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Full Length Research Paper

Impact of Nano Silver on Fenugreek Seed Germination and Seedling Development

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The effects of silver nanoparticles on plant growth metrics, including root length, fresh weight, dry weight, germination speed, and percentage of germination contents, have been studied for the economically significant pulse fenugreek (Trigonella foenum-graecum). Three replications and a randomized block design were used to conduct the investigation. There were five different levels of silver nanoparticles used: 0, 10, 20, 30, and 40 µg mL-1. For 12 days during the plant's growth, a daily supply of 15 milliliters of each concentration was administered after germination. According to the results of seed germination, AgNPs at lower concentrations in fenugreek encouraged seed germination and early seedling growth, but at greater concentrations, they had minor negative impacts. Additionally, control plants had the lowest levels of these parameters; nevertheless, these chemicals were reduced as a result of the increasing level of silver nanoparticles. When compared to seeds of unexposed control germination, a notable favorable impact on root length, fresh weight, and dry weight as well as root elongation was noted for every seed. The findings demonstrated that AgNPs had a substantial impact on the germination rate (P≤0.05). The experiment's findings demonstrated that applying AgNPs improved fenugreek germination.

Key words: Nanotechnology, Silver, Fenugreek, Seed germination.

INTRODUCTION

The One exciting area of multidisciplinary study is nanotechnology. It creates numerous prospects in a variety of industries, including electronics, agriculture, pharmaceuticals, and medicine.

Nanotechnology has a vast array of possible applications and advantages. Atomic or molecular aggregates with at least one dimension between 1 and 100 nm are known as nanoparticles (also known as nanoscale particles, or NSPs) [1], [2], and they have the ability to significantly alter their physico-chemical characteristics in comparison to the bulk material [3].

With a small number of isolated studies addressing adverse effects, the majority of published research indicates that nanoparticles have beneficial effects on plant growth. The first step in comprehending the potential advantages of using nanotechnology in agriculture is to examine how nanoparticles penetrate and move through plants.

Nanoscale Numerous investigations have shown that, even at concentrations as low as 20 mg/l, TiO_2 nanoparticles significantly enhanced spinach growth by promoting photosynthesis and nitrogen metabolism [4]–[6].

It has been observed that nanoscale titanium dioxide (TiO_2) enhances photosynthesis and spinach growth [7].

The impact of nano-ZnO particles on the growth of mung (Vigna radiata) and gram (Cicer arietinum) plant seedlings was examined in another study by Mahajan et al. [8]. They discovered that the seedlings showed good development over control at a specific optimal concentration, and that growth retardation was seen beyond that. One of the most extensively utilized nanomaterials in commerce today is silver nanoparticles (AgNPs) [9].

It is known that silver ions, like AgNPs, prevent ethylene activity [10]. Several groups have found this impact of silver ions on ethylene [11].

In hydroponics systems and agricultural soils, silver eradicates undesirable bacteria. It is applied as a foliar spray to stop mold, rot, fungus, and other plant diseases. Additionally, silver—including silver salt, silicate, and water-soluble polymer to radioactive rays—is an excellent plant growth stimulant [12].

After carbon nanotubes, which are added to the nano world on a daily basis, nano silver, also known as silver nanoparticles, is one of the most often used nanoparticles.

Silver nanoparticles are widely used in electronic, optical, biochemical, pharmacological, and health applications primarily because of their unique physical and chemical characteristics. Since seed germination is a vital component of plant life that ensures its survival, it is a significant phenomenon in contemporary agriculture.

It is appealing to learn more about how silver nanoparticles (AgNPs) affect seed germination given the recent breakthroughs in nanotechnology and its startlingly growing application in agriculture.

The annual plant Trigonella foenum-graecum, also known as fenugreek, belongs to the Fabaceae family and has three tiny, oblong to obovate leaflets. It is a semiarid crop that is grown all over the world, and Indian subcontinental cuisine frequently uses its seeds.

Afghanistan, Pakistan, India, Iran, Nepal, Bangladesh, Argentina, Egypt, France, Spain, Turkey, and Morocco are the main producers of fenugreek. India is the world's largest producer, with Rajasthan, Gujarat, Uttarakhand, Uttar Pradesh, Madhya Pradesh, Maharashtra, Haryana, and Punjab being the main producing states. More than 80% of India's output comes from Rajasthan [13].

Fenugreek is used as a vegetable (fresh leaves, sprouts, and microgreens), a spice (seeds), and a herb (dried or fresh leaves). The molecule that gives fenugreek its unique, sweet scent is called sotolon. A 1500 B.C. papyrus from ancient Egypt contains the earliest known application of fenugreek. In cookery, fenugreek seed is frequently used. In the past, fenugreek was used to treat a number of ailments, such as digestive issues and menopausal symptoms. Additionally, it was used to induce childbirth. Fenugreek is still used today as a folk or traditional treatment for diabetes, appetite loss, and to increase nursing mothers' milk production. In order to reduce inflammation, it is also used topically [14].

High levels of choline, tryptophan, ascorbic acid, niacin, and potassium are found in fenugreek. Ascorbic acid is a potent antioxidant 3, niacin and potassium are essential for immunological function, tryptophan is a precursor to serotonin, and choline is crucial for athletic performance [15].

The goal of the current experiment was to examine the impact of AgNPs on the germination characteristics of fenugreek (Trigonella foenum-graecum) seeds in light of the existing literature.

MATERIALS AND METHODS

This study was conducted in the Biotechnology lab of the Faculty of Veterinary Medicine at Ferdowsi University of Mashhad using a randomized full block design with three replications. The AgNPs came from Transmission Electron Microscopy (TEM) pictures of 20 nm-diameter silver nanoparticles from US Research Nanomaterials, Inc., which are displayed in Fig. 1.

A. *Chemicals*

Every chemical was purchased from Sigma Aldrich in the United States. According to the providers, the nanoparticles have the following physical properties: density (10.5g/cm3), surface area (5.0m2g-1), and particle size (about 20nm)

B. *Preparation of Nanoparticle Dispersion*

To create four distinct concentrations, the SNPs were suspended in deionized water and spread using ultrasonic vibrations (100W, 30kHz) for 30 minutes (0, 10, 20, 30, and 40μg mL-1). Every SNP concentration was chosen at random, and all of the chemicals were purchased from Sigma Aldrich in the United States. According to the providers, the nanoparticles have the following physical properties: density (10.5g/cm3), surface area (5.0m2g-1), and particle size (about 20nm).

C. *Seed Experiment*

Seeds of Fenugreek (Trigonella foenum-graecum) were used for the study and purchased from local market (Fig. 2). The seeds were stored in the dark under room temperature. All the seeds were first checked for their viability by suspending them in deionized water. The seeds which settled to the bottom were selected for further study. Seeds were sterilized in a 5% sodium hypochlorite solution for 10 minutes [16], rinsed through with deionized water several times.

Following surface cleaning, the seeds were rinsed three times in deionized water before being agitated with a magnetic stirrer for two hours in SNPs dispersion (0, 10, 20, 30, and 40µg mL-1). Whatmann After inserting No. 1 filter paper into each 100 x 15 mm Petri dish, 5 ml of the corresponding particle suspensions were added using a Pasteur pipette. After that, the seeds were moved to Petri dishes, with 25 seeds per dish, and kept at a regulated temperature of 25±1°C. After being synthesized directly in deionized water, silver nanoparticles at varying concentrations (0, 10, 20, 30, and 40µg mL-1) were dispersed for an hour using ultrasonic vibration. Three duplicates of each concentration were made.
For 14 days, each test plantlet received a 15 ml supply of silver nanoparticles every other day, along with a control. The shoot and root lengths were long enough to measure using a ruler after 14 days of growth.
Alongside the treated seeds, the controls sets for germinations were also conducted simultaneously. For 14 days, the lab counted the number of germinated seeds every day, and on the final day, the Germination Percentage (GP) was determined.

D. *Germination Speed Index (GSI)*

The germination speed index was calculated by the sum of the number of seeds germinated each day, divided by the number of days elapsed between the seeding and germination [17], according to the Maguire formula (1).

E. *Fresh and Dry Mass*

Following the material's permanence in a kiln with air driven circulation, at a temperature of 70°C, until constant weight, the dry mass was measured by weighing in a precision scale, and the fresh mass was quantified by weighing in a precision scale. Fresh weight and radical and plumule length were measured at the conclusion of the experiment. After 48 hours at 70°C in the oven, the plants were weighed using a sensitive scale.

Statistical Analysis

Analysis of statistics Three replicates of each treatment were used, and the mean ± SD (standard deviation) was used to display the results. Minitab Version 16 was utilized to analyze the results using one-way Anova.

RESULTS AND DISCUSSION

A new field known as nanotechnology has emerged, and researchers are interested in nanoparticles due to their distinct physico-chemical characteristics when compared to their bulk counterparts [11]. Nanotechnology is also thought to be one potential solution to issues in agriculture and food.
As is well known, seed germination offers a favorable environment for plant development, growth, and yield. The current study examined the effects of varying concentrations of AgNPs (0, 10, 20, 30, and 40 µg mL-1) on seed germination and early seedling growth by treating fenugreek seeds with distilled water.
When compared to seeds of unexposed control germination, a notable favorable impact on root and shoot elongation was noted for every seed. According to the results of seed germination, AgNPs at lower concentrations in fenugreek encouraged seed germination and early seedling growth, but at greater concentrations, they had minor negative impacts.
The findings demonstrated that AgNPs had a substantial impact on the germination percentage ($P \leq 0.05$). The usage of 20µg mL-1 of AgNPs produced the highest germination percentage (78%) according to the mean comparison. The experiment's findings demonstrated that using AgNPs nanoparticles can boost fenugreek germination.

The application of 10µg mL-1 of nano silver outperformed the other treatments, yielding the greatest values for seed germination index, seedling vigor index, germination mean time, and seed germination percentage. By improving the parameters of seed germination, the application of nano silver in this experiment increased seed potential (Fig. 3). Because they germinated completely in treated studies faster than control, root systems were well identified. The findings showed that as AgNP concentrations increased, both the degree of seed germination and the subsequent growth of the seedlings that sprouted were reduced (Fig. 4).

The growth of the seedlings that did germinate and the subsequent germination success of the fenugreek seeds were both clearly and dose-dependently inhibited by exposure to the 20-nm-diameter AgNPs (Fig. 5).

AgNPs had an impact on seedling growth at all concentrations, however for all parameters examined, this effect was not statistically significant at 10µg mL-1. Both shoot and root growth were significantly decreased by the higher concentrations of AgNPs (10µg mL-1), particularly as moisture weight, with the suppression of shoot growth being more pronounced than that of root growth (Fig. 5).

The root length showed similar patterns as well (Fig. 5). In comparison to the no AgNPs control, 10µg mL-1 AgNPs decreased the root length by 32% and the root dry weight by 29% (Table I).

TABLE I. EFFECT OF SILVER NANOPARTICLES ON SEED GERMINATION AND SEEDLING GROWTH OF FENUGREEK VALUES ARE AN AVERAGE OF THREE REPLICATIONS ± SE

No.	Concentration	% of Seed Germination	Speed of germination	Root length	Root fresh weight	Root Dry weight
1.	Control (0µg mL^{-1})	64.44	3.26	52.50 A	2.096 A	0.931 A
2.	10µg mL^{-1}	76.11	4.10	76.94	2.783	1.204
3.	20µg mL^{-1}	75.74	4.07	76.38	2.766	1.192
4.	30µg mL^{-1}	74.63	4.04	75.00	2.743	1.086 A
5.	40µg mL^{-1}	70.74	3.96	69.44 A	2.587 A	1.035 A

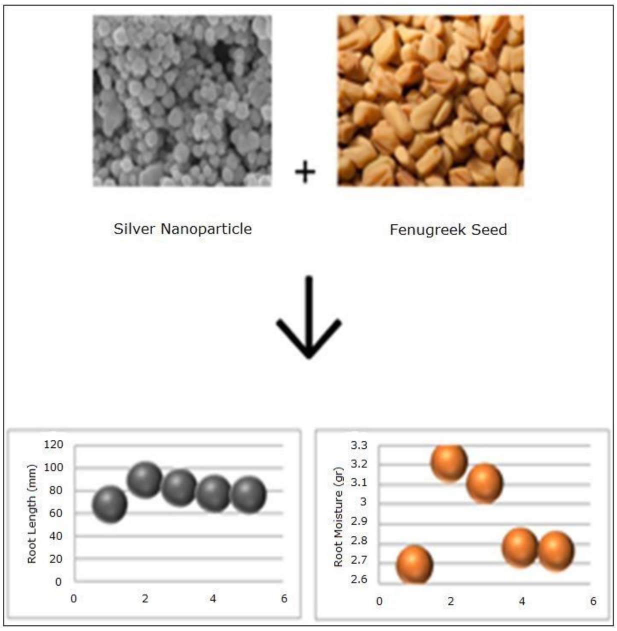

Figure 6. Graphical abstracts

These findings imply that plant communities may only benefit from the discharge of AgNPs into the environment. Achieving crop yield requires both improved seed germination and early plant growth, particularly for crops with low germination rates otherwise. We may be able to increase plant productivity by using nanoparticles, and the significant impact on the early phases of plant growth may be followed by comparable improvements at later stages as well.
The application of silver nanoparticles considerably increased the potential for seed germination, according to the current study's findings. The percentage of seeds that germinated, the mean germination time, the seed vigor index, the seed germination index, and the fresh weight and dried weight of the seedlings were all increased by the application of silver nanoparticles. It was discovered that the concentration of exposure affected the accumulation and absorption of nanoparticles.

CONCLUSION

It is suggested that the materials of the new millennium will be nanomaterials. The transitional region between individual molecules and their corresponding bulk materials is occupied by nanoparticles smaller than 100 nm, which can have both beneficial and detrimental biological impacts on living cells [18]. Research on the biological impact of nanoparticles on higher plants is growing. The promotional effects of modest concentrations of nanoparticles on plants have been the subject of relatively few investigations. When compared to the control, fenugreek responded to AgNPs by having a higher percentage of seeds germinate (Fig. 6). abstractions with graphics. The improved uptake of water and nutrients by the treated seeds may be the cause of the seedlings' faster growth rate.

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