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Dynamics of Foliar Application of Silver Nitrate on *Fusarium* wilt Severity, Growth and Fruit Yield of Tomato

Ganiyu, S. A.*[1], Popoola, A. R. [2], Wahab, O. Y.[2], Imonmion, J. E.[3], Yekini, B. A.[4], Oke, M. O.[2] and Danbabuwa M. Y.[5]

[1]Department of Agronomy, Federal University of Kashere, P.M.B. 0182, Gombe State, Nigeria
[2]Department of Crop Protection, Federal University of Agriculture, Abeokuta, P.M.B. 2240, Ogun State, Nigeria
[3]Department of Science and Agriculture, Central Texas College, Central Campus, Killeen, Texas, USA. 76549
[4]Crop Research Program, Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), Federal University of Agriculture, Abeokuta, P.M.B. 2240, Ogun State, Nigeria
[5]Department of Botany, Federal University of Lokoja, Lokoja, P.M.B. 1154, Kogi State, Nigeria

Abstract

Management of fungal diseases on crop plants has been towards developing safe and sustainable approaches that pose less danger to man and the environment. The study examined the foliar application of silver nitrate in screenhouse for the management of the *Fusarium* wilt of tomato. A completely randomized design was used for the experiment and replicated three times. The experiment consisted of a tomato variety (Roma round) and silver nitrate ($AgNO_3$) at 10 ppm, 50 ppm, and 100 ppm. Untreated control (0 ppm) pots served as negative control while Carbendazim (2500 ppm) served as a positive control. Results revealed that tomato plants treated with silver nitrate at 100 ppm at 8th WAT had a severity index of 3.00, which was significantly lower than the 4.33 and 6.00 disease severity recorded for plants treated with 50, 10 and 0 ppm concentrations of silver nitrate, respectively. The highest harvested fruit yield (35.90 tons/ha) was recorded for plants treated with Carbendazim, followed by 32.59 tons/ha recorded for plants treated with 100 ppm silver nitrate, which were not significantly different from each other. However, both values were significantly different from 20.47, 0.40, and 0.31 tons/ha fruit yield recorded for plants treated with 50, 10, and 0 ppm silver nitrate concentrations, respectively. The results showed that silver nitrate at 100 ppm concentration can reduce *Fusarium* wilt infection on tomato which would consequently translate to fruit yield increase.

Keywords: *Fusarium* wilt, severity, silver nitrate, tomato, yield.

***Corresponding authors email:** ganiyu.sikiru@yahoo.com

Introduction

In 2022, tomatoes accounted for the most vegetable production worldwide, with 186 million tons produced followed by onions (111 million tonnes, including shallots), cucumbers (95 million tonnes, including gherkins), cabbages (73 million tonnes), and eggplants (59 million tonnes) were the next most produced vegetables (FAO, 2023). However, a big threat to the production of tomato in Nigeria is *Fusarium* wilt caused by *Fusarium oxysporum* f.sp. *lycopersici* (Sultan et al., 2024). It is a lethal disease to tomatoes, resulting in critical yield loss in tomato production (Swett et al., 2023; Olanrewaju et al., 2022) in both fields and screenhouses. The pathogen infects tomato plants at vegetative, flowering, and fruiting stages. The disease accounts for harvest forfeiture of between 10-80% (Ma et al., 2023; Simões and Andrade, 2023).

There are several approaches to managing this *Fusarium* wilt disease (Simões and Andrade, 2023). According to Dutta et al. (2023), the practice of novel methods concerning the management of plant diseases is essential. They reiterated that the exploration of nanotechnology such as nanoparticles (NPs) could be a substitute for managing soil-borne pathogens.

In the agricultural sector, silver nitrate ($AgNO_3$) is developed as plant-growth stimulators, fungicides to prevent fungal diseases or agents to enhance fruit ripening (Khan et al*.,* 2023) and environment friendly. Due to their unique properties, silver nanoparticles (AgNPs) are the most widely used nanoparticles in a variety of applications (Khan et al., 2023). Furthermore, antiviral, antibacterial, and antifungal actions of AgNPs provide plants with defense against pathogenic microorganisms. Therefore, this experiment was out to examine the effect of foliar application of silver nitrate ($AgNO_3$) on the incidence and severity of Fusarium wilt, growth, and fruit yield of tomato in the screenhouse.

Materials and Methods

Experimental Site

In FUNAAB/DFID/ARCN tomato research screenhouse, the experiment was carried out, using sandy-loam soil, at the College of Plant Science and Crop Production, Federal University of Agriculture, Abeokuta, Ogun State (3º23'E and 7º20'N) in the year 2022.

Source of Experimental Materials, Design, and Treatments

Viable seeds of tomato (cv. Roma round) were sourced from the National Horticultural Research Institute (NIHORT). Silver nitrate ($AgNO_3$) was sourced from the Plant Tissue Culture Laboratory, Crop Protection, Federal University of Agriculture Abeokuta, Nigeria. A completely randomized design was used for the experiment and replicated three times. The experiment consisted of a tomato variety (Roma round) and silver nitrate ($AgNO_3$) at 10 ppm, 50 ppm, and 100 ppm. Untreated control (0 ppm) pots served as negative control while Carbendazim (2500 ppm) served as a positive control.

Soil Sterilization, Nursery Establishment, and Transplanting

Sandy-loam soil collected from the Federal University of Agriculture Abeokuta premises was steam-sterilized for 30 min at 120 ˚C (Ganiyu et al., 2017). The sterilized soil was packed inside sacks for 2 weeks before use for the soil to stabilize. Tomato seeds were sown in nursery trays containing sterilized soil and seedlings were raised for three weeks before transplanting. Seedlings were transplanted into pots filled with 15 kg of sterilized soil.

Isolation, Morphological Identification and Pathogenicity of Fusarium oxysporum f.sp. lycopersici on Tomato

Wilted tomato plants with *Fusarium* wilt symptoms were collected from a wilt-endemic tomato field at the Directorate of University Farms (DUFARMS), Federal University of Agriculture, Abeokuta, and were taken to plant tissue culture laboratory for *Fusarium oxysporum* f.sp. *lycopersici* isolation. Isolation was done using the method of Okhuoya et al. (2012). Morphological identification of the pathogen was carried out in the Department of Crop Protection laboratory with the aid of visual observation and a compound microscope. All observed features on the pathogen were identified using Burketová and Dugan (2008) fungi identification. A pathogenicity test was carried out on tomato (cv. Roma round). Briefly, seeds were surface sterilized with 70% ethanol for ten minutes, rinsed in sterile distilled water thrice, and air-dried prior to use for 30 minutes. Seeds were sown in a steam-sterilized soil and seedlings were inoculated with *F. oxysporum* f.sp. *lycopersici* suspension ($2x10^7$ conidia/ml) when they were 14 days old as previously described (Rubio et al., 2017). Pots without pathogen inoculation served as control. Seedlings were incubated in screenhouse for 3 weeks at 26.5±2ºC and relative humidity of 87.5%. Tomato plants were watered regularly and checked for symptom development thereafter.

Inoculation of Tomato Seedlings with Fusarium oxysporum f.sp. lycopersici

Seven-day-old pure culture of a Petri plate of *F. oxysporum* f.sp. *lycopersici* was flooded with 100 ml sterile distilled water and a suspension of inoculum was obtained. The suspension was sieved through one layer of cheesecloth and the concentration was adjusted to 10^6 conidia/ml using a hemocytometer. The prepared conidia suspension was inoculated into disease free tomato seedlings using the drenching method, two weeks after transplanting.

Application of Silver Nitrate

Tomato plants (cv. Roma round) were treated with silver nitrate ($AgNO_3$) at 3, 5, and 7 weeks after transplanting (WAT) through foliar spray early in the morning. Silver nitrate ($AgNO_3$) was applied at 10 ppm, 50 ppm, and 100 ppm concentrations. The positive control pots received 2500 ppm of Carbendazim fungicide while the negative control (0 ppm) received no application. Data collected were plant height (cm), number of leaves/plants, number of branches/plants, number of flowers per plant, disease incidence (%), severity and fruit yield (tons/ha). Assessment of disease incidence commenced at 6th and 8th weeks after transplanting. Disease incidence and severity per plant were calculated by:

$$Disease\ incidence\ (\%) = \frac{Number\ of\ infected\ leaves\ per\ plant}{Total\ number\ of\ leaves\ per\ plant} \times 100$$

$$\text{Disease severity} = \frac{\text{Sum of all ratings} \times 100}{\text{Total number of leaves} \times \text{maximum rating value}}$$

The severity of the disease was assessed at the 6th and 8th weeks after transplanting through visual expression using Viljoen et al. (2017) with little modifications as shown in Table 1 below.

Table 1: Disease severity scores for *Fusarium* wilt disease of tomato

Severity score	Symptom description
1	Symptomless (0%), stems and leaves free of any visual symptoms
2	Yellowing and wilting of ≤ 25% of leaves
3	Yellowing and wilting of 26-50% of leaves
4	Yellowing and wilting of 51-75% of leaves
5	Total (76-100%) yellowing and wilting of leaves
6	Plant dead

Source: Viljoen et al. (2017)

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using the Statistical Analysis System (SAS) package and means separated by the Duncan Multiple Range Test (DMRT) ($p \le 0.05$).

Results

Identity and Pathogenicity of Fusarium oxysporum f.sp. lycopersici

The mycelia of *Fusarium oxysporum* f.sp. *lycopersici* are fluffy and whitish in colour. A pinkish-pigmented growth of the mycelia was observed at the point of inoculation at the base of the side of the petri dish. On the pathogenicity test, the first indication of the disease was golden yellowing and drooping of the lower leaves.

Effect of Silver Nitrate on Growth Performance of Roma Round tomato

Plant height (cm) ranged from 29.43 to 78.00 cm for the period of the experiment (Table 2). At 4th week after transplanting (WAT), the highest plant height (45.87 cm) was recorded in pots treated with 100 ppm concentration of silver nitrate. This value was significantly different from 29.43 and 30.40 cm in untreated control and silver-nitrate treated pots at 10 ppm concentration, respectively. The same trend was observed at the 6th and 8th WAT but with the highest plant height of 59.60 cm and 78.00 cm when Carbendazim and silver nitrate were applied at 2500 ppm and 100 ppm, respectively. The numbers of branches/plant were similar when silver nitrate was applied at both 50 and 100 ppm concentrations, which were comparable to the number of branches recorded in pots treated with Carbendazim. At 8th WAT, the 7.00 number of branches recorded in untreated control pots was significantly lower than the 10.05 number of branches when 10 ppm silver nitrate concentration was applied. The number of leaves and flowers followed the same trend.

Effect of Silver Nitrate on Incidence (%), Severity, and Fruit Yield (tons/ha) of Roma Round Tomato

Highest disease incidence (%) of 66.70% and 89.90% were recorded for untreated control pots at 6th and 8th WAT, respectively. These values were significantly higher than 50.10 and 61.55%, 45.70 and 20.00%, 20.00 and 10.00% recorded for plants treated with 10, 50, and 100 ppm silver nitrate, respectively (Table 3). The severity index at 8th WAT for tomato plants treated with silver nitrate (3.00) at 100 ppm was significantly lower than 4.33 and 6.00 disease severity recorded for plants treated with 50, 10, and 0 ppm concentrations of silver nitrate. The highest harvested fruit yield (35.90 tons/ha) was recorded for plants treated with Carbendazim, followed by 32.59 tons/ha recorded for plants treated with 100 ppm silver nitrate, which were not significantly different from each other. However, both values were significantly different from 20.47, 0.40, and 0.31 tons/ha fruit yield recorded for plants treated with 50, 10, and 0 ppm silver nitrate concentrations, respectively.

Table 2: Effect of Silver Nitrate on Growth Performance of Roma Round Tomato at 4, 6, and 8 Weeks after Transplanting (WAT)

$AgNO_3$ concentration (ppm)	Plant height (cm)			Number of branches per plant			Number of leaves per plant			Number of flowers per plant
	4WAT	6WAT	8WAT†	4WAT	6WAT	8WAT	4WAT	6WAT	8WAT	6WAT
0	29.43±0.12^{bc}	43.67±0.01^{bc}	64.97±0.01^{bc}	4.10±0.10^{bc}	5.50±0.50^{b}	7.00±1.00^{c}	20.67±0.07^{b}	44.00±1.00^{c}	64.00±2.00^{c}	47.33±0.33^{c}
10	30.40 ±0.69^{b}	46.93±0.01^{b}	67.90±0.01^{b}	5.25±0.25^{b}	6.00±1.00^{b}	10.05±0.05^{b}	25.33±0.33^{a}	56.33±0.33^{b}	73.00±1.00^{b}	66.67±0.07^{b}
50	43.77±0.40^{a}	55.93±0.01^{a}	77.07±0.01^{a}	8.50±0.27^{a}	10.10±0.17^{a}	14.55±0.05^{a}	25.33±0.33^{a}	65.33±0.33^{a}	83.33±0.33^{a}	67.33±0.57^{b}
100	45.87±0.58^{a}	55.67±0.01^{a}	78.00±1.00^{a}	8.95±0.05^{a}	11.00±1.00^{a}	16.05±0.05^{a}	26.33±0.33^{a}	65.00±1.00^{a}	84.67±0.07^{a}	74.33±0.33^{a}
2500 (Carbendazim)	43.63±0.01^{a}	59.60±0.01^{a}	77.57±0.01^{a}	8.80±0.92^{a}	11.25±0.25^{a}	16.25±0.25^{a}	26.67±0.07^{a}	66.67±0.07^{a}	84.33±0.33^{a}	77.00±1.00^{a}

Values are mean ± standard deviation of three replicates. Means with the same superscript within a column are not significantly different ($p \geq 0.05$) according to Duncan Multiple Range Test (DMRT) ($p \leq 0.05$), †WAT: Weeks after transplanting.

Table 3: Effect of Silver Nitrate on Incidence (%), Severity, and Fruit Yield (tons/ha) of Roma Round Tomato

$AgNO_3$ concentration (ppm)	Incidence (%)		Severity index		Harvested Fruit yield (tons/ha)
	6 WAT[†]	8 WAT	6 WAT	8 WAT	
0	66.70±5.80[a]	89.90±0.17[a]	6.00±1.00[a]	6.00±2.00[a]	0.31±0.02[c]
10	50.10±0.17[b]	61.55±2.69[b]	6.02±0.04[a]	6.00±1.00[a]	0.40±0.10[c]
50	45.70±1.21[b]	20.00±1.00[c]	5.91±0.87[a]	4.33±0.57[a]	20.47±0.81[b]
100	20.00±0.50[c]	10.00±0.50[d]	4.01±0.02[b]	3.00±0.00[b]	32.59±0.52[a]
2500 (Carbendazim)	10.00±0.50[d]	5.09±0.16[e]	3.03±0.05[b]	2.00±0.00[b]	35.90±1.56[a]

Values are mean ± standard deviation of three replicates. Means with the same superscript within a column are not significantly different ($p \geq 0.05$) according to the Duncan Multiple Range Test (DMRT) ($p \leq 0.05$), [†]WAT: Weeks after transplanting.

Discussion

A variety of pathogens infect tomato plants of which *Fusarium oxysporum* f.sp. *lycopersici* (Sacc.), a soilborne pathogen, is among (Sultan et al., 2024). Fungicides proved to be effective against destructive fungal pathogens but cause serious damage to the environment and are as well toxic to human health (Sabir et al., 2022). This work showed that silver nitrate ($AgNO_3$) at 100 ppm concentration significantly promoted tomato growth and improved the number of leaves, flowers, and yield compared with the untreated control pots. A comparable outcome was conveyed by Oyelakin et al. (2023), that the application of silver nitrate ($AgNO_3$) caused significant growth promotion and good quality fruit yield of tomato. The positive effect might be attributed to enhancing the secondary metabolites production in the suspension (Erb and Kliebenstein, 2020). In this work, the significant positive influence of silver nitrate on tomato agronomic parameters depicted the sufficiency of silver ions in the solution. Improvement in the number of leaves of tomato might be a result of the delay in leaf defoliation caused by silver nitrate. The effect of silver nitrate in enhancing plant growth was demonstrated by Oyelakin et al. (2023). Aside from Carbendazim, applying silver nitrate ($AgNO_3$) at 100 ppm concentration reduced the incidence and severity of *Fusarium* wilt and performed best compared with other lower rates and untreated control pots.

Conclusion

The study examined the effect of foliar application of nitrate ($AgNO_3$) on the incidence and severity of fusarium wilt, growth, and fruit yield of tomatoes in the screenhouse. The results showed that silver nitrate at 100 ppm concentration reduced *Fusarium* wilt infection, translating to a fruit yield increase. Therefore, it is suggested that if taken to the field, it could translate to a greater fruit yield increase.

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