Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi, 28 (3), 522-535
Mustafa Kemal University Journal of Agricultural Sciences, 28 (3), 522-535
https://dergipark.org.tr/tr/pub/mkutbd
e-ISSN: 2667-7733

ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effects of silver nanoparticles (Ag-NPs) on physiological and biochemical properties of tomato plants under drought stress

Gümüş nanopartiküllerin (Ag-NPs) kuraklık stresi altındaki domates bitkilerinin fizyolojik ve biyokimyasal özelliklerine etkisi

Yelderem AKHOUNDNEJAD[1], Ozgur KARAKAS[2], H. Yıldız DASGAN[3], Nevzat SEVGIN[1], Gamze GUNDOGDU[4], Baki TEMUR[1]

[1]*Sırnak University, Faculty of Agriculture, Department of Horticulture, Idil, Sirnak, Turkiye.*
[2]*Cukurova university, Faculty of Agriculture, Depatment of Horticulture, Adana, Turkiye.*
[3]*Sırnak University, Faculty of Agriculture, Department of Agricultural Biotechnology, Idil, Sirnak, Turkiye.*
[4]*Uludag University, Faculty of Agriculture, Department of Horticulture, Nilufer, Bursa, Turkiye.*

ARTICLE INFO

Article history:
Recieved / Geliş: 21.03.2023
Accepted / Kabul: 08.06.2023

Keywords:
Silver nanoparticles
Drought
Tomato
Stress

Anahtar Kelimeler:
Gümüş nanopartiküüler
Kuraklık
Domates
Stres

Corresponding author/Sorumlu yazar:
Yelderem AKHOUNDNEJAD
yakhoundnejad@sirnak.edu.tr

ABSTRACT

In this study, the effects of five different concentrations of silver nanoparticles (Ag-NPs) (0, 25, 50, 75, 100 mg l^{-1}) application on two different tomato cultivars grown at three different irrigation levels (25%, 50% and 100%) were investigated. Yield and quality characteristics of tomato fruits were investigated. The level of Ag-NPs that reduces the effects of arid stress on the plant genotypes physiologically and morphologically and their effects on the yield and fruit quality characteristics were also evaluated. Ag-NPs of 50 mg l^{-1} application was found to be more effective than the other applications in protecting tomato plants against the negativities caused by drought stress. In general, the total yield showed a decrease in AgNPs+stress applications according to Chlorophyll (SPAD) and Water use efficiency. In total yield Ag-NPs, Ag-NPs+50% stress and Ag-NPs+25% stress applications, the highest doses were found for Ag-NPs 25 mgl^{-1} (5489.66 g m^2) and Ag-NPs 25 mg l^{-1} (4896.00 g m^2), respectively. This study provides results that may be used by producers in places where tomato plants grown in arid regions. Silver nanoparticles can be used at ppm levels to produce quality tomato fruits by providing drought resistance of the plant.

ÖZET

Bu çalışmada, 3 farklı sulama seviyesinde (%25, %50, %100) yetiştirilen 2 farklı domates çeşidine 5 farklı konsantrasyonda gümüş nanopartiküllerin (Ag-NPs) (0, 25, 50, 75, 100 mg l^{-1}) uygulamasının etkileri incelenmiştir. (Ag-NPs) uygulaması ppm bazında kullanılarak domates meyvesinin verim ve kalite özelliklerini incelenmiştir. Ag-nanopartiküllerin domates genotiplerinde bitki üzerindeki kurak stresin etkilerini fizyolojik ve morfolojik olarak hangi düzeyde azalttığı belirlenirken, uygulamaların verim ve meyve kalite özellikleri üzerindeki etkileri de incelenmiştir. Denemede uygulanan Ag-NPs 50 mg l^{-1} uygulamasının domates bitkisini; kuraklık stresinden kaynaklanan olumsuzluklara karşı korumada diğer uygulamalara göre daha etkili olduğu görülmüştür. Genel olarak toplam verim, meyve uzunluğu ve meyve çapına göre Ag-NPs+stres uygulamaları bir düşüşe neden olmuştur. Toplam verimde Ag-NPs, Ag-NPs+%50 stress ve Ag-NPs+%25 stress uygulamalarında en yüksek dozlar sırasıyla Ag-NPs 25 mg l^{-1} (5489,66 g m^2) ve Ag-NPs 25 mg l^{-1} (4896,00 g m^2) olarak bulunmuştur. Bu çalışma, üreticilerin hemen kullanabilecekleri pratik kısa vadeli sonuçlar sunmaktadır. Bu çalışma, özellikle kurak bölgelerde domates yetiştiriciliğin yapıldığı alanlarda üreticilerin kısa vadede pratik olarak kullanabilecekleri sonuçlar sunmaktadır. Gümüş nanopartiküller, bitkinin kuraklığa dayanıklılığını sağlayarak kaliteli domates meyveleri üretmek için ppm düzeylerde kullanılabilir.

Cite/Atıf Akhoundnejad, Y., Karakas, O., Dasgan, H.Y., Sevgin, N., Gundogdu, G., & Temur, B. (2023). Effects of silver nanoparticles (Ag-NPs) on physiological and biochemical properties of tomato under drought stress. *Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi, 28* (3), 522-535. https://doi.org/10.37908/mkutbd.1266767

INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of the main field and greenhouse vegetable crops grown all over the world (Quinet et al., 2019). Tomatoes contain many health-promoting compounds and are easily integrated as a nutritious part of a balanced diet (Martí et al., 2016). Nanotechnology is developing rapidly in many sectors including agriculture. Nanoparticles differ from bulk products due to their physical and chemical properties. Different responses have been reported regarding commercial and scientific applications of nanoparticles (Oberdorster et al., 2005; Akhoundnejad & Karakaş, 2021). The word nano means very small in Greek and refers to a billionth of any physical size (Tegart, 2003). Silver is used in different stages of plant growth and development due to its nanomaterial and antibacterial properties (Kim et al., 2007; Soylu et al., 2022). Nanotechnology is an applied science field that deals with biological or non-biological particles smaller than 100 nm in diameter (Cıracı et al., 2005). Nanotechnology is the study and use of materials at atomic and molecular sizes (on a scale ranging from 10 to 100 nm) (Kaphleet al., 2018). Nanoparticles can be in the form of organic and inorganic materials. Organic nanoparticles contain carbon while inorganic nanoparticles contain titanium, zinc, silver, gold and copper (Xu et al., 2006). Nanoparticles (NPs) are materials with their unique nanoscale size between 1 and 100 nm (Graf et al., 2003), chemical and physical properties, size and high surface area (Dakal et al., 2016). Among the nanoparticles used in plants, silver nanoparticles (Ag-NPs) are used more effectively and importantly in different applications (Firdhouse & Lalitha, 2015).

Plants face adverse conditions due to fluctuations of environmental conditions. These changes include abiotic nutrient imbalance, stresses such as high or low temperature, salinity and drought affecting plant growth and development (Due et al., 2008). Many researchers extensively studied the drought stress on many plant varieties (Farooq et al., 2009; Dasgan et al., 2018; Laxa et al., 2019, Akhoundnejad & Dasgan, 2020; Akhoundnejad et al., 2022). Drought stress causes biochemical, physiological and morphological changes in plants (Ortiz et al., 2015; Bırgın et al., 2021). Although plants can develop defense and resistance mechanisms, these measures are sometimes insufficient (Cruz de Carvalho, 2008). In recent years, nanotechnology has received increasing attention in the fields of electricity, medicine, food and agriculture. It is widely used, especially because it shows quick results in plants.

The aim of this study was to examine the tomato yield and quality under the application of silver nanotechnology and drought stress. Different doses of Ag-NPs, drought stress, plant growth, effects and toxicities were investigated. In addition, both beneficial and harmful limitations of Ag-NPs application were examined.

MATERIALS and METHODS

The tomato genotype (cv. Fereng) used in the research was widely cultivated in Idil/Sirnak region (Akhoundnejad, 2020). The study was carried out in the research and application garden of Sirnak University. Three different water levels (100%, 50% and 25%) were used in the experiment (Akoundnejad, 2020). The amount of water to be given was calculated according to the formula given below. The amount of water given per plant was shown in Figure 1. Ag-NPs were applied to tomato plants at 0, 25, 50, 75 and 100 mg l^{-1} doses which were chosen according to previous studies (Akhoundnejad et al., 2022). The characteristics of the Ag-NPs, obtained from Sigma Aldrich company, are as follows: AB202468 and 4-7 APS 4-7 micron; 99.9% (metalsbasis). The experiment was set up in a factorial randomized block design with three replications and 10 tomato plants in each replication. Tomato seeds were planted on rows with a distance of 120 cm between rows and 50 cm in rows. In the experiment, seed planting was done on March 15, 2019 according to the weather conditions. The planting of the seedlings was carried out on April 17, 2019. Drought stress onset time was applied after the first flowering in the experiment. Ag nanoparticles (Ag-

NPs) was applied approximately 30 days after planting and every two weeks at doses of 0, 25, 50, 75 and 100 mg l^{-1} from the leaf until the end of the experiment (as a foliar spray).

IR (Amount of Water Used, m^3) = A (Parcel size, decare) * E PAN (Evaporation amount, mm) * KCP (Coefficient of tomato fruit, 0.80) * P (Vegetation, %)

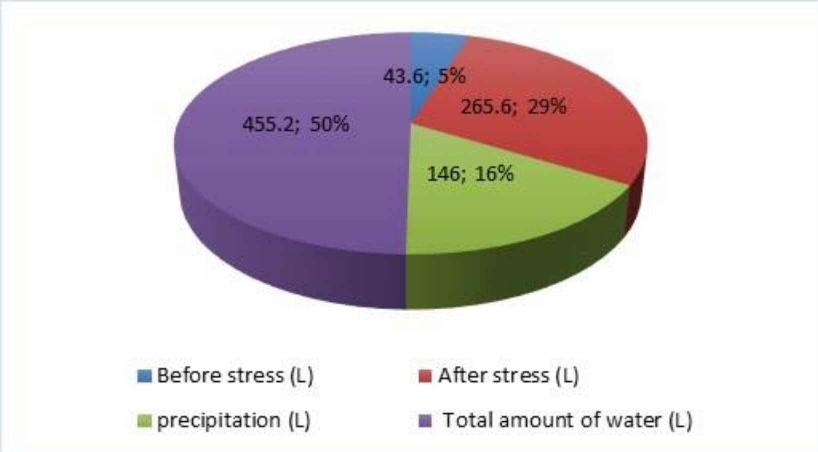

Figure 1. The amount of water used in the experiment (Liter $plant^{-1}$)
Şekil 1. Denemede kullanılan su miktarı (Litre $bitki^{-1}$)

Membrane damage index in leaf cells (%)

In the trial, 1 cm diameter leaf disc was taken by counting 5-6 leaves from the top of the tomato plant during the harvest period and falcon tubes were placed with 20 ml distilled water and measured with an EC meter after 4 hours. In addition, after measuring, the samples were kept at 100 °C for 10 minutes and after they come to room temperature, they were measured again with an EC meter and the following Formula was applied to calculate the membrane damage index in leaf cells (Dlugokecka & Kacperska-Palacz, 1978; Fan & Blake, 1994):

Membrane damage index in leaf cells = (Lt-Lc) / (1-Lc)x100

Lt: EC measurement of stress application in trial before autoclave/ Ec measurement after autoclave

Lc: EC measurement of the control application in the trial EC before/after autoclaving

Determination of the amount of chlorophyll (SPAD)

Chlorophyll amount was measured from six leaves from the top of the tomato plants by using chlorophyll meter (Minolta SPAD-502Plus).

Determination of fresh and dry weight of tomato leaves (%)

During the harvest period, samples were taken from the leaves and weighed. The weights of the samples were also measured after drying in an oven for 72 hours and at 65 °C.

Determination of leaf relative water content (LRWC) (%)

In the experiment, leaves were taken as samples during the harvest period and their fresh weights were measured. In addition, the leaf samples were kept in pure water for 4 hours and the turgor weights were measured again. In addition, after drying in an oven for 48 hours and at 65 °C, the weights were measured again and calculated according to the method of Sanchez et al. (2004).

Potassium and calcium element analyzes of tomato fruits and green parts (mg l^{-1} and %)

After drying samples, 200 mg of the samples weighed and burned in the ash oven at 550 °C for 6 hours. In addition, the blue band filter was taken by dissolving with 3.3% HCl solution. The concentrations of K and Ca elements were determined by reading the filters in an Atomic Absorption Spectrophotometer (Model: FS220, Varian) device in emission mode.

Determination of vitamin C in tomato juice (mg g^{-1})

After taking the juice sample of 1 g of tomato fruits, 45 ml of 0.4% oxalic acid was added, 1 ml was taken after passing through filter paper, 9 ml of dye solution was added, and reading was made according to Özdemir and Dündar (2001) at 502 nm wavelength.

Determination of lycopene (mg kg^{-1})

After the tomato fruits were set, 0.5 g pulp was weighed, 0.3 g starch was added to it, 20 ml acetone was added, and then shaken in a shaker for 20 minutes and centrifuged for 3 minutes. In addition, measurements were made at 503 nm in the spectrophotometer.

Water use efficiency (g l^{-1})

In the experiment, the amount of water given to tomatoes in different arid stress applications was recorded. In addition, the yield amount of the tomato genotype was recorded at each harvest. Water use efficiency was calculated by dividing the tomato yield recorded at the end of the experiment by the amount of water we gave (reference) using the formula given below:

Water Use Efficiency (g / L) = yield per plant (g / plant) / amount of water given to the plant (L / plant)

Total tomato fruit harvest (g/m^2)

After the start of the harvest in the experiment, the harvest of tomato fruits was recorded in each harvest. One harvest was made each week with a total of 5 harvests. At the end of the experiment, the total harvest amount was calculated. In addition, the amounts of tomatoes per unit area were calculated as g per m^2.

Recording of climate data

The climate data during the trial period were taken from the Sirnak Meteorology Station Directorate. The climate data (temperature and precipitation) recorded in the experiment are given in Figure 2 and Figure 3.

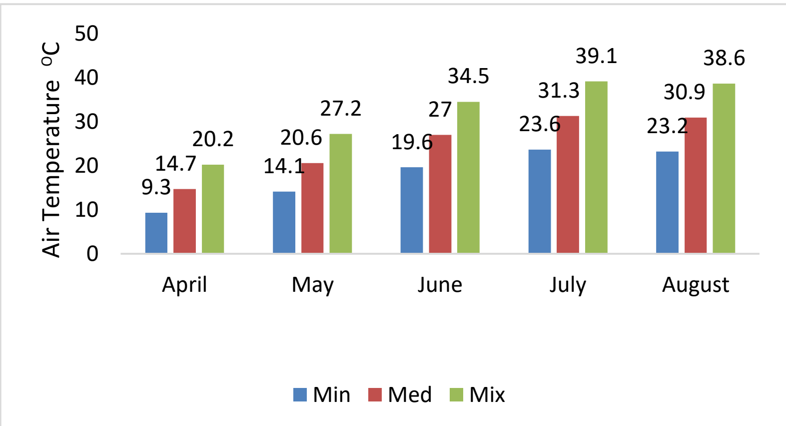

Figure 2. Temperature (°C) data near the experiment site

Şekil 2. Deney sahasına yakın sıcaklık (°C) verileri

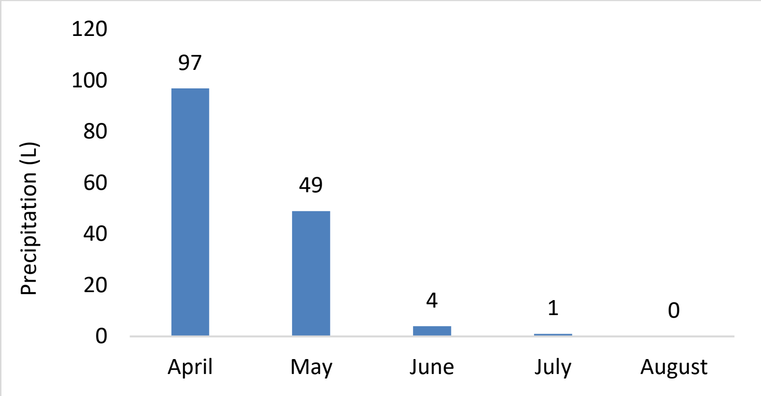

Figure 3. Total precipitation (L) data near the experiment site
Şekil 3. Deney sahasına yakın alanda toplam yağış (L) verileri

Statistical analysis

The data in the experiment were subjected to analysis of variance by using JMP statistic package program (Version 13) and the significance levels of the differences between the means were evaluated according to the LSD test.

RESULTS and DISCUSSIONS

The changes in the total yield was observed the lowest in Ag-NPs, Ag-NPs+50% stress and Ag-NPs+25% stress applications: Ag-NPs 100 mg l^{-1} +100% (5205 g m^2), Ag-NPs 100 mg l^{-1} + 50% stress (4162.00 g m^2) and Ag-NPs were determined as 100 mgl l^{-1} + 25% stress (3849.83 g m^2). In general, the total yield showed a similar decrease in AgNPs+stress applications according to Chlorophyll (SPAD) and Water use efficiency. In Ag-NPs, Ag-NPs+50% stress and Ag-NPs+25% stress applications, the highest doses were found for Ag-NPs 25mgl^{-1} (5489.66 g m^2) and Ag-NPs 25 mg l^{-1} (4896.00 g m^2), respectively. Accordingly, when the average values were examined, it was seen that the total harvest decreases by -19.43% on average in 50% irrigation application compared to their own controls, and the total harvest decreases by -10.32% in 25% irrigation application (Table 1). Considering the total yield according to the data in Table 1, the lowest tomato harvests in different applications were Ag-NPs 100 mg l^{-1} 5205.0 (g m^2), Ag-NPs 100 mg l^{-1} +50% irrigation 4162.0 g m^2 and Ag and -NPs+25% stress 3849.8 g m^2 were reached. In Ag-NPs application, plants develop different defense mechanisms together with stress applications (Ag-NPs+stress). Accordingly, it causes many physiological and biochemical changes in plants by negatively affecting growth and yield. Accordingly, when Ag-NPs are applied, stomata are closed and a more effective water use is realized in stress (drought) mechanisms, especially at 25 mg l^{-1} doses. Therefore, it has an effect on the total yield. As Ag-NP doses increase, its negative effects are observed (Levard et al., 2012). The effects of Ag-NPs on crop harvest are common, especially on edible crops (Kumari et al., 2009; Lee et al., 2012; Qian et al., 2013).

As shown in Table 1, the amount of chlorophyll was seen between 72.4% and 61.1%. In the experiment, the amount of chlorophyll was determined at the lowest level in the two stress trials, Ag-NPs 100 mg l^{-1} + 50% irrigation 66.5and Ag-NPs 100 mg l^{-1} +25% irrigation 61.1 Accordingly, the least affecting chlorophyll amount in the experiment was determined as Ag-NPs 50 mg l^{-1}+ 50% irrigation 71.3 and Ag-NPs 25 mg l^{-1}+25% irrigation 65.8 level in the stress trial. Depending on the Ag-NPs and Ag-NPs+Stress conditions, the amount of chlorophyll decreased with varying amounts of AgNPs doses (Table 1). Ag-NPs 50 mg l^{-1}, Ag-NPs 50 mg l^{-1} + Stress 25% and Ag-NPs25 mg l^{-1} + Stress 25% showed the closest development to the control plants in terms of chlorophyll amount. As the concentration of Ag-NPs increased, the chlorophyll amount decreased. Accordingly, the effect of silver nanoparticles (Ag-NPs), a decrease in total chlorophyll content in Arabidopsis thaliana (Qian et al., 2013) and Oryza sativa (Nair & Chung, 2014) plants has been reported in previous studies in parallel with our study results.. This chlorophyll amount causes inhibition in photosynthesis. In addition, it is generally determined as a result of lipid peroxidation as a result of the production of reactive oxygen species such as O_2 and H_2O_2.

Table 1. Effect of Ag-NPs on the total yield and chlorophyll content of tomato under drought stress
Çizelge 1. Ag-NPs'lerin kuraklık stresi altındaki domatesin toplam verimi ve klorofil içeriğine etkisi

Treatment	100% Ir. L. (T.Y)	100% Ir. L. (Ch.)	50% Ir. L. (T.Y)	50% Ir. L. (Ch.)	25% Ir. L. (T.Y)	25% Ir. L. (Ch.)	50% Cha. (T.Y)	50% Cha. (Ch.)	25% Cha. (T.Y)	25% Cha. (Ch.)
Control	6436.0 b	70.60 c	5332.6 ab	68.78 b	4663.6 b	64.37 b	-17.14	-2.58	-12.55	-6.41
25 mg l^{-1}	6687.3 a	71.67 b	5489.6 a	67.41 bc	4896.0 a	65.79 a	-17.91	-5.94	-10.81	-2.40
50 mg l^{-1}	6731.6 a	72.36 a	5132.6 b	71.29 a	4862.0 a	65.14 ab	-23.75	-1.48	-5.27	-8.63
75 mg l^{-1}	5943.0 c	66.50 e	4854.6 c	67.01 bc	4102.6 c	61.99 c	-18.31	0.77	-15.49	-7.49
100 mg l^{-1}	5205.0 d	67.45 d	4162.0 d	66.49 c	3849.8 d	61.07 cd	-20.04	-1.42	-7.50	-8.15
Mean	6200.6	69.716	4994.3	68.196	4474.8	63.672	-19.43	-2.13	-10.32	-6.62
$LSD_{0,05}$	139	0.603	222	1.841	155	1.108	-	-	-	-

Ir. L.: Irrigation level, T.Y.:Total Yield, Ch.: Chlorophyll (SPAD), Chan.: Change

Effect of Ag-NPs on the Brix and chlorophyll content of tomato under drought stress is shown in Table 2. Considering the averages of the brix values of the tomato genotype in the study, AgNPs and 100%, 50% and 25% irrigation applications, respectively; Considering the averages of 6.412, 6.838 and 7.108 and % change, it was determined as 6.65 in 50% irrigation and 7.1 in 25% irrigation. Accordingly, as the stress increased, the brix values increased due to the increase in the amount of lots of lots. It is given in Table 2 that different Ag-NPs and drought stress applications are affected by the tomato genotype according to their own controls. Considering the average values, an increase is observed in 50% and 25% irrigation applications compared to brix 's own controls. When we look at the data in Table 2 the brix values in drought stress reached 6.92 in Ag-NPs 50 mg l^{-1}+50% irrigation and 7.19 in Ag-NPs 50 mg l^{-1} +25% irrigation in tomato juice. In general, the brix value increases when the plants are under drought stress. The amount of Water-Soluble Dry Matter (brix) was determined between 4 and 6 in tomato fruit (Cramer et al., 2001). Changes in the components of TSS were observed in the glucose / fructose ratio and organic acids after tomato harvest (Javanmardi & Kubota, 2006).

Considering the averages of the green parts dry weight values of the tomato genotype in the study, AgNPs and 100%, 50% and 25% irrigation applications, respectively; Considering the averages of 11.41%, 9.20% and 8.25% and % change, it was determined as -19.30% in 50% irrigation and -10.40% in 25% irrigation. It is given in Table 2 that different Ag-NPs and drought stress applications are affected by the green part dry weight values of the tomato genotype compared to their own controls. According to this, when the average values are examined, it is seen that the dry weight values of green parts decrease in 50% and 25% irrigation applications compared to their own controls. Looking at the data in Table 2, the dry weight values of green parts under drought stress are the highest in 100% irrigation Ag-NPs 50 mg l^{-1} 12.67%, Ag-NPs 0 mg l^{-1}+50% irrigation 10.21% and Ag-NPs 0 mg l^{-1} +25% 9.30% irrigation values. dry weight of green parts in tomato juice reached. In addition, the lowest value among the applications was determined as 100 mg l^{-1}10.32% in 100% irrigation, Ag-NPs100 mg l^{-1} +50% irrigation 8.35% and Ag-NPs100 mg l^{-1} +25% irrigation 7.34%. In general, when the plants are under drought stress, the water use efficiency value decreases.

Table 2. Effect of Ag-NPs on the Brix and dry weight of tomato under drought stress
Çizelge 2. Ag-NPs'lerin kuraklık stresi altındaki domatesin Brix ve kuru ağırlığına etkisi

Treatment	100% Ir. L. (BRIX)	100% Ir. L. (DW)	50% Ir. L. (BRIX)	50% Ir. L. (DW)	25% Ir. L. (BRIX)	25% Ir. L. (DW)	50% Chan. (BRIX)	50% Chan. (DW)	25% Chan. (BRIX)	25% Chan. (DW)
Control	6.45 a	11.98 b	6.88 ab	10.21 a	7.14 ab	9.30 a	6.67	-14.77	3.78	-8.91
25 mg l^{-1}	6.35 a	11.53 b	6.90 a	9.39 b	7.09 bc	8.56 b	8.66	-18.56	2.75	-8.84
50 mg l^{-1}	6.47 a	12.67 a	6.92 a	9.57 b	7.19 a	8.35 c	6.96	-24.47	3.90	-12.75
75 mg l^{-1}	6.30 a	10.56 c	6.70 b	8.49 c	7.15 ab	7.69 d	6.35	-19.60	6.72	-9.42
100 mg l^{-1}	6.49 a	10.32 c	6.79 ab	8.35 c	6.97 c	7.34 e	4.62	-19.09	2.65	-12.10
Mean	6.412	11.41	6.838	9.20	7.108	8.25	6.65	-19.30	3.96	-10.40
$LSD_{0,05}$	0.309	0.545	0.178	0.483	0.083	0.197	-	-	-	-

Ir. L.: Irrigation level, DW: Dry weight, Chan.: Change

Membrane damage index Ag-NPs+50 stress was most affected by Ag-NPs+ 25 stress Ag-NPs 75 mg l^{-1} and Ag-NPs 100 mg l^{-1} (22.26%) and (38.36%) respectively. In addition, control and Ag-NPs 50 mg l^{-1} + 25% stress (17.86%) and (31.85%) were recorded, respectively, in the environments of Ag-NPs + 50% stress and Ag-NPs + 25% stress, respectively (Table 3). However, drought stress caused damage to cells in all applications. It is known to reduce photosynthesis by decreasing the photosynthetic rate per Memberan damage index. In both stress and AgNPs conditions, plants take different measures to protect their water content, and these measures lead to changes in their morphology. Reducing the defense mechanisms created to protect the intracellular water balance (Dasgan et al., 2018). Ag-NPs are known to be absorbed by plants and interact with intracellular parts causing water imbalances, cell damage and decreased photosynthesis have been detected (Kumari et al., 2009; Qian et al., 2013).

Table 3. Effect of Ag-NPs on membrane damage index content under drought strees
Çizelge 3. Ag-NPs'lerin kuraklık stresi altında membran hasar indeksi içeriğine etkisi

Treatment	50% Ir. L.	25% Ir. L.
Control	17.86 c	33.84 bc
25 mg l^{-1}	18.44 c	34.35 b
50 mg l^{-1}	18.08 c	31.85 c
75 mg l^{-1}	22.26 a	38.24 a
100 mg l^{-1}	20.54 b	38.36 a
Mean	19.44	35.33
$LSD_{0,05}$	1.445	2.088

Ir. L.: Irrigation level

Considering the averages of the water use efficiency values of the tomato genotype in the study, Ag-NPs and 100%, 50% and 25% irrigation applications, respectively; Considering 19.90 (g l^{-1}), 24.39 (g l^{-1}) and 33.65 (g l^{-1}) and % change averages, it was determined as 22.46% in 50% irrigation and 38.73% in 25% irrigation. It is given in Table 4 that different Ag-NPs and drought stress applications are affected by the water use efficiency values of the tomato genotype according to their own controls. Considering the average values, it is seen that the water use efficiency values increase in 50% and 25% irrigation applications compared to their own controls. When we look at the data in Table 4, the water use efficiency values in drought stress are the highest in terms of Ag-NPs 29.47 (g l^{-1}) in 100 mg l^{-1}+50% irrigation and 39.80 (g l^{-1}) in Ag-NPs 100 mg l^{-1} +25% irrigation. utilization efficiency. In general, when the plants are under drought stress, the water use efficiency value increases. According to previous studies, Cahn et al. (2001) recommended deficit irrigation up to 70-85% of total patients as a compromise between tomato yield and quality, while Patane et al. (2011) recommended 50% of total patients during the entire growing season. They suggest incomplete irrigation, water saving, water use efficiency increase and tomato fruit quality as a balance between the determined.

In both applications, there was a decrease in the leaf relative water content of the leaves under Ag-NPs+ stress (50% and 25%) conditions. However, this decrease showed differences between Ag-NPs+ stress (Table 4). It was determined as 1+50% stress (64.31%). Between 50% and 25% applications of Ag-NPs, the water losses decreased between -31.41% and -37.81% compared to the control. However, Ag-NPs + control drought stress caused damage to cells at varying rates in all genotypes. Leaf relative water content value, which is one of the most effective parameters that can be used to screen plants for drought tolerance, can also be considered as a value showing the balance between transpiration rate and water supplied to the leaf. Due to this effect, the more water the plant can provide, the more it can save itself from stress (Dixit et al., 2001). Okunlola et al. (2017) state that leaf relative water content is an important indicator in determining drought tolerance, and a decrease in leaf proportional water content values occurs with drought stress.

Table 4. The effect of Ag-NPs on water use efficiency and leaf relative water content under drought stress

Çizelge 4. Ag-NPs'lerin kuraklık stresi altında su kullanım etkinliği ve yaprak nispi su içeriği üzerindeki etkisi

Treatment	100% Ir. L. (Wa. us. eff.)	100% Ir. L. (Le. rel. Wa. Con.)	50% Ir. L. (Wa. us. eff.)	50% Ir. L. (Le. rel. Wa. Con.)	25% Ir. L. (Wa. us. eff.)	25% Ir. L. (Le. rel. Wa. Con.)	50% Chan. Wa. us. eff.)	50% Chan. Le. rel. Wa. Con.)	25% Chan. Wa. us. eff.)	25% Chan. Le. rel. Wa. Con.)
Control	20.43a	81.31 ab	20.42 d	56.79 c	31.82 c	38.03 a	-0.05	-30.16	55.83	-33.03
25 mg l^{-1}	18.76b	81.27 b	23.48 c	62.39 b	28.56d	33.90 c	25.16	-23.23	21.64	-45.66
50 mg l^{-1}	18.38b	82.98 a	22.04cd	64.31 a	31.92 c	35.88 b	19.91	-22.50	44.83	-44.21
75 mg l^{-1}	21.15a	82.00 ab	26.52 b	58.36 c	36.15b	36.34 b	25.39	-28.83	36.31	-37.73
100 mg l^{-1}	20.77a	77.15 c	29.47 a	36.76 d	39.80a	26.31 d	41.89	-52.35	35.05	-28.43
Mean	19.90	80.94	24.39	55.72	33.65	34.09	22.46	-31.41	38.73	-37.81
$LSD_{0,05}$	1.481	1.662	1.853	1.795	1.802	0.743	-	-	-	-

Ir. L.: Irrigation level, Wa. us. eff.: Water use efficiency, Le. rel. Wa. Con.: leaf relative water content, Chan. : Change

Considering the average potassium (K) values of the green parts of the tomato genotype in the study, Ag-NPs and 100%, 50% and 25% irrigation applications, respectively; 7.008 (%), 6.594 (%) and 4.882 (%) and their % change averages were determined as -3.56% in 50% irrigation and -26.16% in 25% irrigation. It is given in Table 5 that different Ag-NPs and drought stress applications are affected by K in the green parts of tomato genotype according to their own controls. According to this, when the average values are examined, it is seen that the K in green parts decreases by -3,56% on average in 50% irrigation application compared to its own controls, and it decreases by -26.16% on average in green parts in 25% irrigation application (Table 5). Looking at the data in Table 5, K Ag-NPs in 50 mg l^{-1}+50% irrigation 7.48 (%) and Ag-NPs in 25 mg l^{-1} +25% irrigation 5.64 (%) in average green parts under drought stress reached the highest K in tomato green parts. In addition, the lowest value in both applications was Ag-NPs 5.45 (%) in 100 mg l^{-1}+50% irrigation and 3.68 (%) in Ag-NPs 100 mg l^{-1} +25% irrigation. Considering the averages of K values in tomato fruit of the tomato genotype in the study, Ag-NPs and 100%, 50% and 25% irrigation applications, respectively; Considering the 9.66 (%), 7.01(%) and 6.71 (%) and % change averages, it was determined as -27,46% in 50% irrigation and -4,20% in 25% irrigation. It is given in Table 5 that different Ag-NPs and drought stress applications are affected by K in tomato genotypes compared to their own controls. According to this, when the average values are examined, it is seen that the K in tomato fruit decreases by -27.46% in 50% irrigation application compared to its own controls, and it decreases by -4.20% in average of K in tomato fruit in 25% irrigation application (Table 5). When we look at the data in Table 5, K in the average tomato fruit under drought stress is K

Ag-NPs 7.62 (%) in 25 mg l^{-1}+50% irrigation and 7.70 (%) in Ag-NPs 25 mg l^{-1} +25% irrigation. reached. In addition, the lowest value in both applications was 5.96 (%) for Ag-NPs 75 mg l^{-1}+50% irrigation and 6.04 (%) for Ag-NPs 100 mg l^{-1} +25% irrigation. One of the osmotic adaptation mechanisms is the accumulation of K with active absorption, increasing the osmotic potential in the cell and ensuring the intracellular water balance (Jaleel et al., 2007; Dasgan et al., 2018). In addition, one of the most important factors that negatively affect plant growth and development is the disruptions in the ion balance. Dasgan et al. (2018), on the other hand, stated that K^+ ion uptake was limited due to salt and drought stress in their study on tomatoes.

Table 5. Effect of Ag-NPs on potassium (K) content in green parts and fruit under drought stress

Çizelge 5. Ag-NPs'lerin kuraklık stresi altındaki yeşil kısımlarda ve meyvelerde potasyum (K) içeriğine etkisi

Treatment	100% Ir. L. (Gre. pa.)	100% Ir. L. (Fr.)	50% Ir. L. (Gre. pa.)	50% Ir. L. (Fr.)	25% Ir. L. (Gre. pa.)	25% Ir. L. (Fr.)	50% Chan. (Gre. pa.)	50% Chan. (Fr.)	25% Chan. (Gre. pa.)	25% Chan. (Fr.)
Control	8.64 a	9.45 b	6.33 bc	6.84 ab	5.01 ab	5.91 b	-26.74	-27.62	-20.85	-13.60
25 mg l^{-1}	5.38 c	9.77 ab	6.86 ab	7.62 a	5.64 a	7.70 a	27.51	-22.01	-17.78	1.05
50 mg l^{-1}	7.48 b	9.99 a	7.48 a	7.59 a	5.55 a	7.49 a	0.00	-24.02	-25.80	-1.32
75 mg l^{-1}	6.87 b	9.44 b	6.85 ab	5.96 b	4.53 bc	6.41 ab	-0.29	-36.86	-33.87	7.55
100 mg l^{-1}	6.67 b	9.67 ab	5.45 c	7.08 ab	3.68 cd	6.04 ab	-18.29	-26.78	-32.48	-14.69
Mean	7.008	9.664	6.594	7.018	4.882	6.71	-3.56	-27.46	-26.16	-4.20
$LSD_{0,05}$	0.840	0.357	1.046	1.517	0.623	1.277	-	-	-	-

Ir. L.: irrigation level, Gre. par.: Green parts, Fr.:Fruit, Chan.:Change

Considering the averages of Calcium (Ca) values in the green parts of the tomato genotype in the study, Ag-NPs and 100%, 50% and 25% irrigation applications, respectively; 24.56 (%), 9.86 (%) and 4.97(%) and the % change averages were determined as -59.73% in 50% irrigation and -50.00% in 25% irrigation. It is given in Table 6 that different Ag-NPs and drought stress applications are affected by Ca in green parts of tomato genotype compared to their own controls. Looking at the average values, it is seen that the Ca in the green parts decreases by an average of -59.73% in 50% irrigation application compared to their own controls, and the Ca in the green parts decreases by -50.00% in 25% irrigation application (Table 6). Looking at the data in Table 6, Ca in the average green parts under drought stress was 12.19 (%) in control + 50% irrigation, and Ca in tomato green parts was the highest in terms of Ag-NPs 50 mg l-1 +25% irrigation 7.23 (%). In addition, the lowest value in both applications was 7.78 (%) for Ag-NPs 100 mg l-1+50% irrigation and 2.87 (%) for Ag-NPs 100 mg l-1 +25% irrigation. Considering the averages of Ca values in tomato fruit of the tomato genotype in the study, Ag-NPs and 100%, 50% and 25% irrigation applications, respectively; 30.60 (%), 14.83 (%) and 6.65 (%) and % change averages were determined as -51.47% in 50% irrigation and -54.26% in 25% irrigation. It is given in Table 6 that different Ag-NPs and drought stress applications are affected by Ca in tomato fruit of tomato genotype compared to their own controls. According to this, when the average values are examined, it is seen that the Ca in tomato fruit decreases by an average of -51.47% in 50% irrigation application compared to its own controls, and the Ca in tomato fruit decreases by an average of -54.26% in 25% irrigation application (Table 6). Average tomato fruit under drought stress reached 16.88 (%) at 25 mg l-1+50% irrigation and Ag-NPs reached 8.47 (%) at 75 mg l-1 +25% irrigation. In addition, the lowest value of Ag-NPs in both applications reached 13.02 (%) in 75 mg l-1+50% irrigation and 4.64 (%) in control +25% irrigation. Drought stress caused a decrease in the green part Ca+2 concentration of tomato plant. The lack of water causes a decrease in the flow of nutrients to other tissues and organs, starting from the stem cells, thus causing nutrient deficiencies in different tissues.

Table 6. Effect of Ag-NPs on calcium (Ca) content in green parts and fruit under drought stress
Çizelge 6. Ag-NPs'lerin kuraklık stresi altında yeşil kısımlarda ve meyvelerde kalsiyum (Ca) içeriğine etkisi

Treatment	100% Ir. L. (Gre. pa.)	100% Ir. L. (Fr.)	50% Ir. L. (Gre. pa.)	50% Ir. L. (Fr.)	25% Ir. L. (Gre. pa.)	25% Ir. L. (Fr.)	50% Chan. (Gre. pa.)	50% Chan. (Fr.)	25% Chan. (Gre. pa.)	25% Chan. (Fr.)
Control	26.82 a	32.39 ab	12.19 a	15.15 ab	5.24 b	4.64 b	-54.55	-53.23	-57.01	-69.37
25 mg l^{-1}	24.37 ab	34.65 a	9.91 b	16.88 a	4.63 bc	5.56 b	-59.34	-51.28	-53.28	-67.06
50 mg l^{-1}	29.5 a	30.03 bc	10.63 a	14.80 ab	7.23 a	8.38 a	-63.97	-50.72	-31.98	-43.38
75 mg l^{-1}	23.44 ab	28.55 c	8.81 bc	13.02 b	4.88 b	8.47 a	-62.41	-54.40	-44.61	-34.95
100 mg l^{-1}	18.7 b	27.37 c	7.78 c	14.31 ab	2.87 d	6.22ab	-58.40	-47.72	-63.11	-56.53
Mean	24.56	30.60	9.86	14.83	4.97	6.65	-59.73	-51.47	-50.00	-54.26
$LSD_{0,05}$	7.181	2.662	1.863	2.615	1.432	2.259	-	-	-	-

Ir. L.: irrigation level, Gre. par.: Green parts, Fr.:Fruit, Chan.:Change

Considering the averages of vitamin C values in fruit juice of the tomato genotype in the study, Ag-NPs and 100%, 50% and 25% irrigation applications, respectively; 21.14 (mg/100 g), 23.84 (mg/100 g) and 25.42 (mg/100 g) and % change averages were determined as -13.10 in 50% irrigation and 6.65 in 25% irrigation. It is given in Table 7 that different Ag-NPs and drought stress applications are affected by tomato genotype vitamin C in Fruit Juice compared to their own controls. Accordingly, when the average values are examined, it is seen that in 50% irrigation application, vitamin C in Fruit Juice increased by 13.10% on average compared to its own controls, and in 25% irrigation application, it increased by 6.65% on average in fruit juice (Table 7). As seen in Table 7, The highest vitamin C, Ag-NP values under drought stress were in 75 mg l^{-1}+50% irrigation 24.93 (%) and Ag-NPs 75 mg l^{-1} + 25% irrigation 25.78 (%) in tomato juice. In addition, the lowest value of Ag-NPs in both applications was 22.93 (%) in 50 mg l^{-1}+50% irrigation and 24.63 (%) in control +25% irrigation. Exposure of the sunflower plant to 150 mg kg^{-1} Ag-NPs and Ag+ caused a significant increase in vitamin C. Accordingly, Ag-NPs were determined to be higher than normal Ag and vitamin C compared to the control (Ag-NPs > Ag + > control), (Shimada et al., 2008). Considering the average values of tomato Lycopene content of the tomato genotype in the study, Ag-NPs and 100%, 50% and 25% irrigation applications, respectively; 31.72 (mg g^{-1}), 31.72 (mg g^{-1}) and 32.86 (mg g^{-1}) and % change averages were determined as 0.89 at 50% irrigation and 3.47 at 25% irrigation. It is given in Table 7 that different Ag-NPs and drought stress applications are affected by tomato genotype, tomato Lycopene content values according to their own controls. Accordingly, when the average values are examined, it is seen that the values of the Lycopene content of tomatoes in 50% irrigation application increase by 0.89% on average compared to their own controls, the average of the values of Lycopene content of tomatoes in 25% irrigation application increases by 3.47% (Table 7). When we look at the data in Table 7, the average values of Lycopene content of tomatoes under drought stress are 33.43 (mg g^{-1}) in 25 mg l^{-1}+50% irrigation and 35.38 (mg g^{-1}) Ag-NPs in 25 mg l^{-1} +25% irrigation. The highest tomatoes reached the values of Lycopene content in tomatoes. In addition, the lowest value in both applications was 28.63 (mg g^{-1}) for Ag-NPs at 100 mg l^{-1}+50% irrigation and 28.46 (mg g^{-1}) for Ag-NPs at 100 mg l^{-1}+25% irrigation. Nair and Chung showed different responses of total chlorophyll and carotenoids at significantly different doses in rice (*Oryza sativa* L.) seedlings after exposure to Ag-NPs for one week (Nair & Chung, 2014). In addition, ascorbic acid, carotenoids and other antioxidants play a role in the antioxidant defense responses of plants to Ag-NPs (Chew & Park, 2004; He et al., 2011).

Table 7. Effect of Ag-NPs on vitamin C and lycopene content under drought stress
Çizelge 7. Ag-NPs'lerin kuraklık stresi altında C vitamini ve likopen içeriğine etkisi

Treatment	100% Ir. L. (Vit. C)	100% Ir. L. (Ly. Con.)	50% Ir. L. (Vit. C)	50% Ir. L. (Ly. Con.)	25% Ir. L. (Vit. C)	25% Ir. L. (Ly. Con.)	50% Chan. (Vit. C)	50% Chan. (Ly. Con.)	25% Chan. (Vit. C)	25% Chan. (Ly. Con.)
Control	21.56 b	31.52 c	23.72b	32.92a	24.63b	34.64 ab	10.02	4.44	3.84	5.22
25 mg l^{-1}	20.71 c	33.16 a	23.96b	33.43a	25.67a	35.38 a	15.69	0.81	7.14	5.83
50 mg l^{-1}	22.61 a	32.46 b	22.93 c	32.21b	24.65b	33.52 bc	1.42	-0.77	7.50	4.07
75 mg l^{-1}	20.09 c	30.50 d	24.93 a	31.41 c	25.78a	32.29 c	24.09	2.98	3.41	2.80
100 mg l^{-1}	20.71 c	29.52 e	23.67b	28.63d	26.36a	28.46 d	14.29	-3.01	11.36	-0.59
Mean	21.14	31.43	23.84	31.72	25.42	32.86	13.10	0.89	6.65	3.47
$LSD_{0,05}$	0.652	0.550	0.300	0.703	0.978	1.288	-	-	-	-

Ir. L.: irrigation level, Vit. C: Vitamin C, Ly. Con.: Lycopene content, Chan.:Change

According to the findings of the experiment, Ag-NPs applications applied to the Fereng tomato genotype under different drought stress levels had statistically different effects on the tomato plant. Ag-NPs 50 mg l^{-1} application applied in the experiment was found to be more effective than other applications in protecting tomato plants against the negativities caused by drought stress. Ag-NPs 100 mg l^{-1} application caused toxic effects on plants. Ag-NPs have different effects in plants at each concentration. As their concentration increases, they affect the intake of nutrients. Ag-NPs are also known to have biochemical effects on the growth of roots and shoots in plants. It has been concluded that the data obtained as a result of the study will contribute significantly to breeders and researchers in arid and semi-arid regions.

ACKNOWLEDGEMENTS
We would like to thank Sırnak University for the financial support of the project numbered 2019.FNAP.13.01.01).

STATEMENT OF CONFLICT OF INTEREST
The authors of the article declare that there is no conflict of interest between them.

AUTHOR'S CONTRIBUTIONS
The authors declare that they have contributed equally to the article.

STATEMENT OF ETHICS CONSENT
Ethical approval is not required as there are no studies with human or animal subjects in this article.

REFERENCES

Akhoundnejad, Y. (2020). Response of certain tomato (*Solanum lycopersicum*) genotypes to drought stress in terms of yield and quality in Sırnak. *Internatioanl Journal of Agriculture Environment and Food Sciences, 4* (1), 107-113. https://doi.org/10.31015/jaefs.2020.1.12

Akhoundnejad, Y., & Dasgan, H.Y. (2020). Photosynthesis, transpiration, stomatal conductance of some melon (*Cucumıs melo* L.) genotypes under different drought stress. *Fresenius Environmental Bulletin, 12*, 10974-10979.

Akhoundnejad, Y., & Karakas, O. (2021). Responses of *Allium cepa* L. exposed to silver nanoparticles. *International Journal of Agriculture Environment and Food Sciences, 3,* 599-605. https://doi.org/10.31015/jaefs.2021.4.20

Akhoundnejad, Y., Daşgan, H.Y., Aydoner Çoban G., Bol, A., & Ünlü, M. (2012). Kuraklığa tolerant bazı domates genotiplerinin arazi performanslarının belirlenmesi. *9. Ulusal Sebze Sempozyumu,* 433-437.

Akhoundnejad, Y., Karakas, O., & Demirci, O. (2022). Response of Lettuce to Silver Nanoparticles Under Drought Conditions. *Iranian Journal of Science and Technology, Transactions A: Science, 46,* 111-120. https://doi.org/10.1007/s40995-021-01241-x(

Birgin, O., Akhoundnejad, Y., & Dasgan, H.Y. (2021). The effect of foliar calcium application in tomato (*Solanum lycopersicum* L.) under drought stress in greenhouse conditions. *Applied Ecology And Environmental Research, 19* (4), 2971-2982. https://doi.org/10.15666/aeer/1904_29712982

Cahn, M.D., Herrero, E.V., Snyder, R.L., & Hanson, B.R. (2001). Water management strategies for improving fruit quality of drip irrigated processing tomatoes. *Acta Horticulturae, 542,* 111-117. https://doi.org/10.17660/ActaHortic.2001.542.13

Chew, B.P., & Park, J.S. (2004). Carotenoid action on the immune response. *The Journal of Nutrition, 134* (1), 257S-261S. https://doi.org/10.1093/jn/134.1.257S.

Cıracı, S., Ozbay, E., Gulseren, O., Demir, H.V., Bayındır, M., Oral, A., Senger, T., Aydınlı, A., & Dana, A. (2005). Nanotechnology in Turkey. TUBITAK Journal of Science and Technology.

Cramer, M.D., Oberholzer, J.A., & Combrink, N.J. (2001). The effect of supplementation of root zone dissolved inorganic carbon on fruit yield and quality of tomatoes (cv 'Daniela') grown with salinity. *Scientia Horticulturae, 89*, 269-289. https://doi.org/10.1016/S0304-4238(00)00243-0

Cruz de Carvalho, M.H. (2008). Drought stress and reactive oxygen species: production, scavenging and signaling. *Plant Signaling & Behavior, 3,* 156-165. https://doi.org/10.4161/psb.3.3.5536.

Dakal, T.C., Kumar, A., Majumdar, R.S., & Yadav, V. (2016). Mechanistic basis of antimicrobial actions of silver nanoparticles. *Frontiers in Microbiology, 7,* 1831. https://doi.org/10.3389/fmicb.2016.01831

Dasgan, H.Y., Bayram, M., Kusvuran, S., Coban, G., & Akhoundnejad, Y. (2018). Screening of tomatoes for their resistance to salinity and drought stress. *Journal of Biology, Agriculture and Healthcare, 8*, 31-37.

Dixit, V., Pandey, V., & Shyam, R. (2001). Differential antioxidative responses to cadmium in roots and leaves of pea (*Pisum sativum* L.cv. Azad). *Journal of Experimental Botany, 52* (358), 1101-1109. https://doi.org/10.1093/jexbot/52.358.1101

Du, Y.Y., Wang, P.C., Chen, J., & Song, C.P. (2008). Comprehensive functional analysis of thecatalase gene family in Arabidopsis thaliana. *Journal of Integrative Plant Biology, 50*, 1318-1326. https://doi.org/10. 1111/j.1744-7909.2008.00741.x

Farooq, M., Wahid, A., Kobayashi, N., Fujita, D., & Basra, S.M.A. (2009). Plant drought stress: effects, mechanisms and management. *Agronomy for Sustainable Development, 29*, 185-212. https://doi.org/10.1051/agro:2008021

Firdhouse, M.J., & Lalitha, P. (2015). Biosynthesis of silver nanoparticles and its applications. *Journal of Nanotechnology,* Article ID 829526. https://doi.org/10.1155/2015/829526

Graf, C., Vossen, D.L., Imhof, A., & Blaaderen, A. (2003). A general method to coat colloidal particles with silica. *Langmuir, 19*, 6693-6700. https://doi.org/10.1021/la0347859

He, D., Jones, A.M., Garg, S., Pham, A.N., & Waite, T.D. (2011). Silver nanoparticle–reactive oxygen species interactions: Application of a charging-discharging model. *The Journal of Physical Chemistry C, 115*, 5461-5468. https://doi.org/10.1021/jp111275a

Jaleel, C.A., Manivannan, P., Sankar, B., Kishorekumar A., Gopi R., Somasundaram, R., & Panneerselvam, R. (2007). Water deficit stress mitigation by calcium chloride ın catharanthus roseus. effects on oxidative stress, proline metabolism and ındole alkaloid accumulation. *Biointerfaces, 60*, 110-116. https://doi.org/10.1016/j.colsurfb.2007.06.006.

Javanmardi, J., & Kubota, C. (2006). Variation of lycopene, antioxidant activity, total soluble solids and weight loss of tomato during postharvest storage. *Postharvest Biology and Technology, 41*, 151-5. https://doi.org/10.1016/j.postharvbio.2006.03.008

Kim, Y.K., Lee, Y.S., Jeong, D.H., & Cho, M.H. (2007). Antimicrobial effect of silver nanoparticles. *Nanomedicine, 3* (1), 95-101. https://doi.org/10.1016/j.nano.2006.12.001

Kumari, M., Mukherjee, A., & Chandrasekaran, N. (2009). Genotoxicity of silver nanoparticles in *Allium cepa*. *Science Total Environment, 407*, 5243-5246. https://doi.org/10.1016/j.scitotenv.2009.06.024

Laxa, M., Liebthal, M., Telman, W., Chibani, K., & Dietz, K.J. (2019). The role of the plant antioxidant system in drought tolerance. *Antioxidants, 8*, 94. https://doi.org/10.3390/antiox8040094

Lee, W.M., Kwak, J.I., & An, Y.J. (2012). Effect of silver nanoparticles in crop plants *Phaseolus radiatus* and *Sorghum bicolor*: media effect on phytotoxicity. *Chemosphere, 86*, 491-499. https://doi.org/10.1016/j.chemosphere.2011.10.013

Levard, C., Hotze, E.M., Lowry, G.V., & Brown, G.E. Jr.(2012). Environmental transformations of silver nanoparticles: impact on stability and toxicity. *Environmental Science & Technology, 46* (13), 6900-6914. https://doi.org/10.1021/es2037405

Martí, R., Roselló, S., & Cebolla-Cornejo, J. (2016). Tomato as a source of carotenoids and polyphenols targeted to cancer prevention. *Cancers (Basel), 8*, E58. https://doi.org/10.3390/cancers8060058.

Nair, P.M.G., & Chung, I.M. (2014). Physiological and molecular level effects of silver nanoparticles exposure in rice (*Oryza sativa* L.) seedlings. *Chemosphere, 112*, 105-113. https://doi.org/10.1016/j.chemosphere.2014.03.056

Oberdörster, G., Oberdörster, E., & Oberdörster, J. (2005). Nanotoxicology: An emerging discipline evolving from studies of ultrafine particles. *Environmental Health Perspectives, 113*, 823-839. https://doi.org/10.1289/ehp.7339.

Okunlola, G.O., Olatunji, O.A., Akinwale, R.O., Tariq, A., & Adelusi, A.A. (2017). Physiological response of the three most cultivated pepper species (*Capsicum* spp.) in Africa to drought stress imposed at three stages of growth and development. *Scientia Horticulturae, 224*, 198-205. https://doi.org/10.1016/j.scienta.2017.06.020

Ortiz, N., Armada, E., Duque, E., Rolda´n, A., & Azco´n, R. (2015). Contribution of arbuscular mycorrhizal fungi and/or bacteria to enhancing plant drought tolerance under natural soil conditions: effectiveness of autochthonous or allochthonous strains. *Journal of Plant Physiology, 174*, 87-96. https://doi.org/10.1016/j.jplph.2-014.08.019

Özdemir, E., & Dündar, Ö. (2001). Effect of Different Postharvest Application on Storage of Kozan and Valencia Late Oranges. *Acta Horticulturae*, *553*, 561–564.

Patane, C., Tringali, S., & Sortino, O. (2011). Effects of deficit irrigation on biomass,yield, water productivity and fruit quality of processing tomato undersemi-arid Mediterranean climate conditions. *Scientia Horticulturae, 129,* 590-596. https://doi.org/10.1016/j.scienta.2011.04.030

Qian, H., Peng, X., Han, X., Ren, J., Sun, L., & Zhengwei, F. (2013). Comparison of the toxicity of silver nanoparticles and silver ions on the growth of terrestrial plant model *Arabidopsis* thaliana. *Journal of Environmental Science, 25*, 1947-1956. https://doi.org/10.1016/s1001-0742(12)60301-5

Quinet, M., Angosto, T., Yuste-Lisbona, F.J., Blanchard-Gros, R., Bigot, S., Martinez, J.P., & Lutts, S. (2019). Tomato fruit development and metabolism. *Frontiers in Plant Science, 10*, 1554. https://doi.org/10.3389/fpls.2019.01554.

Sanchez, F.J., Andres, E.F., Tenorlo, J.L., & Ayerbe, L. (2004). Growth of epicotyls, turgor maintenance and osmotic adjustment in pea plants (*Pisum sativum* L.) subjected to water stres. *Field Crops Research, 86*, 81-90. https://doi.org/10.1016/S0378-4290(03)00121-7

Soylu, S., Kara, M., Türkmen, M., & Şahin, B. (2022). Synergistic effect of *Foeniculum vulgare* essential oil on the antibacterial activities of Ag- and Cu-substituted ZnO nanorods (ZnO-NRs) against food, human and plant pathogenic bacterial disease agents. *Inorganic Chemistry Communications, 146*, 110103. https://doi.org/10.1016/j.inoche.2022.110103

Tegart, G. (2003). Nanotechnology: The technology for the 21th century. *The Second International Conference on Technology Foresight,* Tokyo, 27-28 February, 1-12 pp.

Xu, Z.P., Zeng, Q.P., Lu, G.Q., & Yu, A.B. (2006). Inorganic nanoparticles as carriers for efficient cellular delivery. *Chemical Engineering Science, 61* (3), 1027-1040. https://doi.org/10.1016/j.ces.2005.06.019