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Effects of seed coating with (titanium dioxide and selenium) nanoparticles on fenugreek (*Trigonella foenum graecum* L.) plant growth and antioxidant activity

Wasan H. Mazeil Al-Shammeryi

Abstract

Background: The fenugreek plant is a kind of herbaceous plant that resembles a clover. It is extensively used as a spice and condiment, as well as a medicinal plant. Studying the effect of seed coating on fenugreek is an important step to learn about the effects it imprints on plant growth and its antioxidant activity when its seeds are coated by nanoparticles of titanium and selenium.

Methods: To study the effects of seed coating with Nanoparticles of Titanium dioxide at concentrations of (0, 100, 200, 300, and 400) ppm and selenium at concentrations of (0, 20, 40, 60, and 80) ppm on shoot length, number of leaves per plant, carbohydrate %, protein %, and antioxidant activity peroxidase %, single and two way interaction on fenugreek's growth is taken into account. Treatments are designed as a properly randomized factorial experiment (5×5×3), with three replicates in a totally randomized design.

Results: It was revealed that a single application of the previously mentioned ingredients had a significant impact on fenugreek growth and antioxidant activity, especially at high concentrations.

Conclusions: Plant physiological properties were favorably influenced by seed coating with (Titanium dioxide and Selenium) nanoparticles. Based on the results of TiO_2 NPs' effect on seed germination and early seedling growth, it is possible that NPs aided in seed water absorption, increased seed ability to absorb and utilize efficiently, and activated and promoted hydrolytic enzymes in the seed antioxidant system.

Introduction

Fenugreek plant is a kind of herbaceous plant that resembles a clover. The stem may grow to be more than (50) cm long depending on the location in which it is produced and is considered a winter crop. Its feathery leaves are a three-leaf complex, and its blossom is white with a yellowish tint. They can be found alone or in pairs in the armpits of leaves [1]. Fenugreek (*Trigonella foenum graecum* L.) is a plant in the Leguminosae and Papilionaceae families. It is extensively used as a spice and condiment, as well as a medicinal plant because both seeds and leaves contain a diverse range of therapeutic compounds. Fenugreek's antioxidant activity was discovered to reduce oxidative damage produced by reactive oxygen species (ROS) by serving as ROS scavengers, and it may help prevent the formation of illnesses such as cancer and aging. Furthermore, feeding 1% fenugreek seed powder (FSP) continuously prevents colon cancer and inhibits the development of breast, pancreatic, and prostate cancer cell lines [2].

Because of its broad range of applications in agricultural ecosystem preservation, nanotechnology has risen to prominence among other advances in technology. Furthermore, nano-biotechnology has piqued the interest of agricultural nanotechnologists due to its outstanding biocompatibility, high rate of penetration, and absorption of nanoparticles in plants. Furthermore, the nanoparticles' (NPs) extra-small size structure and surface features result in unique physiochemical capabilities. Titanium dioxide nanoparticles (TiO_2 NPs) mediated by plants have received a lot of interest because of their great biocompatibility, low toxicity, significant capacity to scavenge free radicals, and high bioavailability. Titanium dioxide nanoparticles (TiO_2 NPs) are expected to have a wide range of important effects on the biochemical and morphological properties of various plants [3,4].

Recently, nanoparticles that contain important trace elements have been increasingly explored in agriculture as growth stimulators improving crop adaptive ability, along with different modifications of selenium nanoparticles (Se NPs) attracting interest. It increases vegetative growth and crop productivity. The supply of selenium to plants has a major impact on their physiological condition, which opens up the prospect of directly affecting specific parts of metabolism by controlling plant mineral nutrition [5]. Nanoparticles (NPs) act as a connection between molecular and bulk structures. Because of its size, porosity, surface area, bio-dispersion, reactivity, and movement within plants, the nano form of Se provides several advantages over other forms of Se. The use of Se and TiO_2 to modify biochemical and physiological responses in crops is an advanced approach that materialized in this work through the coating of Fenugreek (*T. foenum-graecum* L.) seeds with these nanoparticles to study their effect on the growth and antioxidant activity of this nutritional plant [6].

Methods

Planting

The planting date was November 1, 2022. The pot experiment was carried out at Wasit's greenhouse before being grown in compartmentalized containers filled with (Van Egmond) peat moss, which has a high concentration of vital components, a pH of 6.4, and an electrical conductivity between (1.2 and 1.6). It was split into three sections, each of which had fifteen panels. There were 75 panels in all, each containing ten seeds.

Treatments

The seeds were coated with Nano Titanium dioxide at concentrations of (0,100,200,300, and 400) ppm and nano-selenium at concentrations of (0,20,40,60, and 80) ppm. Nano titanium dioxide and nano-selenium were obtained from Baghdad, Bab al-Muadham.

Growth characteristics

After 25 days of seed coating, the average shoot length cm, the number of leaves per plant, and the protein content were evaluated using the micro-Kjeldahl technique developed by [7]. Carbohydrates were assessed calorimetrically using the [8] technique. Antioxidant activity % was evaluated using the method described [9].

Statistical analysis

To investigate how statistically various treatments differed, the Randomized Complete Block Design (RCBD) analysis of variance test was utilized. Discovering discrepancies between means, analysis of variance and least significant difference were calculated. The level of statistical significance was set at > 0.05 [10].

Results

Average Plant Height

Table 1 indicates that Nano Titanium dioxide has a significant impact on average plant height. When the nano titanium dioxide concentration was raised from 100 ppm to 400 ppm, the mean height of the plants reached consistently from 29.462 to 35.051 cm. Plants treated with 400 ppm nano titanium dioxide grew the fastest. The nano-selenium also had a substantial impact on the average plant height. Similarly, when the concentration of nano-selenium increased, it also increased the average plant height. Compared to 20 ppm (29.384cm) and the control (26.679cm), 80 ppm of nano-selenium produced the largest plants (34.949cm).

Nano Titanium Dioxide ppm	Nano-selenium ppm					Average Nano Titanium Dioxide
	0	20	40	60	80	
0	23.210	25.440	7.730	27.730	29.500	26.722
100	25.433	27.433	9.870	31.503	33.070	29.462
200	27.063	28.800	2.580	33.997	34.657	31.419
300	28.433	32.103	5.220	36.663	38.367	34.157
400	29.257	33.143	5.857	37.850	39.150	35.051
Average Nano-selenium	26.679	29.384	2.251	33.549	34.949	-
LSD (P>0.05) Nano-selenium	0.5468					LSD (P>0.05) Nano Titanium Dioxide 0.5468
Two-way interaction LSD (P>0.05)	1.2226					

Table 1: Seed coating with Nano-Titanium Dioxide and Nano-selenium and their two-way interactions on Average height of the plant (cm).

There was a substantial interaction impact between nano titanium dioxide and nano-selenium (see Table 1). Plants coated with 400 ppm nano titanium dioxide and 80 ppm nano-selenium grew the tallest.

Average number of leaves per plant

Table 2 suggests that Nano Titanium dioxide had a significant impact on the average number of leaves per plant. When the nano titanium dioxide concentration grew from 100 ppm to 400 ppm, the mean height of the plants reached consistently from 15.759 to 21.661 leaves per plant. Plants treated with 400 ppm nano titanium dioxide produced more leaves per plant. Nano-selenium also had a substantial impact on the average number of leaves per plant.

Nano Titanium Dioxide ppm	Nano-selenium ppm					Average Nano Titanium Dioxide
	0	20	40	60	80	
0	10.33	11.843	12.880	13.887	16.020	12.992
100	12.21	13.813	16.367	17.150	19.250	15.759
200	12.61	16.027	18.397	21.473	22.887	18.279
300	15.32	17.100	19.693	23.550	25.583	20.250
400	16.33	18.773	21.287	24.620	27.293	21.661
Average Nano-selenium	13.36	15.511	17.725	20.136	22.207	-
LSD (P>0.05) Nano-selenium	0.4838					LSD (P>0.05) Nano Titanium Dioxide 0.4838
Two-way interaction LSD (P>0.05)	1.0818					

Table 2: Seed coating with Nano-Titanium Dioxide and Nano-selenium and their two-way interactions on Average number of leaves per plant.

Similarly, when the quantity of nano-selenium increased, so did the average number of leaves per plant. In comparison to 20 ppm (18.773) and the control (16.330), 80 ppm of nano-selenium produced 27.293 leaves per plant.

There was a significant interaction impact between nano titanium dioxide and nano-selenium (see Table 2). The plants with 400 ppm nano titanium dioxide and 80 ppm nano-selenium had the most leaves (27.293).

Table 3 demonstrates that Nano Titanium dioxide has a significant effect on carbohydrates. When the nano titanium dioxide concentration was raised from 100 ppm to 400 ppm, the mean carbohydrate climbed progressively from 51.205% to 58.722%. Plants exposed to 400 ppm nano titanium dioxide grew glucose. The micro selenium also had a substantial impact on the average carbohydrate. Similarly, when the concentration of nano-selenium increased, so did the average carbohydrate. Compared to 20 ppm (50.187%) and the control (47.973%), 80 ppm of nano-selenium produced carbohydrate (58.413%). Table 3 shows that the interaction impact between nano titanium dioxide and nano-selenium was considerable. Carbohydrates content in seeds coated with 400 ppm nano titanium dioxide and 80 ppm nano-selenium (66.027%) were the most common.

Nano Titanium Dioxide ppm	Nano-selenium ppm					Average Nano Titanium Dioxide
	0	20	40	60	80	
0	45.663	46.730	47.807	48.840	50.130	47.834
100	46.807	49.390	51.130	52.960	55.737	51.205
200	47.433	49.613	53.700	56.773	58.773	53.259
300	48.500	51.057	54.773	58.470	61.397	54.839
400	51.463	54.143	58.537	63.440	66.027	58.722
Average Nano-selenium	47.973	50.187	53.189	56.097	58.413	-
LSD (P>0.05) Nano-selenium	0.4756					LSD (P>0.05) Nano Titanium Dioxide 0.4756
Two-way interaction LSD (P>0.05)	1.0634					

Table 3: Seed coating with Nano-Titanium Dioxide and Nano-selenium and their two-way interactions on Average Carbohydrate %.

Average Protein

Table 4 demonstrates that Nano Titanium dioxide has a significant effect on protein. When the nano titanium dioxide concentration was raised from 100 ppm to 400 ppm, the mean protein rose consistently from 31.497% to 37.963%. Plants treated with 400 ppm nano titanium dioxide produced protein. The micro selenium also had a substantial impact on the average protein content. Similarly, when the quantity of nano-selenium increased, so did the average protein content. In comparison to 20 ppm (31.509%) and the control (29.577%), 80 ppm of nano-selenium produced an average protein content of 37.169%. Table 4 shows that the interaction impact between nano titanium dioxide and nano-selenium was considerable. The protein content (43.810%) was observed in seeds coated with 400 ppm nano titanium dioxide and 80 ppm nano-selenium .

Nano Titanium Dioxide ppm	Nano-selenium ppm					Average Nano Titanium Dioxide
	0	20	40	60	80	
0	26.210	27.360	28.477	29.947	32.280	28.855
100	28.143	30.020	31.653	33.373	34.293	31.497
200	28.317	30.317	32.880	34.780	36.323	32.523
300	31.470	34.477	35.780	37.507	39.137	35.674
400	33.743	35.373	36.780	40.107	43.810	37.963
Average Nano-selenium	29.577	31.509	33.114	35.143	37.169	-
LSD (P>0.05) Nano-selenium	0.5350					LSD (P>0.05) Nano Titanium Dioxide 0.5350
Two-way interaction LSD (P>0.05)	1.1962					

Table 4: Seed coating with Nano-Titanium Dioxide and Nano-selenium and their two-way interactions on Average Protein %.

Average Antioxidant activity

Table 5 shows that Nano Titanium dioxide has a significant impact on antioxidant activity. When the nano titanium dioxide concentration was raised from 100 ppm to 400 ppm, the mean antioxidant activity rose consistently from 27.729% to 36.017%. Plants treated with 400 ppm nano titanium dioxide developed antioxidant activity. Nano-selenium also had a substantial impact on overall antioxidant activity. Similarly, when the quantity of nano-selenium increased, so did the average antioxidant activity.

Nano Titanium Dioxide ppm	Nano-selenium ppm					Average Nano Titanium Dioxide
	0	20	40	60	80	
0	23.337	25.000	27.027	28.390	29.390	26.629
100	25.780	26.780	27.143	28.803	30.137	27.729
200	27.700	30.703	33.700	34.983	35.700	32.557
300	30.130	33.040	34.113	37.520	39.500	34.861
400	31.507	33.483	36.150	37.767	41.180	36.017
Average Nano-selenium	27.691	29.801	31.627	33.493	35.181	-
LSD (P>0.05) Nano-selenium	0.6187					LSD (P>0.05) Nano Titanium Dioxide 0.6187
Two-way interaction LSD (P>0.05)	1.3835					

Table 5: Seed coating with Nano-Titanium Dioxide and Nano-selenium and their two-way interactions on Average Antioxidant activity %.

In comparison to 20 ppm (29.801%) and the control (27.691%), 80 ppm of nano-selenium produced 35.181% antioxidant activity. Table 8 shows that the interaction impact between nano titanium dioxide and nano-selenium was considerable. Those covered with 400 ppm nano titanium dioxide and 80 ppm of nano-selenium had the highest antioxidant activity (41.180%).

Discussion

Plant physiological properties were favorably influenced by seed coating with (Titanium dioxide and Selenium) nanoparticles (Table1,2). Based on the results of TiO_2 NPs' effect on seed germination and early seedling growth, it is possible that NPs aided in seed water absorption, increased seed ability to absorb and utilize water efficiently, and activated and promoted hydrolytic enzymes in the seed antioxidant system [11].

TiO_2 NPs absorption via roots result in increased root and shoot length as well as root and shoot fresh weight in seedlings. The uptake of nanoparticles across the cell wall is primarily determined by particle size and cell wall pores. Because of the tiny diameter of TiO_2 NPs, these nanoparticles may enter plant roots through cell wall pores. As previously shown, smaller NPs with greater surface reactivity may widen or generate new root pores, resulting in increased hydromineral movement in roots. As a result, the increased root length is due to enhanced nutrient intake, increasing shoot and root length as well [12]. TiO_2 NPs stimulated both shoot and root development in seedlings, with shoot growth being more prominent than root growth. Gibberellins (GAs) are known to promote shoot development, therefore photocatalytic TiO_2 NP supplements may have increased GA levels. The shoots will develop into leaves, which will be the primary portion consumed by consumers of these green vegetables. NP supplementation might be a novel approach to improve the development of economically important agricultural plants [13]. Priming with TiO_2 NPs has been shown to improve seed germination (SG) and seedling growth. This might be owing to the rapid completion of metabolic activities during the pre-germination stage during the priming phase, which resulted in increased SG levels and greater seedling growth levels. TiO_2 increased SG and promoted radicle and plumule development in plant seedlings [14].

Plants benefit from selenium nanoparticles by protecting the shape and fluidity of chloroplast and plasma membranes, activating membrane enzymes, transferring metabolites in chloroplasts, boosting photosynthetic activity, delaying aging, and increasing plant yield [15]. Selenium is the principal component of many selenium-containing enzymes that may be identified by improving the morpho-functional properties of seeds and young plants, this compound is non-toxic and regulate metabolic processes [16]. It had an advantageous influence (Table 3,4,5) on the seed coating with (Titanium dioxide and Selenium) nanoparticles affecting active chemicals and oxidizing enzymes. Because of its hydrophilic nature, exogenous application of Se NPs to carrot plants increased total soluble carbohydrates, soluble protein, and proline, which is extremely sensitive to environmental stresses and controls the numerous genes involved in growth and metabolism by providing energy resources and carbon [17]. The impacts of Se NPs preparation and looking into the effects of Se NPs on the germination characteristics of other popular crops including maize, rice, and soybeans. Se NPs enhance root growth and organogenesis as well. Trace amounts of Se have been demonstrated to enhance growth in lettuce, ryegrass, Brassica oleracea, and potato plants [18]. Se NPs improve photosynthesis by protecting chloroplast enzymes and protecting the chloroplast structure from severe oxidative damage, such as the loss of grana and stromal lamellae. According to research, Se speeds up chlorophyll formation by facilitating respiration and electron transfer in the respiratory chain. It is possible that enhanced biomass after seed priming is due to Se NPs mediated greater photosynthesis in plants under both studied watering regimes [19].

According to the results of the previously mentioned study, seed coating fenugreek (*Trigonella foenum graecum* L.) with nano-titanium dioxide and nano-selenium to the plant significantly increased all traits, regardless of whether the characteristics of vegetable or antioxidant activity achieved the highest concentrations used the highest effects, whether alone or in combination with two other compounds.

Conflict of Interest

The author declare that there is no conflict of interest regarding the publication of this paper.

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