver nanoparticles has proven effective in obtaining silver nanoparticles with dimensions of 12 nanometers. As for the seed soaking experiment we can conclude that the seed soaking of durum wheat (*Triticum durum L.*, var. Sham 7) before planting in silver nanoparticles (Ag NPs) or regular silver nitrate ($AgNO_3$) for two hours had a significant effect on the studied germination indicators (germination rate, germination percentage, shoot length, root length, dry weight of shoots and roots) .The values were higher when seeds were soaked in a 20 and 40 ppm of silver nanoparticles.

Finally, the study recommends to soaking wheat seeds in a solution of silver nanoparticles at a concentration of 20-40 ppm for two hours before planting, also recommends to conducting several seed priming experiments with different nanomaterials for other varieties and crops.

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