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ORIGINAL ARTICLE **OPEN ACCESS**

Green Synthesis of Iron Nanoparticles and Assessment of its Effect on Microbial Growth and Seed Germination of *Zea mays* and *Cucumas sativus*

Omar M. Al Zoubi
Department of Biology, Faculty of Science, Taibah University, Yanbu Branch, 46423, Yanbu, Saudi Arabia
Corresponding author: omaralzoubi73@yahoo.com (O. Al-Zoubi)

ABSTRACT
Green synthesis of nanoparticles is used in agriculture as an ecofriendly technique. Iron nanoparticles were synthesized using leaf extracts of several desert plants including Peganum harmala, Zygophyllum album, Caleotropsis procera and Avecennia marina. The impact of these plant extracts either with (PH-FeNPs, ZA-FeNPs, CP-FeNPs and AM-FeNPs) or without FeNPs on seed germination and root growth of cucumber (Cucumas sativus and maize (Zea mays) was tested and evaluated in a lab scale system. Results revealed that, PH-FeNPs was the most effective FeNPs-supplemented plant extract. PH-FeNPs at concentration of 2.5% increased the germination of maize seeds by 100.0% with 30 mm of root length. However, the 5% concentration of PH-FeNPs increased the germination of cucumber seeds to 87.5% with 21.9 mm of root length. Therefore, NPs-FeG can function as a promoter of seeds germination. Longer and thicker roots were also observed in case of P. harmala (leaf), C. procera and A. marina extracts treated with NPs-FeG on root length of Maize (at concentration of 7.5%)and cucumber (at concentration of 2.5%). No negative effects on bacterial growth were observed for all the used plant extracts. On the orhter hand, the extracts of C. procera and Z. album caused substantial inhibitions of Fusarium sp growth. This study suggests the usage of the desert plant extracts for controlling fungal growth and also for their usage in overcoming seed dormancy and stimulating seedling growth of crop plants.
Keywords: *Desert plants; nanoparticles; germination; seeds; extract*

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INTRODUCTION

Green nanotechnology methodology uses plants or their extracts as reducing and capping agents. The whole plant and/or their parts (seed, root, leaf, stem, bark, fruit, pulp, a secretory substance like latex and *in vitro* raised calli) were stated in literature for green synthesis of different NPs [1-4]. Primarily, the complete plants were used in the green synthesis of metal NPs. The exploration of plants mediated route of green synthesis using plants extracts with metal ions is considered a widespread protocol in recent years for the development of nanoparticles and nanostructured materials [5].

The main benefit of using plant extracts for biogenesis is that they are effortlessly available, safe, and nontoxic, have ample of metabolites. The growing significance in minimization of cost, time, waste etc. lead to the outline of photo biological approach [6-7].

Various literature reported phytochemicals existing in the plants as the base of reducing, stabilizing and capping agents, contrasting with the chemical method of nanoparticles synthesis that involve the use of harsh and toxic chemicals, that are adsorbed on the surface of nanoparticle. Therefore, this reduces the synthesized nanoparticles incompetent for medical applications [8]. Additionally, biomolecules in plants and spices (polyphenols, carbohydrates, essential oils (terpenes, eugenols)) are found to comprise of active functional groups like the aldehyde, amine and carboxyl entities [9].

Various researches were supported by plant-mediated routes to nanoparticles synthesis [10]. Green synthesis of Ag NPs, Au NPs, Zn NPs, Cu NPs, and Iron (Fe and its oxides, and have been studied in recent years [11-16]. Synthesis of iron oxide NPs using aqueous extracts of monocotyledonous plant Hordeum, (30 nm, unstable) and dicotyledonous plant Rumex, 40–10nm, highly stable) has been reported in literature [17].

Iron is an excellent choice among the several noble metals in the area of medicine, biological systems and living organisms due to its properties such as higher surface area, small band gap and stability [18-23]. Iron is a micronutrient and it is considered as one of the utmost essential part for plant life. It assists to form some enzymatic systems that act in the breathing processes of plants [24-25]. Nowadays, the effect of NPs of micronutrients such as Fe and Zn in plants is studied. Several literatures have reported that nanoparticles can be helpful in aiding the biological molecules in plant cells, germination of seeds, plant growth and for the application of herbicides [26].

The usage of many desert plants for medicinal products has increased immensely over the past few decades. Antimicrobial properties of medicinal plants are being gradually stated from different parts of the world [27]. Numerous plant species are used for the medicine because they contain several active compounds. These active compounds are generally extracted from the various plant parts [28-30]. In the desert of Saudi Arabia have many valued plants that might be used for medical reasons. For instance, this paper discusses the use of four different desert plants (*P. harmala*, *Z. album, C. procera, and A. marina*) distributed in Yanbu governorate, Saudi Arabia.

P. harmala (belongs to Zygophyllaceae family in the order of Zygophyllales (22 genera; more than 250 species) [31-34]. It is bright-green, densely foliaged, herbaceous succulent and white flowering plant (each flower likely grow into a fruit: leathery, three-valve seed capsule contained more than fifty dark-brown angular seeds [35-36]. broadly scattered in the Central Asia, North Africa and Middle East. If the soil is very dry, roots of this plant can penetrate to a depth of up to 6.1 m [35,37]. Conventional propagation of *P. harmala* is from seed. It has various limitations, including germination [32, 36]. Pharmaceutical studies regarding *P. harmala* have shown a variety of effective curing affect in tumor, insecticidal, malaria [31, 38-40], anti-spasmodic, anti-histaminic, vasorelaxant effects wound healing, anti-oxidant activity [41], immunomodulator properties, leukemia healing [42], hypoglycemic, analgesic, anti-inflammatory, antinociceptive, hepatoprotective, cytotoxic activity antibacterial, antifungal, antibacterial [43] and antiviral effects among others [44-45]. Research studies have revealed that the alkaloids are present in reasonable amounts in this plant [45].

Z. *album* is the type genus of the flowering plant family Zygophyllaceae (stem: branched, branches: succulent, leaves: green, flowers: yellow and shrub up to 50 cm long). The genus comprises more than 50 species that are distributed in arid and semi-arid regions of Africa, the Mediterranean Basin, central Asia and Australia.

The leaves, fruits and stems are used for rheumatism, asthma, hypertension, diuretic, antihistaminic, local anesthetic and antidiabetic agent [46].

Calotropis gigantea and *C. procera* are the two most common species in the genus. *C. procera* are tall, evergreen trees grows about 3 to 6 ft in height and extent throughout the region of Saudi Arabia. The leaves are sessil, sub-sessile, opposite, ovate, cordate at the base. The flowres of *C. procera* are colored white to pink and have fragrance. The flowers size is about 3.8 to 5.1 cm, with umbellate lateral cymes. Moreover, the seeds are compressed, broadly ovoid, with a tufted micropylar coma of long silky hair. Some parts of this plants are used for medicinal purpose. Entire plant is used to treat fever, jaundice, rheumatism, indigestion, cold, eczema, diarrohea, and so on.

A. marina (Grey mangrove) belongs to the family Aviceniaceae. It grows as a shrub or tree to a height of 3 to 14 m in the saline intertidal zones of sheltered coast lines [47]. They are normally located only in tropical climates (warm conditions for development and survival). For centuries, Mangrove plant extracts have been used for curing numerous health disorders. It has been reported that the Mangrove extracts contains biologically active antiviral, antibacterial and antifungal compounds [48-51].

The present study aimed to test the effect of desert plant leaf extracts on the germination of cucumber (*Cucumis sativus)* and Maize (*Zea mays*) seeds. Firstly, Iron nanoparticles using various plant extracts has been synthesized. Secondly, the antimicrobial, antioxidant activity and seed germination of synthesized Fe nanoparticles have been studied, respectively. Lastly, the effect of such desert plant leaf extracts on the growth of *E. coli* bacteria and *Fusarium spp*. fungus was also planned to be studied.

MATERIAL AND METHODS

Plant materials

P. harmala fresh leaves and green pods (seeds) were collected from the desert areas surronding Yanbu El-bahr city, Saudi Arabia. Leaves of *C. procera* and *Z. album* were collected from the desert area near Yanbu El-senayia, Saudi Arabia. Leaves of *A. marina* were collected from Yanbu El- Senayia Red sea coast, Saudi Arabia. Leaf materials were collected freshly at the same day of extraction.

Preparation of plant leaf and seed extracts

Washing and drying plant leaf materials

The collected plant leaves (*P. harmala, C. procera, A. marina, Z. album*) and seeds (pods of *P. harmala*) were washed with tap water twice and then washed with distilled water for removing dust and any other impurities attached to them. At least, 1h was needed to completely air dried the washed leaves at room temperature

Extraction of plant leaf constituents

100 g fresh leaf materials from each plant were wieghed and grinded in a blend mixer with 100 ml of 1:1 (v/v) methanol/dist.H_2O. After that homogenates were poured into the glass flasks, mixed well till all the contents are mixed properly and then the flask are stored at 4˚C for 6 days. Firstly, cotton textile mesh was used to filter the plant extracts and then the whatmann No. 1 paper was used. The plant leaf homogenates were then stored at 4˚C until the time of usage.

Synthesis of FeNPs green nanoparticles

Leaves of plants were washed with distilled water to remove dust from the surface, then dried at room temperature. The extract for each plant was prepared by putting 15 g of dried leaves in deionized water (250 mL) at 80°C for 1 hour. Meanwhile, the filtrate was maintained at -4°C until its usage. For FeNPs using different leaf extract (*P. harmala*: PH-FeNPs, *Z. album*: ZA-FeNPs, *C. procera*: CP-FeNPs and *A. marina*: AM-FeNPs) were synthesized by the addition of the extract to 0.10 M $FeSO_4$ at a volume ratio of 1:2 at room temperature and the mixture was stirred for 30 min. The stability of the nanoparticles was increased by the method (0.01M D-sorbitol) implied by Kaviya et al. [59]. The disappearance of color signifies the reduction of Fe^{2+}. The obtained solid was filtered, rinsed with ethanol and dried under vacuum at 50°C [60-64] and were used immediately.

Evaluation of the effects of the different plant leaf extracts on seed germination

Variable dilutions (2.5%, 5%, 7.5%, and 10%) of the pre-prepared plant leaf extracts were prepared to be used for seed germination experiment. Distilled water was used as controls. Seeds of *Cucumas sativus* and *Zea mays* were cleaned twice with 70% ethanol and then soaked in the different plant extracts concentration overnight (about 12 h). For estimation of the effect of plant extracts on seeds germination, plant seeds (8 seeds per plate) were incubated in 25 cm plastic petri dishes at room temperature and left about 4-5 days.

Germination rate was calculated from the following equation:

Germination rate = (No. of germinated seeds/ Total No. of seeds) *100

Evaluation of the antimicrobial activity of the different plant leaf extracts

Plant leaf extracts were examined for their antimicrobial activity. Concentrated plant extracts (100%) was used. *E. coli* bacteria and *Fusarium sp* fungus was used for this experiment. Firstly, the E. coli bacterial suspension was spread on the nutrient agar medium followed by making of small holes in each plate for extract injection (50 µl). Likewise, *Fusarium sp* spore suspension was spread on Malt extract agar plates, and plant extracts were injected into the holes made in the agar plates. The bacterial plates were incubated at 37˚C (overnight) and fungus plates were incubated at 28 ˚C (3 day's). Later, the plates were checked and photographed.

Statistical analysis

The experiments were designed as completely randomized design. Data were subjected to one-way ANOVA analysis. Mean values were compared according to Duncan Multiple Range test at $p = 0.05$. Data were analyzed using SPSS (20) package.

RESULTS AND DISCUSSION

Effect of P. harmala seed extracts on seed germination and root length

It was evident that 2.5% of *Peganum harmala* seed extracts induce seed germination of cucumber (GR= 87.5%) whereas 10% of *Peganum harmala* seed extract was able to initiate 83.33% GR of maize seeds (Figure 1A).

It can be seen that higher concentration of *P. harmala* seed extracts (10%) totally inhibits seed germination of cucumber. From the result, it is obviously identified that the size of synthesized NPs is decreased on increasing the concentration of a plant extract [52].

Additionally, a clear correlation between *P. harmala* seed extracts concentration and Germination rate of maize seeds was observed. This data (Table 1a) support the hypothesis that harmal seed extracts can be used to initiate seed germination of maize and cucumber but this effect is reliant on concentration. Moreover, we studied the effect of *P. harmala* seed extracts on root length at four different concentrations (Table 1b). There was no increase in the root length was observed in the case of Maize and cucumber, respectively.

Effect of P. harmala leaf extracts on seed germination and root length

The effect of *P. harmala* leaf extracts on seed germination was also examined. Results of this test are shown in Figure 1B and Table 2(A-B).

Leaf extracts of harmal exhibited to decrease the germination rate of cucumber but not maize. Results in Figure 1B clearly showed that all the used concentrations of harmal leaf extracts have negative effects on the germination of cucumber seeds. On contrary, harmal leaf extracts of (2.5% and 7.5%) are able to induce seed germination of maize seeds.

This result indicates that harmal leaf extract is not really able to induce seed germination of both cucumber and maize while compared to harmal seed extract (section 4.1). Although, at 2.5 and 7.5 concentrations (Table 2b) increase in the root length was observed in the case of Maize. However, in case of cucumber there was no increase.

Effect of Z. album leaf extracts on seed germination and root length

The results of this test are represented in Table 3(a-b) and Figure 2. No obvious effects for *Z. album* leaf extracts was seen for both cucumber and maize seed germination. Though, the germination rate data represented in Table 3(a) shows that higher concentrations of *Z. album* leaf extracts (i.e. 2.5% to 10%) trigger inhibition of maize seed germination. Similar results were also spotted for cucumber plants especially at extract concentration of 7.5%. As can be seen in Table 3b, there was no increase in the root length for Maize and Cucumber. The reason behind these above results for germination rate and root length might be localization of nanoparticle in the plant, that depend on the size, shape of nanoparticles, content of metal ions in various tissues and also the subsequent chances of nanoparticle movement and penetration [53]. These factors could influence the growth of root length.

Effect of C. procera leaf extracts on seed germination and root length

Results of this test are represented in Figure 3 and Table 4(A-B). The results showed that *C. procera* leaf extracts might marginally induce cucumber seed germination but not maize (especially at extract concentration of 7.5%). Higher concentration of *C. procera* leaf extracts cause a great delay of both test plant seed germination (concentration of 10%). The overall results of *C. procera* leaf extracts suggest an inhibitory effect of the plant leaf constituents on seed germination rather than induction. Table 4b shows the effect of increase in root length of cucumber at 7.5 concentration. This concentration promoted the good development of the root system in cucumber.

Effect of A. marina leaf extracts on seed germination

Effect of leaf extracts from *A. marina* plants were also tested on the germination of cucumber and maize seeds. Results of this experiment are shown in Figure 4 and Table 5(A-B).

It was observed that mangrove leaf extracts has negative effects on the germination of cucumber seeds especially at 7.5% and 10% of extract concentration (Figure 4). But, low or medium concentrations of mangrove leaf extracts were shown to induce seed germination of maize seeds (i.e. 2.5%, 5%, and 7.5%). This suggest that mangrove leaf extract could able to induce seed germination of monocotyledonous plants like maize but not dicotolydonous plants like cucumber. Table 5b showed that the application of NPs-FeG at concentration 2.5 on Cucumber increased the root length to its best. It can function as a promoter of cucumber seed germination, as the results demonstrated, the root system increased its length.

Evaluation of desert plant leaf and seed extracts on microbial growth

All the pre-prepared 5 plant extracts (i.e. leaf extracts of *P. harmala, Z. album, A. marina, and C. procera*; and seed extracts of *P. harmala*) were used for this experiment. Two different microorganisms comprising *E. coli* bacteria and *Fusarium* fungus were used. 50 µl from each concentrated extract (i.e. 100%) were tested for its effect on the used bacterial and fungal strains. The results of are shown in Figure 5 (A-B).

No negative effects on bacterial growth were detected for all the used plant extracts. After incubation of bacterial cultures at 37˚C, *E. coli* bacteria grows normally in presence of extracts (Figure 5(a)). On contrary, extracts of *C. procera* and *Z. album* cause substantial inhibition of *Fusarium sp* fungus growth (Figure 5(b)). Such growth inhibition effects were not seen for Harmal leaf and seed extract and also for *A. marina*. These results suggested that extracts of *C. procera* and/or *Z. album* can be used for suppression of fungal growth.

By the above results, this study may represent a promising approach focusing on the usage of the distributed desert plant extracts for controlling microbial growth and also for their usage in overcoming seed dormancy of crop plants.

Variable studies were performed using such plant extracts though for their medicinal values. Imran [54] have studied the effect of *Peganum harmala* seed extracts on the germination of wheat and barley seeds. The author reported that the aqueous extracts of *P. harmala* seeds inhibited the germination, while the

extracts increased the shoot length of *T. aestivum* and *H. vulgare* but this extracts decreased the root length of test species and increased the dry weight of the shoot, while decreased the weight of roots of the test species.

Harmal leaf extracts were also examined for their cytogenetic disturbances and germination abnormalities in *Ficia faba* plants [55]. Substantial concentration depended increase and duration depended decrease MI were observed with aqueous extracts, whereas with ethanolic extract the mitotic index revealed concentration and duration depended decreases. The two extracts induced significant ($p < 0.01$) increase in the percentage of nuclear abnormalities (NA) and chromosomal abnormalities (CA) in *Ficia faba* seedlings. Concentration and duration depended increases in the number of branches per plant but decrease in the other studied growth factors were also observed with all treatments of the aqueous and ethanolic extracts. Likewise, *Caleotropsis procera* plant leaf extracts were also tested for its effect on microbial growth [56]. It was shown that ethanol is a more effective extractive solvent for *C. procera* leaf constituents that have antimicrobial activity. The ethanol extract of the latex gave the widest zone of inhibition (21mm) against *B. subtilis*. All the extracts inhibit the growth of all the organisms except *B. subtilis* where the aqueous extract has no effect. This could justify the negative effect of C. procera leaf extracts used in the present study as the ethanolic fresh leaf extracts of *C. procera* did not show any inhibitory effects on *E. coli* growth.

In a study for the effect of *A. marina* leaf extract cancer cell lines [57] it was revealed that the number of mutant colonies decreased in the presence of ethanol and water extract with (+S9) and without (+S9) metabolic activation. The ethanol extract displayed a higher antimutagenic effect than the water extract, with an inhibition rate of 71% on the mutated bacterium. In another study centring on the antimicrobial effect of mangrove leaf extracts [58], it was shown that difference in activity was observed between the disc diffusion method and the well diffusion methods. More activity was noticed in well-diffusion method than in disc diffusion method. The test organisms (*Pseudomonas aeruginosa* and *Proteus vulgaris,* Gram positive bacteria*; Bacillus subtilis* and *Staphylococcus aureus, unicellular fungus Candida albicans* and *phytopathogenic fungi viz., Rhizoctonia solani, Colletotrichum gloeosporioides, Curvularia lunata* and *Fusarium oxysporum*.) varied in their sensitivity to the various solvent extracts. Similar tendency was noted for the fungi also. The inhibitory effect observed may be ascribed to the inhibitory compounds existing in the leaf extract of *A. marina.* This could justify the negative effects of the *A. marina* leaf extracts used in the present study on bacterial and fungal growth, since the method of extraction and extract application plays a major role. The results represented in the current study indicates the possible usage of some desert plant extracts in overcoming seed dormancy and controlling some microbial growth in the field.

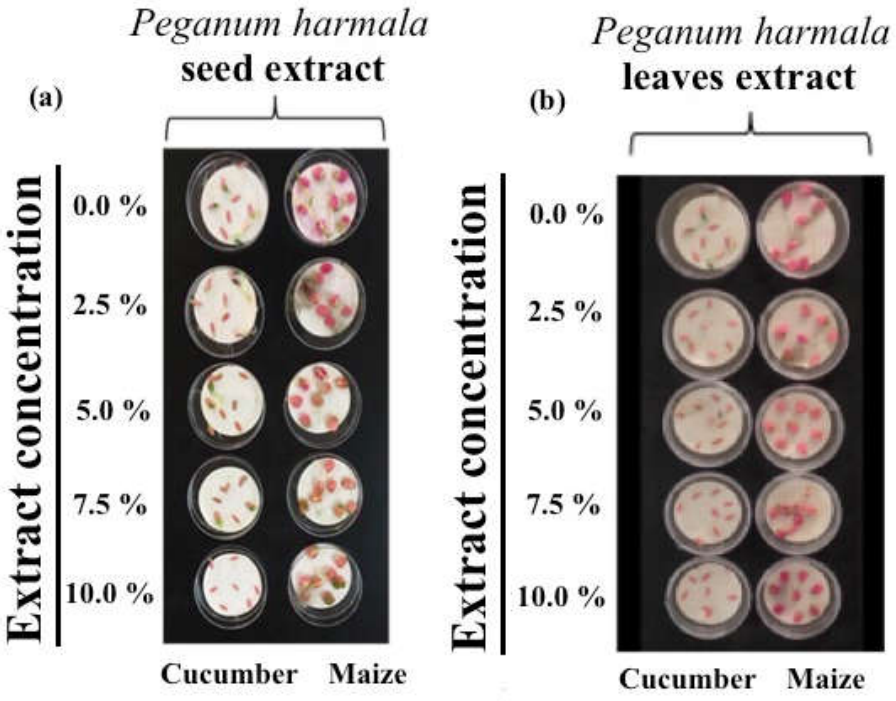

Fig 1. A photographic representation of the effect of *Peganum harmala*. **(A)** seed extract; and **(B)** leaf extracts on the germination of cucumber and maize seeds.

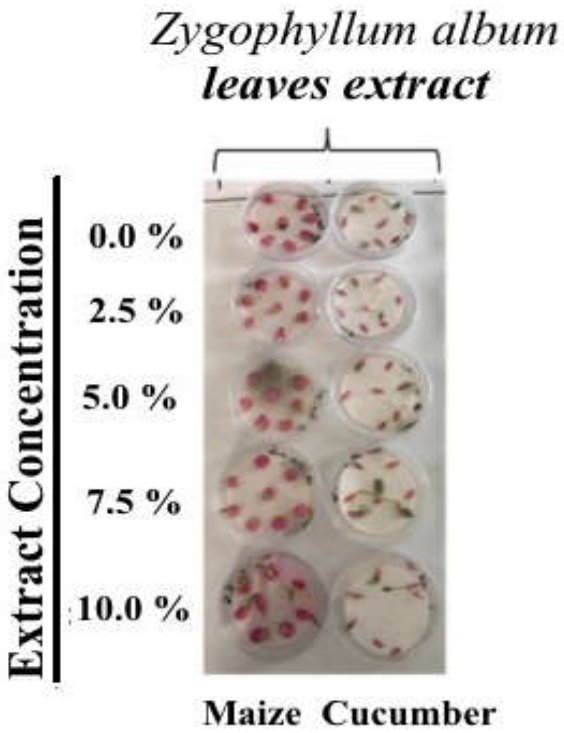

Fig 2. A photographic representation of the effect of *Zygophyllum album* leaf extracts on the germination of cucumber and maize seeds.

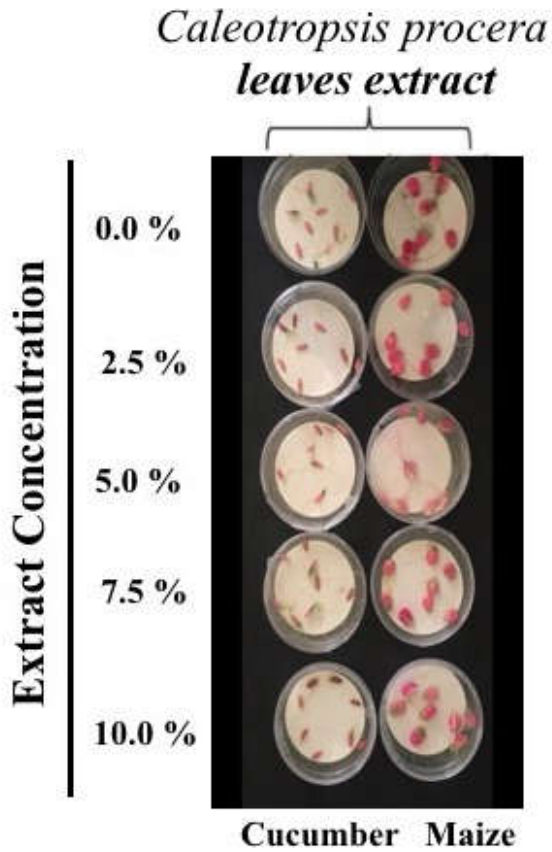

Fig 3. A photographic representation of the effect of *Caleotropsis procera* leaf extracts on the germination of cucumber and maize seeds.

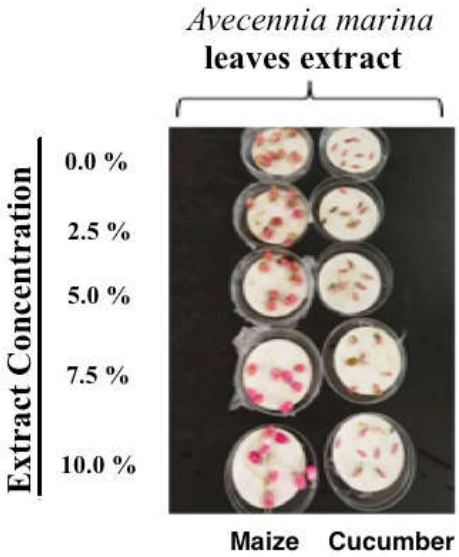

Fig 4. A representative photograph of the effect of *Avecennia marina* leaf extracts on the germination of cucumber and maize seeds.

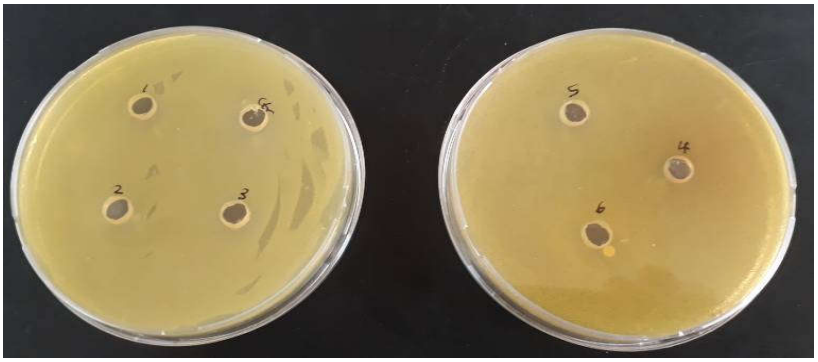

Fig 5. (A) Effect of desert plant leaf extracts on bacterial growth.

Fig 5. (B) Effect of desert plant leaf extracts on fungal growth.

Table 1(a). Effect of *Peganum harmala* seed extracts on germination rate of cucumber and maize seeds.

Concentration	Germination of Maize(%)		Germination of cucumber (%)	
	Extract	NPs-FeG	Extract	NPs-FeG
0	76.7a	80.0a	66.7a	73.3a
2.5	16.7c	28.75c	73.3b	87.5b
5	53.3b	62.5b	30.0c	37.5c
7.5	56.7b	66.7b	46.7d	57.14d
10	73.3a	85.71a	16.7e	28.57e

Table 1(b). Effect of *Peganum harmala* seed extracts on Root length of cucumber and maize seeds.

Concentration	Root length of Maize (mm)		Root length of cucumber (mm)	
	Extract	NPs-FeG	Extract	NPs-FeG
0	24a	25.71a	19.7a	20.0a
2.5	5b	8.63b	20.33a	21.88a
5	16c	18.75c	7.5b	9.8b
7.5	17c	20c	11.68c	14.29c
10	22a	25a	4.18e	7.15b

Table 2(a) Effect of *Peganum harmala* leaf extracts on germination rate of cucumber and maize seeds.

Concentration	Germination of Maize (%)		Germination of cucumber (%)	
	Extract	NPs-FeG	Extract	NPs-FeG
0	76.7a	73.3a	70.0ab	70.0a
2.5	86.7b	100b	50.0d	62.5c
5	80.0ab	87.5c	80.0a	87.5b
7.5	90.0b	100b	66.7b	75.0a
10	10.0	14.28d	53.3d	62.5c

Mean followed by the same letter within each species are not considerably different according to LSD test at $p<0.05$. Each treatment comprised of five replicates and each sample contained five petri dishes. Data obtained after incubation for 7 days

Table 2(b). Effect of *Peganum harmala* leaf extracts on Root length of cucumber and maize seeds.

Concentration	Root length of Maize (mm)		Root length of cucumber (mm)	
	Extract	NPs-FeG	Extract	NPs-FeG
0	24a	27.5a	22.5a	25a
2.5	26a	30a	12.5d	15.63c
5	24a	26.25a	20b	21.88b
7.5	27a	30a	16.68c	18.75bc
10	3b	4.28b	13.33cd	15.63c

Mean followed by the same letter within each species are not considerably different according to LSD test at $p<0.05$. Each treatment comprised of five replicates and each sample contained five Petri dishes. Data obtained after incubation for 7 days

Table 3(a). Germination rate (GR) of cucumber and maize seeds upon exposure to Zygophyllum album leaf extracts.

Concentration	Germination of Maize (%)		Germination of cucumber (%)	
	Extract	NPs-FeG	Extract	NPs-FeG
0	76.7a	80a	73.3a	76.7a
2.5	16.7b	25b	36.7b	50b
5	10b	12.5c	40.0b	50b
7.5	3.3c	12.5c	20.0c	25c
10	0c	0d	43.3b	50b

Mean followed by the same letter within each species are not considerably different according to LSD test at $p<0.05$. Each treatment comprised of five replicates and each sample contained five Petri dishes. Data obtained after incubation 7 days

Table 3(b). Root length of cucumber and maize seeds upon exposure to Zygophyllum album leaf extracts.

Concentration	Root length of Maize (mm)		Root length of cucumber (mm)	
	Extract	NPs-FeG	Extract	NPs-FeG
0	25a	26.7a	21a	22.5a
2.5	5b	7.5b	9.18b	12.5b
5	3b	3.75c	10b	12.5b
7.5	0.9c	3.75c	5c	6.25c
10	0c	0d	10.83b	12.5b

Mean followed by the same letter within each species are not considerably different according to LSD test at $p<0.05$. Each treatment comprised of five replicates and each sample contained five Petri dishes. Data obtained after incubation 7 days

Table 4(a). Effect of *Caleotropsis procera* leaf extracts on germination rate of cucumber and maize seeds.

Concentration	Germination of Maize(%)		Germination of cucumber (%)	
	Extract	NPs-FeG	Extract	NPs-FeG
0	73.3a	83.3a	76.7a	76.7b
2.5	40.0b	50b	66.7b	75b
5	76.7a	85.71a	70.0ab	75b
7.5	16.7d	25c	76.7a	87.5a
10	36.7c	50b	33.3c	42.85c

Mean followed by the same letter within each species are not considerably different according to LSD test at $p<0.05$. Each treatment comprised of five replicates and each sample contained five Petri dishes. Data obtained after incubation 7 days

Table 4(b). Effect of *Caleotropsis procera* leaf extracts on Root length of cucumber and maize seeds.

Concentration	Root length of Maize (mm)		Root length of cucumber (mm)	
	Extract	NPs-FeG	Extract	NPs-FeG
0	22a	26.25a	18.7a	18.75b
2.5	12b	15b	16.7ab	18.75b
5	23a	25.71a	17.5a	18.75b
7.5	5c	7.5c	19.18a	21.875a
10	11b	15b	8.325c	10.72c

Mean followed by the same letter within each species are not considerably different according to LSD test at $p<0.05$. Each treatment comprised of five replicates and each sample contained five Petri dishes. Data obtained after incubation 7 days

Table 5(a). Effect of *Mangrove* leaf extracts on germination rate of cucumber and maize seeds.

Concentration	Germination of Maize(%)		Germination of cucumber (%)	
	Extract	NPs-FeG	Extract	NPs-FeG
0	70.0a	76.7a	73.3c	76.7c
2.5	36.7b	50b	90a	100a
5	23.3c	33.33c	86.7a	100a
7.5	23.3c	37.5c	46.7d	50d
10	10d	20d	80.0ab	87.5b

Mean followed by the same letter within each species are not considerably different according to LSD test at $p<0.05$. Each treatment comprised of five replicates and each sample contained five Petri dishes. Data obtained after incubation 7 days

Table 5(b). Effect of *Mangrove* leaf extracts on Root length of cucumber and maize seeds.

Concentration	**Root length of Maize (mm)**		**Root length of cucumber(mm)**	
	Extract	NPs-FeG	Extract	NPs-FeG
0	26a	24.5a	20.0b	21b
2.5	11b	15b	22.5a	25a
5	7c	10c	21.68a	25a
7.5	7c	11.25c	11.68c	12.5c
10	10b	6d	20b	21.88b

Mean followed by the same letter within each species are not considerably different according to LSD test at $p<0.05$. Each treatment comprised of five replicates and each sample contained five Petri dishes. Data obtained after incubation 7 days

CONCLUSION

This study is a laboratory attempt regarding the rapid and efficient synthesis of FeNPs using traditional medicinal desert plants in Yanbu governorate of Saudi Arabia as reducing and capping agent due to their ease in availability, ecofriendly and economic viability. The effect of leaf and seed extracts of *P. harmala, Z. album, C. procera, A. marina* with (PH-FeNPs, ZA-FeNPs, CP-FeNPs and AM-FeNPs) and without FeNPs on seed germination and root length of some crop plants as cucumber and maize are evaluated. Moreover, the antimicrobial activity of these plant leaf extracts with and without Iron NPs were also studied. The results exhibited that some plant leaf extracts and Fe-NP can induce seed germination and root length such as harmal leaf and seed extracts as well as *A. marina* and *Z. album* at variable dose. Despite apparent limitations, has a substantial potential and a number of considerable benefits relative to traditional methods of nanoparticle synthesis. Furthermore, the results also showed that Fe-NPs *Z. album* and *C. procera* leaf extracts has more antifungal activity than the normal extract. No negative effects on bacterial growth were detected for all the used plant extracts. A substantial inhibition of *Fusarium sp* fungus growth was observed by the extracts of *C. procera* and *Z. album*.

This methodology emphasized the promising usage of desert plant leaf extracts in controlling fungal growth and overcoming dormancy of crop plant seed and the used leaf extracts are amicable. The dominant inhibitory activities of these plant may be owed to the synergistic effect of phytochemicals present in it. The particles demonstrated efficient antimicrobial activity against the tested pathogens.

The present research work discovered the green synthesized FeNPs using traditional medicinal desert plants can be prospective source for antibacterial therapy. Owing to the opulent biodiversity of plants, their prospective for the synthesis of metal NPs is yet to be fully explored. Further research is ongoing in our research lab for interpreting the exact mechanism behind green synthesis of FeNPs using traditional medicinal desert plants of Saudi Arabia.

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