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EFFICIENCY OF COPPER OXIDE NANOPARTICLES (CuONPs) AND/OR PEROXY ACETIC ACID ON SESAME VEGETATIVE GROWTH, AND CONTROL WILT DISEASE CAUSED BY *FUSARIUM OXYSPORUM* f. sp. SESAME

Heba Z. Ahmed[1], Hanaa. A.H. Armanious[2], Nabila A. Abd-El-Aziz[2], Maisa L. Abdel-Moneim[1], Anwar A. Galal[2].

Central Lab. Organic Agric. Res. ARC. Giza, and [(2)]Plant pathology Department, Fac. Agri. Minia University

Corresponding author: Heba Z. Ahmed, zeinheba@yahoo.com

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ABSTRACT

A Commercial product of Copper oxide nanoparticles (CuONPs) that chemically synthesis showed spherical plats with size (11.4-16nm) was concerned in this study singly or combined with peroxy acetic acid (PAA) to explore a proper control approached towards sesame wilting fungus *Fusarium oxysporum* f. sp. sesame**.** Using CuONPs as seed socking gave somewhat toxic effect toward sesame seed germination specially at100 mg/L CuONPs concentration more than PAA. However, CuONPs when it applied singly, improved seed germinations under *Fusarium oxysporum* infection more than PAA alone. A synergistic effect was provided when CuONPs was combined with PAA in this respect. As for fungal growth, a substantial antifungal activity was more addressed by CuONPs than PAA. Meanwhile, combining CuONPs with PAA explored the most inhibitory effect toward mycelial dry weight of the pathogen. Furthermore, *F. oxysporum* f. sp. sesame infectivity was strongly suppressed by CuONPs compared with PAA, but its infectivity was the most suppressed by combining treatments and considered as additional values for use low CuONPs concentrations that save environmental clean and human health.

Keyword: Sesame wilt – *Fusarium oxysporum* - Copper oxide nanoparticles- Peroxy acetic acid (PAA).

INTRODUCTION

The sesame plant (*Sesamum indicum* L.) holds significant importance as an oil crop in Egypt, thriving particularly well in desert conditions. Egypt's sesame cultivation spans approximately 34,000 hectares, yielding around 44,000 tons **(FAO, 2020).** However, sesame crops face considerable threats from various pathogens, resulting in significant yield losses **(Ara *et al*., 2017).** Among these, the *Fusarium oxysporum* f.sp.*sesame* fungus stands out as a widespread and damaging pathogen **(Abdou *et al*., 2001; Bedawy and Moharam., 2018)**.

In recent decades, there has been increased interest in finding eco-friendly alternatives to traditional fungicides (**Galal., 2018; Theerthagiri *et al*., 2019 and Ali *et al*., 2022**), with copper oxide nanoparticles (CuONPs) emerging as a successful antimicrobial against phytopathogenic bacteria **(Zhou *et al*., 2021)** and fungi **(Ayoub *et al*, 2017; Pariona *et al*., 2020).** Additionally, peroxyacetic acid (PAA) has shown promise as an eco-friendly fungicide and bactericide, effectively controlling plant diseases **(Buschmann and DelNegro., 2012; EL-Ashmony *et al*., 2017; Galal., 2017 and Galal., 2018)**. While posing minimal risks to the environment and human health **(Elamawi *et al*., 2016 and Omara *et al*., 2020)**.

This study aims to: 1) isolate and conduct pathogenicity tests on *Fusarium oxysporum* causing sesame wilt, 2) confirm the identification of the most virulent *Fusarium oxysporum* through DNA profiling, and 3) evaluate the efficacy of copper oxide and/or peroxyacetic acid (PAA) on sesame vegetative growth, *Fusarium oxysporum* growth, and sesame wilt development.

MATERIALS AND METHODS

Samples collection, isolation and identification of sesame wilt incident fungus:

Naturally wilted sesame plants (*Sesamum indicum* var. Shandawil-3) were collected from different locations in El-Minya governorate. Samples were placed in a paper bags and stored in a cooler. Roots were washed in running tap water, cut into small pieces about 0.5 cm long, surface disinfected with 0.5% $NaOCl_3$ for 3 min, rinsed several times with sterile distilled water (SDW) then dried on sterile towel paper. Then transferred onto potato dextrose agar (PDA) containing Petri plat then incubated at 25^{o}C for 5-7 days. The isolated fungi were further purified using both hyphal tip or single spore techniques (**Hildebrand**, **1938**) and identified according to (**Booth., 1971; Booth and Sutton., 1984 and Leslie and Summerell., 2006).** Eight fungal isolates that showed typical of *Fusarium oxysporum* were selected in this study.

Pathogenicity tests

The pathogenicity of the obtained isolates through inoculation of sesame plants was performed. Inocula preparation and inoculation were conducted essentially as described by **(Ahmed *et al*., 2024)** at 25^{o}C±2 for two weeks to obtain sufficient inocula. Healthy apparent sesame seeds cv. Shandawil-3 were used in this study. The test was carried out in pots (30 cm in diameters) in the green house. Pots were sterilized by soaking in formalin solution (5 %) for 5 min, then pots were aerated for 15 days, the disinfested pots were filled with autoclaved clay soil (121ºC for 30 min) mixed with the desired fungal inoculum growing on barely grains at 2.5% (w/w). In check treatment, equal amount of the un-inoculated substrate was added. Seven days later, sesame seeds were surface sterilized by soaking in 0.5% $NaOCl_3$ for 3 min and then washed thoroughly three times with (SDW) then sown. The experiment was designed as a complete randomized plots with 3 replicates (3 pots) each contains 25 seeds/pot.

Disease assessment:

The disease severity of root rot in which was determined by applying the arbitrary (0-5) disease scale as described by **Abd Elrazek *et al.* (1974).** There are five possible infection levels: 0 = no infection, 1 = 1–20% infection, 2 = 21–40% infection, 3 = 41-60% infection, 4 = 61–80% infection, and 5 = 81–100% infection. the following equation was used to calculate the percentage of disease index (DSI) for each tested isolate : (**Sallam *et al.*, 2013*)***

DSI (%) = Σ d/ (d $_{max}$ × n) ×100

Where d, is the disease rating of each plant, d $_{max}$ the maximum disease rating and n the total number of tested plants.

Molecular identification of fungal isolate:

The most virulent fungal isolate (F1) was subjected for molecular identification. The fungal isolate that was grown in sterile Petri plates containing autoclaved PDA medium and incubated for 7 days at 25°C **(Pitt and Hocking, 2009)**. However, DNA profile and it is phylogenic analysis was performed as described by **white *et al.* (1990)**

Nanoparticles

Copper oxide nanoparticles (CuONPs) were purchased from Nanotechnology & Disease survey Research Department, ARC, Giza, Egypt. According to the source, the particles size was 11.4-16 nm and the shape is spherical. The characterization and properties of CuONPs were confirmed through Transmission electron microscope (TEM) (Central Laboratory for Micro analysis and Nano technology, Minia University).

Effect of CuONPs and/or PAA on *Fusarium oxysporum* mycelial dry weight (MDW):

Unless otherwise stated, a complete randomized experiments were designed with three replicates, and each experiment was repeated twice. The efficiency of Peroxyacetic acid (PAA), with various concentrations were tried in this study similarly as described by **(Ahmed *et al*. 2024)**. *Fusarium oxysporum* (isolate F1) was grown in 250-ml conical flasks, each containing 50 ml of PDA broth medium. Concentrations were prepared in (SDW) and aliquots were pipetted to medium to obtain final concentration of PAA (0.05 g/l acetic acid (AA)+0.5 g/l hydrogen peroxide (H_2O_2), (0.1 g/l AA+1 g/l H_2O_2) and (0.2 g/l AA+2.0g/l H_2O_2). In case of CuONPS (0,025 g/l, 0.5 g/l and 0.1 g/l) were used. while combined PAA(0.1 g/l AA+1 g/l H_2O_2) with CuO NPs 0.0 25 g/l , PAA(0.1 g/l AA+1 g/l H_2O_2) with 0.5g/l and PAA(0.1 g/l AA+1 g/l H_2O_2) with 0.1 g/l CuONPs. For check treatment, conical flasks containing medium without test compound. Were used one disc of a 4-day- old cultures grown on PDA provided the inoculums of each flask;

the disc floated. Cultures were incubated at 25±2^{o}C and growth was measured by weight after 10 days. Mycelial mats were removed from the solutions, rinsed with distilled water and oven-dried for 24 hr at 75-80^{o}c. Three replicates were used, and the experiment was repeated twice. The percentage of inhibition of fungal growth was calculated as described by **Sutton and Starzyk, (1972)**. as follow:

$$\text{Inhibition \%} = \frac{\text{MDW of the control} - \text{MDW of the treatment}}{\text{MDW of the control}} \times 100$$

Seed inoculation and treatments:

The fungal isolate, *F. oxysporum* (F1) was tested to inoculate the seeds of sesame cv. Shandawil-3. The sesame seeds were surface sterilized and washed as mentioned before, then dried on sterile filter paper.

For inoculation, 25 surface-sterilized sesame seeds were placed in each 9 cm diameter Petri dish, and 10 ml of *F. oxysporum* propagules suspension (1×10^{4} cfu /ml) was added **(Ahmed *et al*.2024).** The infected seeds were allowed to dry for an hour at room temperature. Next, the seeds were singly treated by the test solution as described above (10 treatments). Ten ml of the respective solution were added into each Petri dish containing fungal infected seeds and incubated for one hour **(Behrani *et al*., 2015).** For one hour, seeds in the control treatment were just steeped in distilled water that had been sterilized.

Effect of CuONPs and/or PAA on sesame seed germination and vigor index:

The germination rate, root length, shoot length, and vigor index of sesame cv. Shandawil-3 infected with *F. oxysporum* were evaluated in relation to the ten treatments previously indicated. Ten seeds were placed on a sheet of water-soaked filter paper in each replicate, and the sheet was covered with another wet sheet of paper. The sheets were placed in a 500 mL glass beaker with 50 mL of water to keep the seeds moist and promote germination at room temperature. The two layers of filter paper with the seeds in between were then rolled into a scroll to give the seedlings enough oxygen. Three replicates, each contain 10 seeds were used. To verify the results, the experiment was conducted twice. Ten days later, the germination percentage was determined as follows:

$$\text{Germination percentage (G\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of total seeds.}} \times 100$$

The length of either shoots and roots (cm) of 10 sesame seedlings/ replicate were assayed and used to calculate vigor index (VI) according to the formula described by **Abdul-Baki and Anderson (1973):**

Vigor index (VI)=(shoot length+root length)×germination percentage

Effect of CuONPs and/or peroxyacetic acid (PAA) on sesame root rot /wilt incidence:

This study investigated the impact of the aforementioned ten treatments on the percentages of root rot/wilt in sesame cv. shandawil-3 that were infected with *F. oxysporum.* Treated seeds were sown in a 30-cm pot that previously prepared and infested similarly as described in the pathogenicity test. In each of the three replicates for each treatment, for a total of three pots per treatment. Sterilized water was used to inoculate the seeds in the check treatment. Data were compared using the estimated means of the two trials. Disease assessment: Disease severity (Ds%) was measured at 60 days after sowing as described before:

Statistical analysis

Values of the least significant difference (L.S.D) at (P< 0.05) were calculated to test the variants among treatments **(Gomez and Gomez, 1984).**

RESULTS:

Pathogenicity tests :

Eight isolates of *Fusarium* sp. were tested for determine their pathogenicity using Shandwell-3 sesame cultivar. All isolates tested were infective to sesame plants causing pre- emergence damping-off, post - emergence damping-off and root rot/wilt (Table 1 and Figure 1) , however pathogenicity was varied with isolates tested. Among eight isolates, one isolate (F1) revealed the most virulent that exhibited the greatest disease severity (22.7%) followed by isolateF2 and F6 (14.7) while, isolate F4 and F5 induced the least pre- emergence damping-off. (5.3%). No significant post-emergence damping-off and root rot caused by the different isolates among eight isolates, one isolate (F1) reviled the most virulent that exhibited the greatest disease severity (27.2%) followed by isolate F6 (22.7%) and isolate (F2) which induced 6.5%. While isolate F7 induced the least disease severity (0.%). To be mentioned, all fungal isolates tested were incited an obvious Pre-EDO more than Post-EDO but the root rot/wilt severity was the greatest values for each isolate tested.

Fig. 1: Infected (right) and non-infected (left) sesame plants, 60 DAS.

Table (1): Pathogenicity test of *Fusarium oxysporum* on sesame, Pre EDO, Post EDO and root rot/wilt plants.

Fungal isolates	Pre EDO	Post EDO	RRS/wilt	DS(%)
F1	22.7a	14.7a	26.7a	27.2a
F2	14.7b	13.3a	20.0a	16.5bc
F3	10.7bc	8.0a	20.0a	11.2c
F4	5.3d	10.7a	22.7a	12.8c
F5	5.3d	10.7a	18.7a	11.2c
F6	14.7b	12.0a	24.0a	22.7ab
F7	9.3cd	9.3a	18.7a	10.1c
F8	6.7cd	10.7a	22.7a	14.4c
LSD 0.05	4.58	7.11	11.4	6.45

(1)Each reading is an average of 3 replicates, each one contain 25 plants.

(2) Each reading with the same letter in the same column is a not significant at 5%.

Molecular identification of the fungal isolate:

The fungal isolate F1, that reacted as the most virulent one, was subjected for identification. Analysis of its phylogenic (Figure 2) based on IT sequences of rDNA confirmed that F1 is *Fusarium oxysporum* fungus.

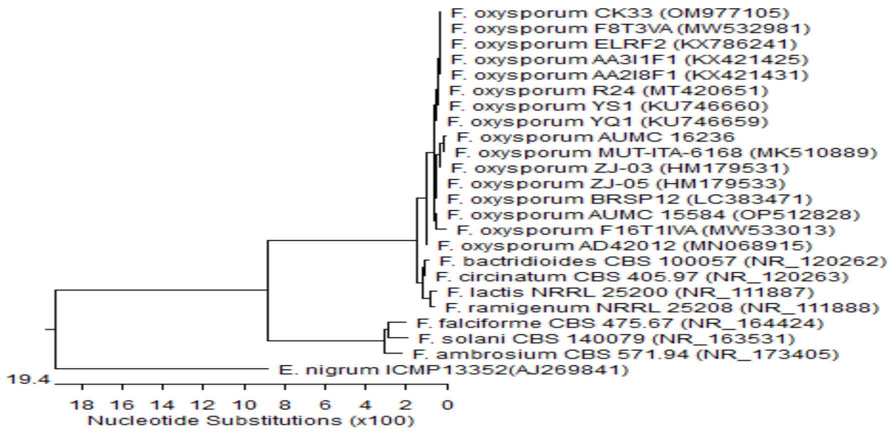

Figure (2): Phylogenetic tree based on IT sequences of rDNA of the fungal samples isolated in the present study (AUMC16236, arrowed) aligned with closely related strains accessed from the GenBank (F1= *Fusarium oxysporum* f. sp. sesame Accession number for isolate F1 is *OR896546*

Copper oxide nanoparticles (CuONPs)

Figures (3) and (4) showed that the particles used in this study were spherical and their size ranged between 11.4 and 16nm.

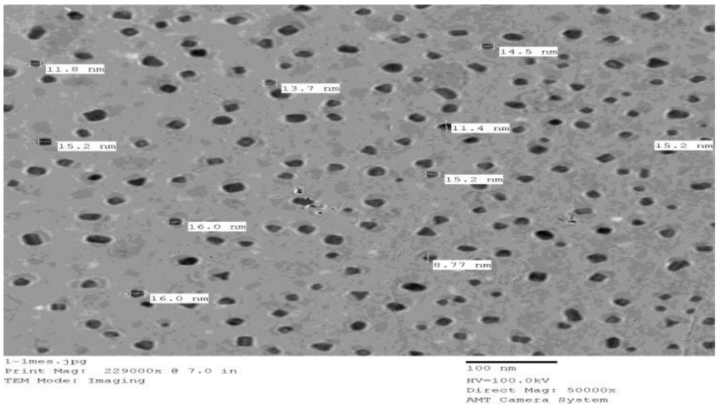

Figure (3): Transmission electron microscopic image of copper oxide nanoparticles (CuONPs)

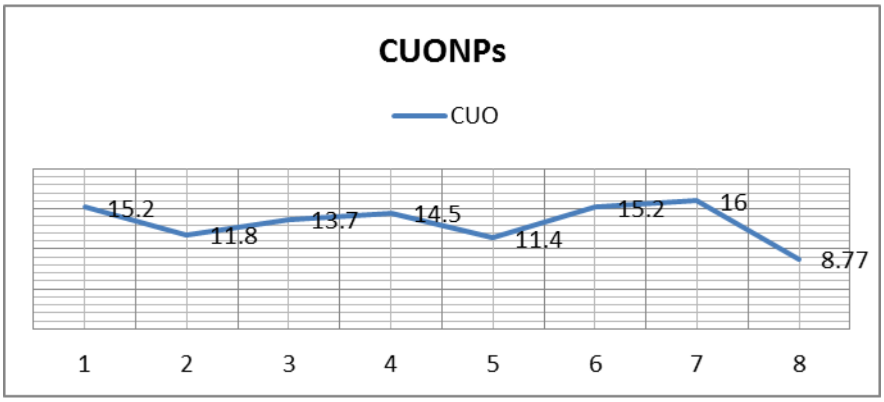

Fig.4: Particle size of Copper oxide nanoparticles (CuONPs) (droplet size = 16nm)

Effect of Copper oxide nanoparticles (CuONPs) and/or peroxyacetic acid (PAA) on mycelial dry weight of *Fusarium oxysporum*.

Growth of *F. oxysporum* that monitored as mycelial dry weight (MDW) was significantly affected by CuONPs and/or PAA tested (Table 2 and figures 5). Antifungal activity of CuONPs or PAA was increased as concentration enhancement. Utilization of (CuONPs) showed mycelial inhibitory effect more than PAA. The greatest inhibitory effect (86.7% efficiency) was obtained by combining 0.1g/l CuONPs with PAA (0.1g/l AA +1.0 g/l H_2O_2) compared to single application of each compound.

Table (2): Effect of Copper oxide nanoparticles (CuONPs) and/or Peroxyacetic Acid (PAA) on mycelial dry weight of Sesame root rot/wilt pathogen.

Comp.	*Conc.(g/l)*	Mycelial dry weight (mg/50 ml liquid media)			
		EXP.I	**EXP.Π**	**Mean**	**Efficiency%**
CuONPs	0.025	445[1]c	448c	446.5c	24.9h
	0.5	352e	353e	352.5e	40.7e
	0.1	225h	227h	226h	62.0f
PAA	0.05AA+0.5H_2O_2	489b	491b	490b	17.6c
	0.1AA+0.1H_2O_2	430d	432d	431d	27.5g
	0.2AA+0.2H_2O_2	344f	346f	345f	42.0e
CuONPs+ PAA	0.025+0.1	257g	258g	257.5g	56.7d
	0.5+0.1	146i	148i	147i	75.2b
	0.1+0.1	80j	78j	79j	86.7a
control	0	600a[2]	590a	595a	0j
LSD5%		7.7	6.9	4.3	0.7

(1) Each value in an average of 3 replicates (plates)
(2) Each reading with the same letter is in-significant at 5%.

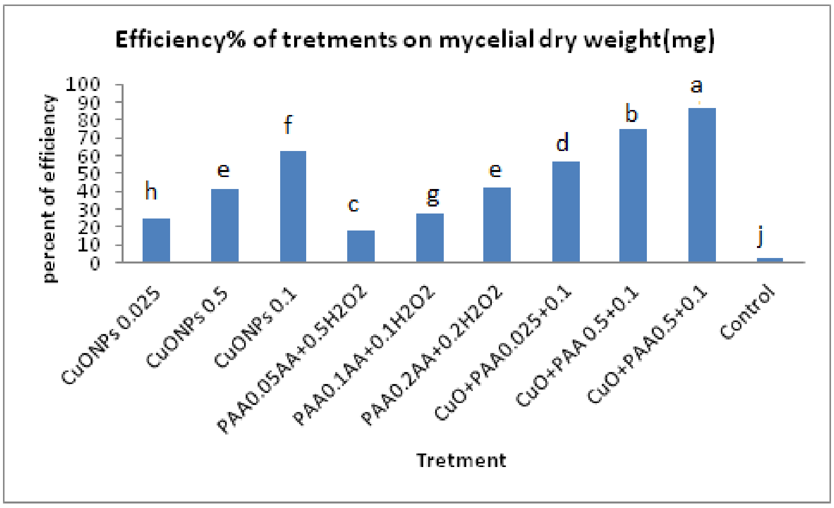

Fig. (5): Effect of Copper oxide nanoparticles (CuONPs) and/or peroxyacetic acid (PAA) on mycelial dry weight (mg) of sesame root rot/wilt pathogen .

Viability of sesame seeds under *Fusarium oxysporum* infection as influenced by Copper oxide nanoparticles (CuONPs) and/or peroxyacetic acid (PAA) treatment :

Viability of sesame seeds was assayed as germination % at ten days after incubation at 25ºC. Data (Table 3) and Figures (6 and 7) showed insignificant effects for CuONPs, PAA and CuONPs combined with PAA at low concentration. Using the highest concentrations of the test compounds caused significant reduction in all vegetative growth parameters .The highest germination % was provided with non-infected untreated seeds (control, 85.4%). The least concentrations of the tested compounds, however slight germination % reductions was expressed as compared with the control or with the highest concentrations of the tested compounds. Regarding *F. oxysporum* infected seeds the least germination % was explored (61.8%) with infected untreated seeds. Meanwhile, treated–infected seeds was significant improved seed germination% under *F.oxysporum* infection condition . Increasing CuONPs or PAA concentrations raised seed germination %. Combining 0.1g/l CuONPs + PAA (0.1g/l AA+1.0 g/l H_2O_2) enhanced seed germination % better than single application of each compound. The highest seed germination %.

Table (3): Effect of Copper oxide nanoparticles (CuONPs) and/or Peroxyacetic acid (PAA), on sesame seed germination.

Comp.	Conc. (g/l)	Non-infected				*F. oxysporum*				Mean	
		G%	SL (cm)	R l (cm)	VI	G%	SL (cm)	R l (cm)	VI	G%	VI
CuONPs	0.025	83.4(*)a(1)	7.0a	7.9a	1242.6a	63.6b	6.8ab	7.5ab	909.4b	73.5a-c	1076b
	0.5	80.4ab	6.4ab	6.6ab	1045.2d	54.5c	5.2b-d	6.5b-d	637.6g	67.4de	841.4g
	0.1	75.4bc	4.6c	6.3ab	821.8h	46.3d	3.2f	3.9f	328.7j	60.8f	575.1i
PAA	0.05	84.3a	6.9a	7.4a	1205.4b	71.8a	6.3a-d	7.2a-c	969.3a	78.0a	1087.3a
	0.1	79.2ab	5.5a-c	6.1ab	918.7f	63.6b	4.4d-f	5.3d-f	616.9h	71.4b-d	767.8h
	0.2	77.5a-c	4.6b-c	5.2b	759.5i	45.5d	3.7e-f	4.5e-f	373.1i	61.5f	566.3j
CuONPs +PPA	0.025+0.1	80.4ab	6.9a	7.6a	1165.8c	45.5d	7.9a	8.5a	746.2e	62.9ef	956c
	0.5+0.1	74.1bc	6.1ab	7.4a	1000.3e	63.6b	6.2a-c	7.4a-c	864.9c	68.8cd	932.6d
	0.1+0.1	70.4c	5.8a-c	7.0ab	901.1g	72.7a	4.3d-f	6.9a-d	814.2d	71.5b-d	857.6f
Control	0	85.4a	7.1a	6.5ab	1161.4c	61.8b	5.0c-e	6.0c-e	679.8f	73.61b-d	920.6e
LSD5%		7.8	1.9	1.8	14.8	4.7	1.6	1.6	15.9	4.9	4.5

*Each reading is an average of 3replicates, each containing 10 seeds.

(1) Each reading with the same letter is a not significant at 5%.

Related *Fusarium oxysporum* was obtained by 0.1g/l CuONPS+ PAA(0.1g/l AA +1.0 g/l H_2O_2) highest 72,7% germination. Similarly shoot and root length were positively affected by CuONPs and/or PAA particularly at low concentrations tested even under *F. oxysporum* infection as compared to untreated infected ones . However increasing concentration decreased either shoot or root length. Data related to seed viability, shoot length or root length reflected an improvement of VI values as result of treatments tested even upon *F. oxysporum* stress as compared to untreated infected ones.

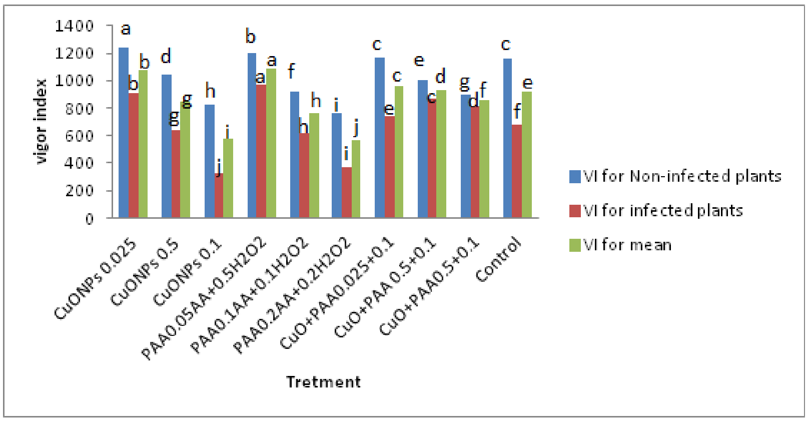

Fig. (7): Effect of Copper oxide nanoparticles and/or PAA on Vigor index of sesame seedlings

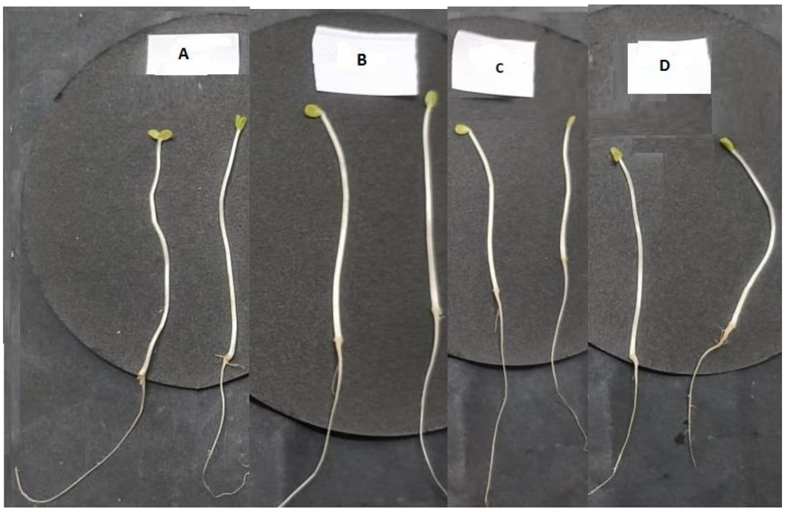

Fig. 8: Shoot and root length of sesame, 10 days old sesame seedlings length as affected by (A) untreated (control), (B) CuONPs(0.1/gl) with PAA (0.1g/l AA +1.0 g/l H_2O_2), (C) CuONPS(0.1/gl) and (D) PAA (0.1g/l AA +1.0 g/l H_2O_2).

Effect of Copper oxide nanoparticles (CuO-NPs) and/or peroxyacetic acid (PAA) on sesame root rot severity :

Either CuONPs or PAA were effective to reduce sesame root rot/wilt severity caused by *Fusarium oxysporum* infection (Table 4 and Figs. 9 and 10). Increasing concentration of the test compounds enhanced their efficiency to decreased infection . Singly utilization of PAA was more effective to decreased sesame root rot/wilt than using (CuONPs). CuONPs (0.1g/l) single gave lower efficiency (82.1%). Then PAA (0.2g/l AA +2.0 g/l H_2O_2) (86,1%) to be noticed, combining CuONPs with PAA gave more efficiency than when those were used singly. Combining PAA(0.1g/l AA +1.0 g/l H_2O_2) with CuONPs at (0.025-0.5-0.1 g/l) undividedly gave higher efficiency to reduces sesame root rot/wilt severity than they applied singly. The most efficiency to decrease sesame root rot/wilt infection was exhibited by combining 0.1g/l CuONPs with PAA(0.1g/l AA +1.0 g/l H_2O_2) (90,6%).

Table (4): Effect of Copper oxide nanoparticles CuONPs and/or Peroxyacetic Acid (PAA) on sesame root rot/wilt .

Comp.	***Conc.(g/l)***	***EXP.1***	***EXP. П***	***mean***	**Efficiency%**
CuONPs	**0.025**	**22.0c**	**26.7c**	**24.3c**	**48.4d**
	0.5	**15.8d**	**15.2de**	**15.5d**	**67.0bc**
	0.1	**9.1f**	**7.7f**	**8.4f**	**82.1a**
PAA	**0.05**	**28.8b**	**31.2b**	**30.0b**	**36.3e**
	0.1	**10.6ef**	**12.7e**	**11.65e**	**75.2b**
	0.2	**5.3g**	**7.8f**	**6.5fg**	**86.1a**
CuONPs+PAA	**0.025+0.1**	**21c**	**27.3bc**	**24.1c**	**48.8de**
	0.5+0.1	**14.3de**	**17.4d**	**15.8d**	**66.4c**
	0.1+0.1	**4.1g**	**4.7f**	**4.4g**	**90.6a**
infected	**0**	**47.6a**	**46.7a**	**47.1a**	**0f**
control	**0**	**0**	**0**	**0**	**0**
LSD5%		**3.8**	**4.3**	**2.4**	**9.2**

(1)The reading is an average of 3 replicates, each containing 25 seeds

(2) Each value with the same litter in non-significant at 0.05%

Control(2): Soil infected with the pathogen

Control(3): Non- infected soil

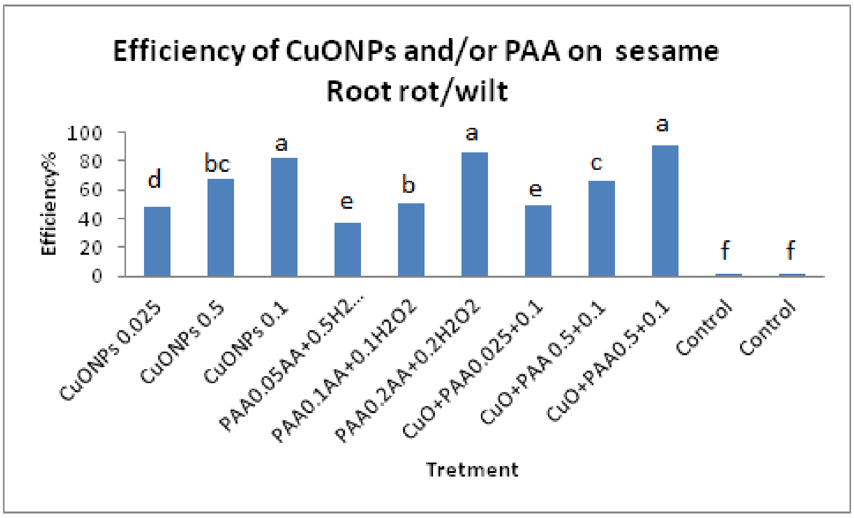

Fig.9 : Effect of Copper oxide nanoparticles (CuONPs) and/or Peroxyacetic Acid (PAA) on sesame root rot/wilt.

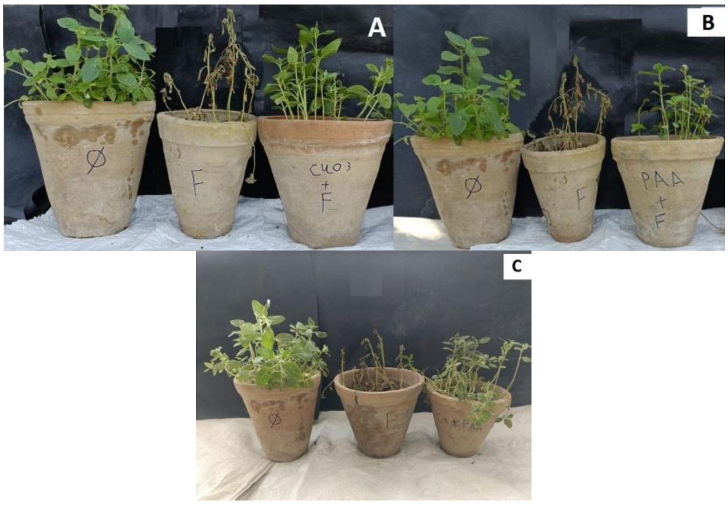

Fig.10: : Growth of sesame plant growing in non-infected (A,B,C) (control, left), Infected (A,B,C) untreated (medium) b *Fusarium oxysporum* y and treated infected (a) CuONPs, (b) CuONPs with PAA and (c) PAA

DISCUSSION

Sesame wilt, caused by *Fusarium oxysporum* f. sp. *sesame,* remains a major threat to sesame cultivation worldwide. Isolation trials identified eight *F. oxysporum* isolates, all of which provided wilt symptoms during pathogenicity tests. Among these isolates, F1 exhibited the highest wilt severity, while F5 showed the weakest virulent. The most virulent isolate, F1, was further identified using PCR, and phylogenetic analysis confirmed its classification as *Fusarium oxysporum*. This isolate was selected for subsequent studies outlined in this paper. As sustainable plant disease control methods that minimize environmental pollution and human health risks gain importance, reducing fungicide applications becomes a primary goal in agriculture. Nanotechnology, including the use of copper oxide nanoparticles (CuONPs) and peroxyacetic acid (PAA), offers promising solutions to address these challenges effectively.

The percent work revealed that CuONPs which purchased are characterized as spherical shape with size 11.4 -16 nm. Several researchers showed that CuONPs of small particle are more efficient than those large **(Sirelkhatim *et al.*, 2015 and Yusof *et al.*, 2022)**. However, antifungal action mechanisms of Copper oxide nanoparticles (CuONPs) as suggested by **(Alghuthaymi *et al*., 2021 and Mondaca *et al*., 2022).** the antifungal properties of commercial CuONPs have also been evaluated **(Elmer *et al.*, 2021-a; Vera-Reyes *et al*., 2019; Elmer *et al.*, 2021-b; Hao *et al*., 2019 and Elmer *et al.*, 2021-c).** As previously mentioned, the concentration of nanoparticles and the species of the fungi are important factors that influence antifungal activity **(Cruz-Luna *et al.*, 2021)** As in the case of ZnO-NPs, the antifungal activity of CuO-NPs tends to increase with the increase in the nanoparticles' concentration **(Pariona *et al.*, 2021; Elmer *et al.*, 2021-c; Vera-Reyes *et al*., 2019; Devipriya and Roopan, 2017; Henam *et al*., 2019 and Shammout and Awwad, 2021).** Interestingly, low concentrations (100–1000 ppm) of CuO-NPs have shown good results in the control of phytopathogenic fungi. Moreover, the effects of CuONPs on different species of phytopathogenic fungi have been evaluated. **(Vera-Reyes *et al*., 2019; Devipriya and Roopan, 2017; El-Batal *et al*., 2020 and Shammout and Awwad., 2021, Mohamed *et al*., 2021; Pariona et al., 2021)**

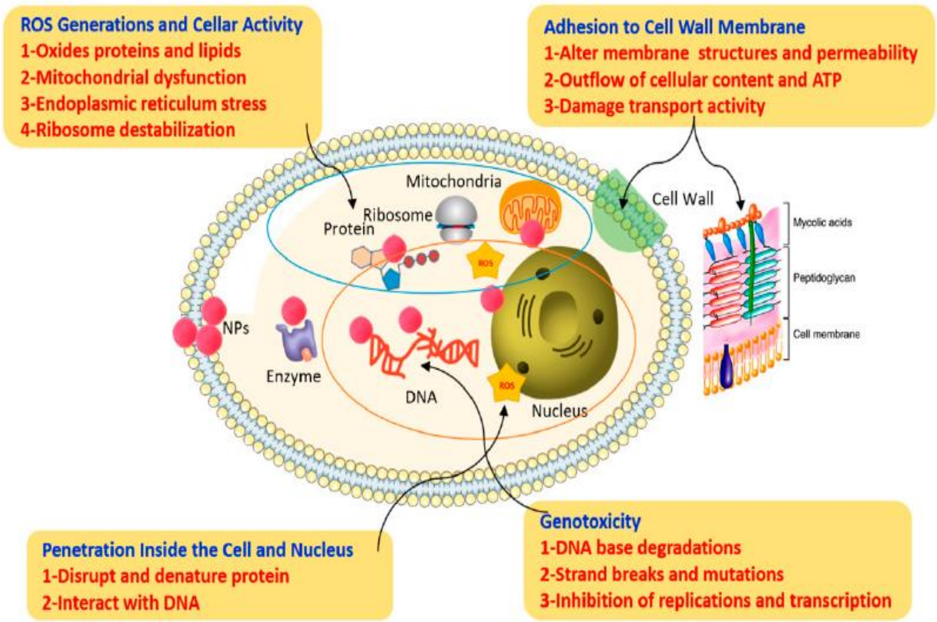

Fig. 11: Possible antifungal mechanisms of metal oxide nanoparticles. Reproduced by (Alghuthaymi *et al*., 2021)

The current results pointed to the effect of (CuONPs) and/or (PAA) on growth of the sesame root rot/wilt pathogens. The tested compounds significantly inhibited the growth of *F. oxysporum*, and reduced both (MDW). Antifungal activity of CuONPs was more than PAA. CuONPs is shown to give effective pathogen growth inhibition. It has been established that the PAA mixture has antifungal efficacy against plant pathogenic fungi **(Mari *et al*., 2004; and Elbouchtaoui *et al.*, 2015;EL-Ashmony et al., 2017; Abdelrhim *et al*., 2022 and Ali *et al*., 2022).** The obtained results show inhibitory effect for PAA against *F. oxysporum* growth. In addition , PAA enhanced the antifungal activity of CuONPs. Energetic antifungal activity was explored when CuONPs was combined with PAA and the maximum antifungal activity was pronounced by combining (0.1g/l) CuONPs with PAA (0.1g/l AA+1.0 g/l H_2O_2). These results are similar as explored by **Ayoub *et al.* (2017).** Meantime, viability of *F. oxysporum* infected sesame seeds were positively affected by CuONPs and/or PAA. Infected sesame seeds gave the least germination %. Meanwhile, CuONPs significant increase in germination % followed by PAA. The greatest germination % was achieved by combining CuONPs with PAA. Generally, CuONPs, PAA and (CuONPs+PAA) provided growth promotion as shoot length and root length enhancement in uninfected or infected satiations, that reflected an improvement of vigor index (VI) values. The greatest VI value was explored when CuONPs combined with PAA followed by CuONPs and PAA. Data indicate that sesame growth promotion exhibited by CuONPs more than PAA. The sesame growth promotion was reached the greatest VI value by combining CuONPs with PAA. It has been shown that CuONPs reacted as plant growth promoter **(Jaya Borgatta *et al*.,2018).** Likewise, PAA showed plant growth promoter for other plants **(Tantawy *et al.*, 2020).**

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الملخص العربي:

تأثير كفاءة جسيمات أكسيد النحاس النانوية (CuONPs)
و/أو حمض البيروكسي أسيتيك على النمو الخضري للسمسم، ومكافحة الذبول الناجم
عن الفطر*Fusarium oxysporum* f. sp. *sesame*

هبه زين العابدين احمد [1] – هناء عياد ارمانيوس[2] – نبيله عبد الظاهر عبد العزيز[2]
مايسه لطفي عبد المنعم[1] - انور عبد العزيز جلال[2]
1- المعمل المركزي للزراعة العضوية، مركز البحوث الزراعية
2- قسم أمراض النبات- كلية الزراعة- جامعة المنيا- المنيا- مصر

تم في هذه الدراسة استخدام منتج تجاري مكون من جسيمات أكسيد النحاس النانوية (CuONPs) التي أظهرت تخليقها كيميائيًا كصفائح كروية بحجم (11.4-16 نانومتر) منفردة أو مجتمعة مع حمض البيروكسي أسيتيك (PAA) لمكافحه مرض ذبول السمسم

Fusarium oxysporum. f. sp. *sesame*. تم استخدام CuONPs للبذور الذي أعطى تأثيرًا سامًا إلى حد ما تجاه إنبات بذور السمسم خاصة بتركيز 100 ملجم/لتر من CuONPs أكثر من المركب PAA ومع ذلك، عندما تم تطبيق CuONPs بشكل فردي، تم تحسين إنبات البذور تحت عدوى *Fusarium oxysporum*أكثر من PAA وحده. تم إحداث تأثير أقوى عندما تم خلط المركبان CuONPs مع PAA في هذا الصدد. وقد ظهر تأثير مضاد لنشاط النمو الفطري CuONPs عن PAA وزاد هذا النشاط بخلط CuONPs مع PAA حيث زاد تثبيط النمو الفطري (الوزن الجاف). علاوة على ذلك فقد قلت نسبه العدوي بالفطر *F. oxysporum* f. sp. *sesame* علي نباتات السمسم عند المعاملة ب CuONPsمقارنة بـPAA ، لكن العدوى كانت الأكثر قمعًا من خلال خلط CuONPs و PAA . يعتبر استخدام CuONPs مع PAA بتركيزات منخفضة مناسبة لمقاومه المرض مع المحافظة على نظافة البيئة وصحة الإنسان.