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Original Article

The Effect of Nanoparticles and Plant Growth Regulators on Germination of Miaze Seeds: A Comparative Study

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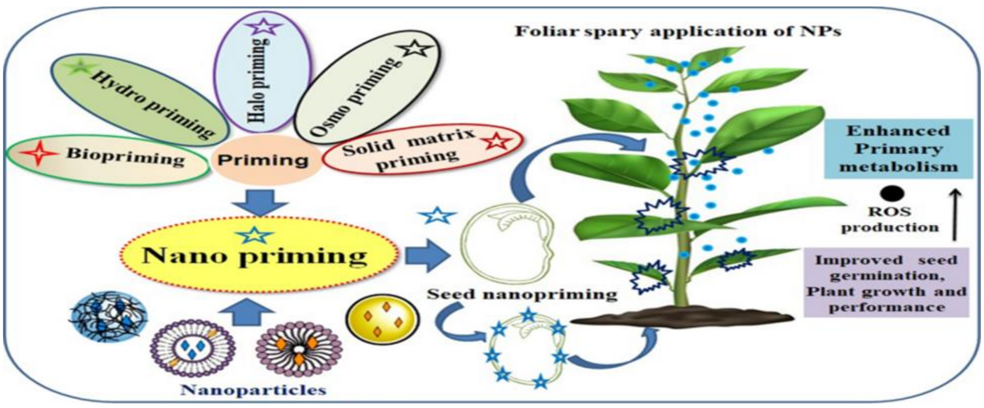
ABSTRACT

Nowadays, nanoparticles (NPs) are used for agricultural purposes, such as developing germination of the seeds and enhancing nutrients in the soil. They are also applied in the synthesis of nanopesticides and nanofertilizers. The current study was carried out to examine the effect of using zirconium oxide, yttrium oxide, and other solutions (Gibberellin, Indol acetic acid (IAA), and Naphthol acetic acid (NAA) in the germination of maize seeds. Before germination, the maize seeds weighted as a dry seed, and then they were soaked in a solution of 70% alcohol, then it was sterile by water. After that, the seeds were immersed in one of the 14 solutions for 2 hours. Next, the seeds were weighted as wet seeds, and then the seeds were transferred to petri dishes for 120 hours at 25°C. After the five days, the plants were taken from Petri dishes, studied, and evaluated by calculating the germination percentage, germination rate, and measuring the number, the length of roots, and shots. It is noticed that the best solutions for maize germination are Zirconium 100 + IAA and Yttrium 100 µg both of which had a significant difference ($p<0.05$) which indicate the highest germination percentage of 100% and the highest germination rate of 0.6. Different concentrations and combinations were prepared successfully and used as treatment solutions in germination of maize seeds. The results were compared and it was found that Zirconium 100 + IAA was the best solution used in the treatment of maize seeds. The test was considered as significant difference at ($p<0.05$). However, the authors recommend the examination of the effect of temperature and humidity on the germination of maize seeds as a future work.

GRAPHICAL ABSTRACT



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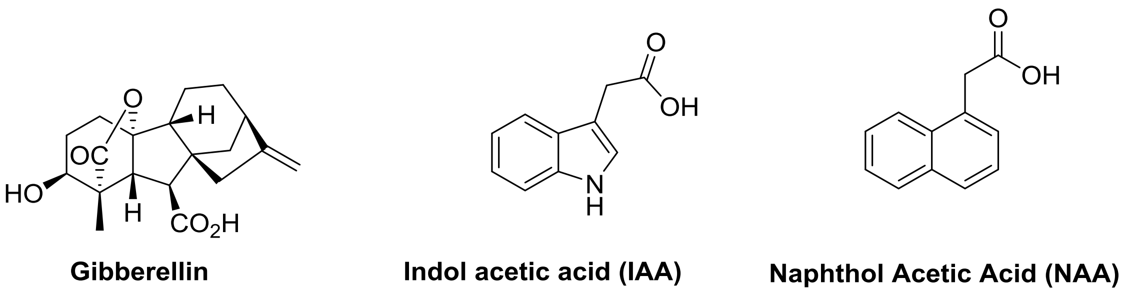
Introduction

In recent decades, a lot of nanoparticles were applied in developing germination agriculture purposes including water remediation, soil, nanopesticides, and nanofertilizers. However, the goal of these applications is to enhance the plants quality and increase food production. In addition, using nanoparticles has less toxic effect on environment and it is considered as friendly-environmental materials to the surroundings [1-3]. Nowadays, nanotechnology is widely applied in agriculture and seeds germination and contributes in its growth via the effective processes with eventually leads to modify and changes in the seeds metabolism that made significant changes in the lifecycle pathway of the plants and the seeds germination [4-7].

Tian *et al.* [8] reported that the experiments of seed germination were conducted by using different methods, techniques, and approaches to reach the optimal growth conditions, best traits, and yield; this will also enhance the food availability all over the world [8]. The results of germination (Zea mays L.) shows a higher rate of inhibitions by using certain reagents and this will lead to increase the biomass of roots of the maize seedlings [8, 9]. Presoaking of the seeds will enhance the seedling particularly if reagents are used such as NaCl which significantly improve and increase the plant biomass in very noticeable percentages. Thus, pre-treatment is considered as an effective and successful technique that can be approached to improve the germination performance, seed growth, biomass, and the seeds yield [10]. Meng *et al.* [11] studied the effect of temperature on the germination of spring maize. The researchers evaluated the stress of low temperature on the germination and found that this will retard the seeds growth and mechanism of late seedling growth is still unknown and ambiguous. They did their recent study on both low temperature resistance and low temperature sensitive maize; they found that in order to improve the germination maize and reduce the effect of low temperature stress, it is recommended to propose a certain plan technique [11].

In addition, many naturally occurring products and semi-synthetic compounds derived from them have also significant influence in seed germination improvement [12-17]. Scheme 1 displays the chemical structure of Gibberellin, Indol acetic acid (IAA), and Naphthol acetic acid (NAA).



Scheme 1: Chemical structures of Gibberellin, Indol acetic acid (IAA), and Naphthol acetic acid (NAA)

In the current study, by using plant growth regulators such as gibberellins, nanoparticles (yttrium and zirconium nanoparticles), and a combination of gibberellins and nanoparticles were applied and evaluated to enhance the maize germination.

Materials and Methods

All the chemicals were bought from local markets Zirconium and Yttrium nanoparticles (ZrNPs, and YNPs), Gibberellin, Indol acetic acid (IAA), and Naphthol acetic acid (NAA), respectively.

Germination of seeds

Before germination, the seeds were soaked in ethanol (70%) for about two minutes, after that and with sterile water, the seeds were rinsed many times to clean them from the traces of remaining alcohol (ethanol), and then immersed the seeds in sterile water and nanoparticles suspension of metal oxide (zirconium oxide /or yttrium oxide). This treatment process should be for at least two hours and repeated with different solutions, as displayed in Figure 1 and Table 1 lists the components of the immersed solutions. Subsequently, every 10 seeds were germinated in Petri dish at 25 °C in a dark environment for five days. After that, the germination rate was evaluated by measuring the shoot and root length [18, 19].

The germination rate was calculated according to the following equation:

$$Percentage\ of\ Germination\ rate\ (GP\%) = \frac{GN}{SN}\ X\ 100\ \ldots\ldots\ 1$$

Where, SN is the number of the tested maize seeds and GN represents the number of the germinated maize seeds.

Statistics

Each treatment was repeated for 3 times (triplicates), the standard deviation (SD) was taken to each treatment and was considered significant at ($p < 0.05$). The SPSS statistical software was used to examine the data (Version 23). For data analysis, simple descriptive statistics such as mean standard error (SE), t-test, ANOVA, and post-hoc analysis were utilized. The p-value (0.05) denotes the level of statistical significance [20].

Figure 1: Maize germination in Petri dishes

Table 1: Germination solutions components

Treatment number	Component of the germination solution
1	Control
2	Yttrium 100 µg
3	Yttrium 300 µg
4	Zirconium 100 µg
5	Zirconium 300 µg
6	Gibbrilne 300 µg
7	IAA
8	NAA
9	Yttrium 100 µg + Gibbrilne
10	Yttrium 100 µg + IAA
11	Yttrium 100 µg + NAA
12	Zirconium 100 µg + Gibbrilne
13	Zirconium 100 + IAA
14	Zirconium 100 + NAA
15	LSD

IAA is Gibberellin, Indol acetic acid, NAA is Naphthol acetic acid, and LSD is least significant difference

Results and Discussion

Table 2 presents the percentage of germination, and the germination rate of maize seeds. The data was calculated according to Equation 1 as well as the actual measurements.

Based on Table 2, it is noticed that the best solutions for maize germination are Zirconium 100 + IAA and Yttrium 100 µg. According to the best germination percentage and its rate, both of them had the highest germination percentage of 100% and the highest germination rate of 0.6, this result was matched with the findings of Karunakaran *et al.* [21] and Yousif *et al.* [22].

Table 3 and 4 shows the effect of nanoparticle solution on maize germination through counting and measuring the number and the length of the roots, respectively. It is clear that the combination of Zirconium 100 + IAA gave the best length of root as 14.17 which was the best compared with other combinations. This finding was matched with the previous studies carried out by [23-25].

Figure 2 indicates the length of maize shots, and it is clear that Zirconium 100+ IAA shows the longest maize shots, while Zirconium 100 µg+ Gibbrilne shots is less than it and other solutions shows less than that, these results were match with the findings of Yanmei *et al.* [26] and Sun *et al.* [27].

Table 2: Germination percentage and germination rate

No.	Treatment	(GP %)	GR
-	Control	83.33	0.5
1	Yttrium 100 µg	100	0.6
2	Yttrium 300 µg	94.44	0.57
3	Zirconium 100 µg	77.78	0.47
4	Zirconium 300 µg	88.89	0.53
5	Gibbrilne 300 µg	72.22	0.43
6	IAA	88.89	0.47
7	NAA	58.89*	0.43
8	Yttrium 100 µg + Gibbrilne	88.89	0.53
9	Yttrium 100 µg + IAA	88.89	0.53
10	Yttrium 100 µg + NAA	58.89*	0.53
11	Zirconium 100 µg + Gibbrilne	88.89	0.53
12	Zirconium 100 µg + IAA	100	0.6
13	Zirconium 100 µg + NAA	70.18	0.47
14	LSD	23.168	0.165

**Significant*

IAA is Gibberellin, Indol acetic acid, NAA is Naphthol acetic acid, LSD is least significant difference, GP is germination percent, and GR is germination

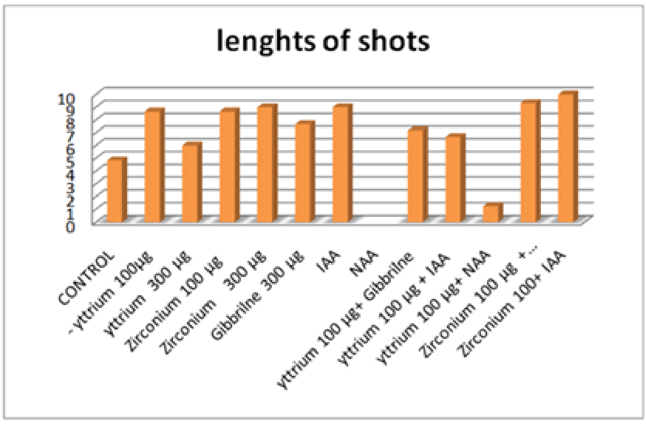


Figure 2: Length of maize shots after germination

Table 3: Number and length of roots

Treatment	Number of roots	Length of roots
CONTROL	2	4.67
Yttrium 100 µg	6*	9.67*
Yttrium 300 µg	6.33*	7
Zirconium 100 µg	6*	9.83*
Zirconium 300 µg	8*	12.5*
Gibbrilne 300 µg	4	10*
IAA	6.33*	11.67*
NAA	N/A	N/A
Yttrium 100 µg+ Gibbrilne	10.33*	11.83*
Yttrium 100 µg + IAA	9*	9.33*
Yttrium 100 µg+ NAA	N/A	1.17*
Zirconium 100 µg+ Gibbrilne	9.67*	14*
Zirconium 100 + IAA	8.33*	14.17*
Zirconium 100 + NAA	N/A	N/A
LSD	2.321	2.885

**Significant*

IAA is Gibberellin, Indol acetic acid, NAA is Naphthol acetic acid, LSD is least significant difference, and N/A means not applicable (no value)

Table 4: Wet and dry weights

Treatment	Wet weight	Dry weight
CONTROL	0.33	0.02
Yttrium 100 µg	0.49	0.03
Yttrium 300 µg	0.31	0.02
Zirconium 100 µg	0.37	0.02
Zirconium 300 µg	0.4	0.02
Gibbrilne 300 µg	0.3	0.03
IAA	0.44	0.02
NAA	---	---
Yttrium 100 µg+ Gibbrilne	7.19	0.03
Yttrium 100 µg + IAA	6.67	0.02
Yttrium 100 µg+ NAA	1.25	0.01
Zirconium 100 µg + Gibbrilne	9.33	0.02
Zirconium 100 + IAA	10	0.02
Zirconium 100 + NAA		
LSD	0.078	0.012

IAA is Gibberellin, Indol acetic acid, NAA is Naphthol acetic acid, and LSD is least significant difference.

The results show that (Zirconium 100+ IAA) is the solution to be used in the treatment of maize seeds comparing with the rest of treatment solutions, this could be related to the maize seeds, zirconium nanoparticles, chemical composition, size of the particles, modification that can be occurs in the seeds surface due to the treatment solution that may increase the germination rate of maize seeds and the phytohormones. However, further studies are recommended to examine the effect of heat (temperature), humidity, and other factors. This recommendation was also confirmed by Xue *et al.* [28]. Figure 3 depicts the length and number of roots to some of the germinated maize seeds after treating them with solutions.

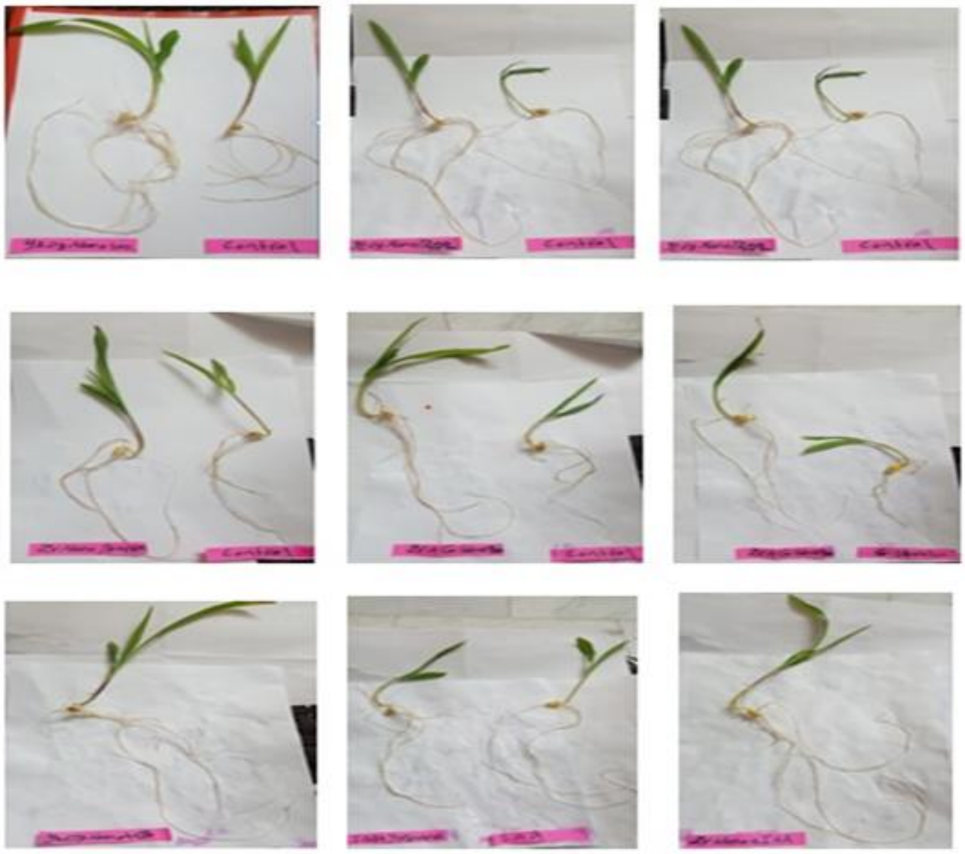


Figure 3: Roots and shots of germinated maize seeds in different solutions

Conclusion

Fourteen treatment solutions with different concentrations and combinations were prepared successfully and were used as treatment solutions in germination of maize seeds. The results were compared and it was found that Zirconium 100 + IAA is the best solution used in the treatment of maize seeds. The test was considered as significant at ($p<0.05$). However, the authors recommend investigating the effect of temperature and humidity on the germination of maize seeds as a future work.

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Authors' contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

Conflict of Interest

The author declared that they have no conflict of interest.

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