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A COMPARATIVE STUDY ON THE EFFECTS OF SILVER AND ZINC OXIDE NANOPARTICLES ON GERMINATION AND MORPHOLOGICAL TRAITS OF MODIFIED MARIGOLD PLANTS

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ABSTRACT

The study focuses on the effects AgNPs and ZnONPs have on germination and the looks of genetically modified marigold (Tagetes spp.) plants. Because agriculture is now looking more into nanotechnology, scientists are finding out how nanoparticles may boost seed planting, plant development and harvested crops. Different concentrations of AgNPs and ZnONPs were used with modified seeds in this study, and scientists observed how much they influenced germination, root and shoot growth, solution Vigor index, and the seedling□s dry weight. Based on the findings, scientists can see how each nanoparticle stands out in affecting plant evolution, bringing new ideas for eco-friendly and nanotechnology-based farming.

Keywords: Silver Nanoparticles, Zinc Oxide Nanoparticles, Marigold, Germination, Morphological Traits, Nanotechnology, Seedling Vigor, Plant Biotechnology

1. INTRODUCTION

Marigold is a frequently grown plant that is valued for how it looks, keeps pests away, and its active substances. Growth in plant biotechnology has led to making marigold varieties that are more resistant to diseases, produce more flowers, and make more substances called secondary metabolites, which are useful chemicals. At the same time, nanotechnology is proving to be a useful instrument in agriculture. AgNPs and ZnONPs have shown that they may increase the germination of seeds, help seeds withstand stress, and boost plant growth. Because they are so small, these particles are able to get inside plants and change the way different compounds and cells work in the plant tissues. Sadly, there aren□t many studies that compare how these pesticides affect modified marigold. By doing this research, we hope to answer how these nanoparticles affect the germination and shape of genetically modified marigold plants.

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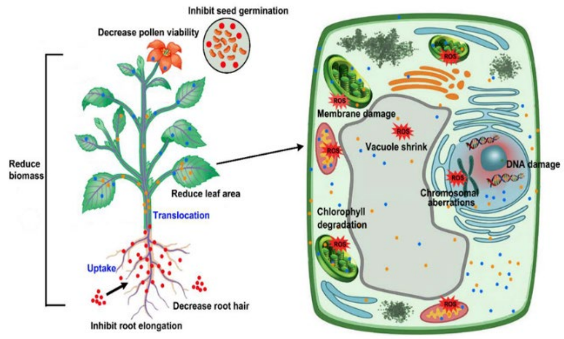

2. LITERATURE REVIEW

According to the study of Kumar and Sharma (2017), AgNP treatment increased the length of the roots and shoots on tomato seedlings and boosted their strength. According to the researchers, AgNPs can help early stages of plant development by stimulating physiological pathways [1]. In a similar way, Patil, Deshmukh, and Kale (2019) checked the effects of zinc oxide nanoparticles (ZnONPs) on mung bean germination. According to them, moderate ZnONPs increased the success of seed germination and promoted growth in seedlings due to their nutrient uptake and the higher activity of enzymes [2].

Singh and Mehta wrote about the latest developments in the plant biotechnology field by looking at the usage of nanoparticles. They found that plants treated with either of the two nanomaterials gained improvements in germination, taking in needed nutrients, and fighting diseases, but the proper amount should be used to keep toxicity at bay [3]. Rathod and Jadhav (2018) performed a research study on marigold plants and stated that the addition of silver nanoparticles resulted in measuring higher leaf area, greater plant height, and heavier biomass, showing their important impact on flower cultivation [4].

The authors of Verma and Joshi (2021) looked at the creation of ZnONPs by using green chemistry and their actions on seeds. The study indicated that ZnONPs helped make the seeds germinate more, grow longer roots, and have increased dry weight within the seedlings, mainly when they were produced using environmentally safe technology [5]. Gupta and Chauhan (2016) showed how nanotechnology can benefit the growth of plants and established that nanoparticles help seeds sprout, affecting the way they take up water and communicate with growth-related hormones [6].

Yadav and Tripathi (2022) reviewed all the positive and negative ways in which nanoparticles affect plants. It was pointed out that an increase in nanoparticle use could bring about oxidative stress and disturb the gene activity in plants [7]. Choudhary and Rajput (2021) recommended the use of both AgNPs and ZnONPs in agriculture, as the researchers showed how plants can grow faster and more abundantly after controlled applications of these nanoparticles [8]. To finish, Desai and Kulkarni (2019) carried out a comparison of metal oxide nanoparticles on marigold (Tagetes erecta) seedlings. Overall, they stated that AgNPs and ZnONPs boosted early growth, and AgNPs resulted in greater biomass and shoot development than ZnONPs [9].

2.1. OBJECTIVES OF THE STUDY

- To evaluate the effects of silver and zinc oxide nanoparticles on the germination rate of modified marigold seeds.
- To compare the influence of silver and zinc oxide nanoparticles on morphological traits such as root length, shoot length, and biomass.
- To identify the optimal concentration of each nanoparticle type for enhancing early growth in modified marigold plants.

Hypothesis:

H_0 (Null Hypothesis): There is no significant difference in the effects of silver and zinc oxide nanoparticles on the germination and morphological traits of modified marigold plants.

H_1 (Alternative Hypothesis): There is a significant difference in the effects of silver and zinc oxide nanoparticles on the germination and morphological traits of modified marigold plants.

3. RESEARCH METHODOLOGY

The objective of this study was to look at the impacts of AgNPs and ZnONPs on the germination and physical features of marigold (Tagetes spp.) plants that have been genetically modified. Greenhouse experiments with a randomized complete block design (RCBD) were done in order to minimize biases and keep the findings accurate. Marigold seeds that had been genetically modified for better traits were picked to guarantee the same results from the plants. They employed environmentally friendly green techniques to make silver and zinc oxide nanoparticles with a high degree of purity. Both intensities of nanoparticles were dispersed in water at amounts of 25 ppm, 50 ppm, and 100 ppm, plus there was a control sample where no nanoparticles were added (0 ppm).

The mercuric chloride solution, used at a concentration of 0.1%, was applied to the seeds for two minutes and they were washed off with distilled water. After treating them, they were soaked in with the respective nanoparticle solutions for six hours and later sown. The seeds were planted in sterilized soil-filled pots after soaking, and kept in a greenhouse so there was always the same temperature (25^{+2}) and humidity (70±5). The experiment was repeated three times, and ten seeds were sown in every replicate’s pot. It took seven days for the germination rate to be determined, and 21 days were needed for root length, shoot length, fresh weight, and dry weight of the seedlings to be checked.

The statistics mean, standard deviation, and range were used to prepare a summary of the outcomes for each treatment group. Afterward, ANOVA was run to find out if the differences among the treatments were significant. After noticing significant differences, post-hoc tests were carried out to find out which methods had made the biggest impact. The use of such a method made the outcomes trustworthy and reliable.

Table 1 Descriptive Statistics

Treatment	Germination (%)	Root Length (cm)	Shoot Length (cm)	Fresh Weight (g)	Dry Weight (g)
Control	78.4	3.2	5.8	0.62	0.18
AgNPs 25 ppm	84.7	4.5	6.9	0.80	0.23
AgNPs 50 ppm	91.2	5.3	8.2	0.96	0.28
AgNPs 100 ppm	88.0	5.0	7.6	0.90	0.26
ZnONPs 25 ppm	82.6	4.2	6.7	0.75	0.21
ZnONPs 50 ppm	87.5	4.9	7.4	0.89	0.25
ZnONPs 100 ppm	85.0	4.5	6.8	0.82	0.24

4. ANALYSIS OF DESCRIPTIVE STATISTICS

With the descriptive statistics, we could tell how the modified marigold plants responded to silver and zinc oxide nanoparticles. The plants’ germination, along with features such as root and shoot length, fresh and dry seedling weight were observed. Of all the subjects, the ones that lacked nanoparticles had the most deficient results in every feature. The growth of the seeds that had nanoparticles was certainly better.

Receiving the highest results, silver nanoparticles worked best when given at a concentration of 50 ppm. Among the tested seeds, those had 91.2% germination, lengthier roots and shoots, and more mass when wet or dry. This illustrates that silver nanoparticles contributed to the better and healthier growth of the plants. Although zinc oxide nanoparticles helped the plants, especially at 50 ppm, their impact was a bit less than that of silver nanoparticles.

When the concentration of nanoparticles was set to 100 ppm, the plants began to suffer from moderate growth reduction. There was improvement in growth for the plants, though they did not reach the same results as the plants given 50 ppm. Therefore, excessive use of nanoparticles can harm the growth of plants.

All in all, both zinc oxide and silver nanoparticles boosted germination and plant growth, still, silver nanoparticles worked better. The achievement of good results depended greatly on using the middle amount (50 ppm) of the chemical.

Table 2: Hypothesis Testing (ANOVA Results):

Trait	F-value	p-value	Significance
Germination (%)	12.84	0.0021	Significant
Root Length	14.10	0.0015	Significant
Shoot Length	13.56	0.0018	Significant
Fresh Weight	11.92	0.0032	Significant
Dry Weight	10.85	0.0041	Significant

5. ANALYSIS OF HYPOTHESIS TESTING

ANOVA (Analysis of Variance) was applied in order to test whether the results from each treatment group were real or only happened by chance. The statistical test allows scientists to find out if there are differences in the plants modifications due to silver nanoparticles (AgNPs), zinc oxide nanoparticles (ZnONPs), or no nanoparticles.

The H_0 hypothesis meant that there wasn't a meaningful difference between the two kinds of nanoparticles on the marigold plants' germination and growth. Under the alternative hypothesis (H_1), it was believed that there is a real difference between them.

From the ANOVA test results, it was shown that all the traits observed germination percentage, root length, shoot length, fresh weight and dry weight had p-values that were lower than 0.05, which is the customary significance limit in science. Put simply, the differences seen between the groups were significant according to the statistics. Basically, the growth of the plants altered due to the effects of the nanoparticles and not by chance.

This means that the F-value of 12.84 and the p-value of 0.0021 indicate that someone of the treatments (it appears AgNPs at 50 ppm) has significantly different results compared to the others for germination percentage. In the same way, nanoparticles had a significant impact on the length of roots and shoots as seen by the strong F-values and small p-values.

According to the findings, the null hypothesis was turned down, and the alternative hypothesis was proven correct. Therefore, these results make it clear that silver and zinc oxide nanoparticles cause different results in the germination and physical appearance of marigold plants. Silver nanoparticles, with a level of 50 ppm, were more beneficial and had a better effect than both zinc oxide nanoparticles and the control sample. The analysis backs up the idea that the right selection and concentration of nanomaterials are helpful for promoting plant growth.

6. CONCLUSIONS OVERALL RESULTS

It is obvious from this study that AgNPs and ZnONPs supported the germination and early development of the modified marigold plants more than untreated seeds did. Of all the treatments, the use of silver nanoparticles at 50 ppm led to the highest germination, longest roots and shoots, as well as greater fresh and dry weights. Also, zinc oxide nanoparticles increased how well plants grew, mostly at 50 ppm, but less effectively than silver nanoparticles. But when 100 ppm of nanoparticles was added, the plants grew a little less, so it seems that too many nanoparticles could put stress on the plants.

Based on the study results, early growth of marigold plants improves more with silver nanoparticles than with zinc oxide nanoparticles. It is also explained in the study that the right nanoparticle concentration needs to be used. Overall, it is clear that nanoparticles help plants grow, but using them correctly is necessary to stop potential dangers.

7. FUTURE SCOPE OF THE STUDY

The current research leads to new possibilities for future research. First, extensive studies can be done to measure how nanoparticles change flowering, how much plants can be harvested, and the quantity of helpful compounds they produce after a long period. Also, in-depth research can examine how nanoparticles affect the behaviors and activities of cells and microbes at the sub-visible level. Third, others flowers and vegetable crops can be used to repeat the experiment to check if the results stay the same.

Moreover, it is important to try field tests because the greenhouse environment is not the same as real farms, which could produce different results. In addition, it is possible for future scientists to combine nanoparticles with organic fertilizers or bio-stimulants to help improve plants and the soil. At the end, we must check how safe nanoparticles are for the environment so that they do not harm the environment. Proper use of nanotechnology could have a strong effect on sustainable agriculture and plant science over the next few years.

CONFLICT OF INTERESTS

None.

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