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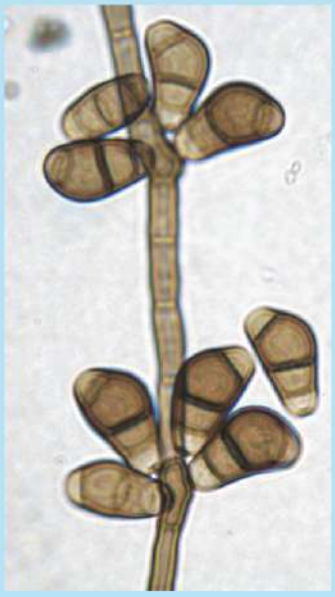

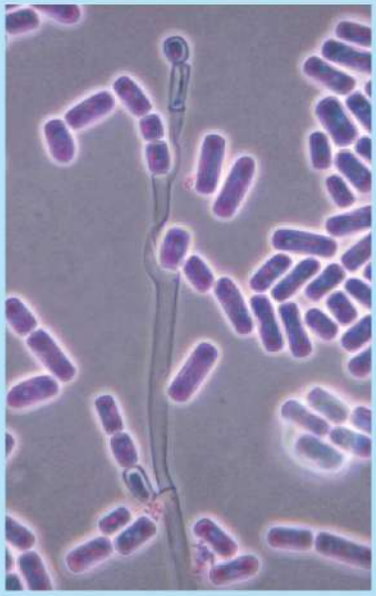

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Synergistic impact of *Alternaria cerealis* infection and salinity stress on some physiological processes of tomato plants (*Solanum lycopersicum* L.)

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Abstract: Plants are often confronted by the combined effects of biotic and abiotic stresses, and their responses vary from those caused by each element separately. Salinity and pathogens are the main stressors that limit plant growth, physiological processes and oxidative damage in cells and organelles. Biotic and abiotic stresses have beneficial and detrimental effects on plant pathogen interactions, thus increasing or decreasing disease severity. In the current study, tomato plants were subjected to biotic (*Alternaria cerealis*) and abiotic stresses (salinity). *Alternaria cerealis* was isolated as a phytopathogic fungus from tomato plants and identified as *A. cerealis* MT808477 in Egypt. The purpose of this research is to focus on the joint response of plants to biotic and abiotic stress. It could be noticed that specific response of tomato plants to the stress of comprehensive salinity- pathogen, which varies with salinity intensity and incubation periods. It is demonstrated for the first time, that salinity stress at certain levels remarkably enhances the effect of concurrent stresses in plants infected with *A. cerealis* and a more dramatic effect on enhancing the redox buffer potential for suppressing *A. cerealis* infection. The results indicated more drastic effect of combined stress on disease severity, improvement of plant tolerance and activation of plant defense compared to the individual stress. In general, the total of flavonoids, terpenoids, total protein, in addition to malondialdehyde (MDA) and hydrogen peroxide (H_2O_2) of the tomato leaves were increased, while catalase (CAT) activity was decreased due to the tested stresses.

Keywords: *Solanum lycopersicum* L., *Salt stress, Alternaria cerealis*, *Antioxidant enzyme*

Introduction

Salinity is one of the main abiotic stress sources that limit crop yields, decline in plant growth, dry matter yield, fruit weight, relative moisture content and threaten global food security. About 20% of cultivated and 50% of irrigated lands have different salinities **(Abogadallah 2010 and Mohamed *et al.* 2018).** Plants are affected by salt stress in many ways, including morphological, physiological, biochemical, and molecular changes **(Abogadallah 2010 and Sarker *et al.* 2018).** Salinity stress interrupts ion homeostasis in plants by causing osmotic pressure and ion toxicity, which causes delaying in shoot and root length, fresh and dry weight, pigment content, and mineral uptake **(Ahmad *et al.* 2014).** These are the primary causes of salt stress's long-term negative effects on plants **(Acosta-Motos *et al.* 2015).** The impact of salt on many agricultural areas around the world with plant pathogens is a good example of abiotic and biotic stress that occur simultaneously in the field and their interaction may seriously affect food quality and safety. Plants are challenged by the combined action of biotic and abiotic stresses, and their response to combined stress is different from the response triggered by each factor alone **(Kissoudis *et al.* 2014)**. Salinity and pathogens are the main stressors that limit plant growth and reducing crop yield. They have a negative impact on plant growth and physiological processes, and their impact involves oxidative damage in cells and organelles **(Shahbaz and Ashraf 2013 and Abid *et al.* 2020).** There is evidence

that plants' physiological responses to abiotic pathogen stress are substantially different than their responses to a singular stress **(Zhang and Sonnewald 2017).** Salinity and pathogenic fungi have been extensively studied as individual stresses, but their combined effects on crops have not been well understood. The synergistic effect indicates that abiotic stress has positive and negative effects on the interaction with plant pathogens by enhancing or reducing the severity of diseases (**Chojak-Koźniewska *et al.* 2018)**. Some studies showed that the plants suffer from biotic and abiotic stress at the same time. A major role in promoting plant diseases thereby enhancing or reducing the severity of the disease and the response to pathogens overlaps with the response to abiotic stress, and reactive oxygen species (ROS) and stress hormones represent central nodes in the interactive signaling pathway **(Luo *et al.* 2005 and Desprez-Loustau *et al.* 2006 and Chojak-Koźniewska *et al.* 2018).** Salinity leads to cause a development of fungal diseases caused by *Oidium neolycopersici* in tomato plants and increases the sensitivity of tomato to *Phytophthora* and *Pseudomonas syringae*, and increases the resistance to *Botrytis cinerea* (**Thaler and Bostock 2004 and Achuo *et al.* 2006).** The increased susceptibility to pathogens under stress may be related to the changed hormonal balance, reduced defense genes expression and to primary metabolism down-regulation which was observed as a general response to multiple stresses **(Mohr and Cahill 2003 and Prasch and Sonnewald 2013).**

Tomato plants are the largest horticultural crop in the world. Their productivity under field conditions is affected by the high incidence of increased soil salinity**.** Although most modern tomato varieties are sensitive to moderate salinity stress, wild tomato species have shown natural variation in salinity tolerance **(Giorgi and Lionello 2008)**. Tomato plants are vulnerable to abiotic stresses such as salt and drought, which have an effect on plant growth and productivity. Plants' ability to generate organic compounds (such as proline and sugar) under saline conditions is critical to their survival **(Latif and Mohamed 2016, Krishna *et al.* 2019, Ma *et al.* 2020 and Sachdev *et al.* 2021)**.

The present study was conducted to investigate the combined effect of *Alternaria cerealis* infection and different concentrations of salinity (NaCl) on physiological traits of tomato plants.

Materials and Methods

Plant material

Tomato (*Solanum lycopersicum* L.) seedlings were kindly provided by Agriculture Research Center, Assiut Governorate, Egypt. On 11 September 2019 the seedlings were planted in sterilized soil (2 kg). *Solanum lycopersicum* (13-day-old) plants grown in a black polyethylene bag (30 cm) with 1K sterilized soil and grown under greenhouse condition: relative humidity (RH, 42-55%), average maximum temperature (T, 35±2ºC) and average minimum temperature (T, 22±2ºC) **(Dhouib *et al.* 2019).** Chemical soil characterization was recorded in ppm as follows: sodium (Na^+, 186.3), potassium (K^+, 46.8), calcium (Ca^{++}, 574), chloride (Cl^-, 887.5), magnesium (Mg^{++}, 344.4 and carbonate (HCO^-, 1525. The physical properties of the soil texture were 56.7% clay, sand 12.4% and silt 30.9%, soil pH 7.11, electrical conductivity (EC) is 2.27 ds/cm.

Preparation of conidial suspensions

Conidial suspension of *Alternaria cerealis* MT808477 was prepared from 7 days old culture grown on PDA. It was firstly isolated from infected tomato plants and maintained on Potato Dextrose Agar (PDA) at 28±2°C. Conidia were adjusted to 10^5/ml using the haemocytometer count technique. Conidial suspension of *Alternaria cerealis* was inoculated to tomato leaves after making deep wounds in tomato plants **(Solino *et al.* 2017).**

Synergistic stress of salinity and *Alternaria cerealis* MT808477

Three different levels of NaCl-salinity (in terms of electrical conductivity) were applied as 2 ds/m, 4 ds/m and 6 ds/m throughout the experiment. The NaCl range was chosen for the evaluation of low to moderate salinity stress on tomato plants. The tomato plants were treated with different levels of NaCl as following: T1) tomato plants were infected only with conidial suspension (10^5conidia/ml) of *A. cerealis*, T2) tomato plants were treated only with NaCl (2 ds/m, 4 ds/m and 6 ds/m), T3) tomato saplings injected with conidial suspension (10^5conidia/ml) of *A. cerealis* and different levels of NaCl-salinity (2 ds/m, 4 ds/m and 6 ds/m), T4) tomato plants without treatment were used as negative control. The plants were collected at intervals 2, 24 and 48 h for further analysis.

Total flavonoid

The concentration of total flavonoids was determined according to the colorimetric method **(Chang *et al.* 2002).** The tomato extract was analyzed independently in triplicate, and the average of the three tests was used and the absorbance was read at 496 nm. Quercetin (0.2-1.0 mg/mL ethanol solution) was used as a standard.

Total terpenoid

Total terpenoid content was carried out by colorimetry according to the method of **Fan and He (2006)**. The terpenoid contents were determined by colorimetric method at 548 nm and were expressed as milligram ursolic acid equivalents (mg ursolic acid/g extract).

Total antioxidants

Total antioxidant activity was determined as described by **Prieto *et al*. (1999**). Solution concentrations used for calibration consist of 50 µl with 3 ml of reagent solution (0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate). The sample was kept in a water bath at 95°C for 90 minutes. Absorption of the samples was measured on the spectrophotometer at 695 nm. The results were expressed as µg g^{-1} protein**.**

Total soluble protein

Total soluble protein content was conducted according to the method described by **Lowry *et al.* (1951).** The absorbance of the supernatant was measured at 750 nm. A standard curve was made using bovine serum albumin.

Lipid peroxidation

Lipid peroxidation was amounted by quantifying malondialdehyde (MDA) content (**Hodges *et al*. 1999).** The level of lipid peroxidation was expressed as nmol g^{-1} FW of MDA formed using an extinction coefficient of 155 mM^{-1} cm^{-1}.

Hydrogen peroxide (H_2O_2)

Hydrogen peroxide content in tomato leaves was determined in accordance with the method of **Velikova *et al.* (2000).** The absorbance of the supernatant was measured at 390 nm. The content of H_2O_2 was calculated by comparison with a standard calibration curve by using different concentrations of H_2O_2 expressed as mg g^{-1} FW.

Catalase (CAT) activity

Catalase (CAT) activity was determined by the reaction medium (3 ml volume) contained 50 mM potassium phosphate buffer (pH 7), 100 µl H_2O_2 (10 mM) and 20 µl of enzyme extract and measuring the decrease in absorbance at 240 nm (DA_{240} mg $protein^{-1}$ min^{-1}) **Aebi (1984).**

Statistical analysis

Statistical analysis was carried using one way analysis of variance (ANOVA), and differences among means were determined at $p \leq 0.05$ by using Duncan's multiple range

tests. SPSS software version 25 was for all statistical calculations.

Results

Total flavonoids

Total flavonoids content of tomato leaves with different salinity levels was determined after 2, 24 and 48 h. As portrayed in **figure (1),** there was an elevation in the total flavonoids content in tomato plants infected with *A. cerealis* after 2 h (83.14 ±3.57 mg/g FW), compared to the control (50.86± 0.22 mg/g FW). Then a decrease in total flavonoids content was observed after the remaining incubation periods (24 & 48 h). Results additionally explained that total flavonoid in plant treated with different levels of salinity stress (2, 4 and 6 ds m^{-1}) was significantly decreased in all treatment periods. On the other hand, the combined stress of *A. cerealis* infection and different levels of salinity showed an increase in total flavonoids content in all concentrations and incubation periods compared to individual stress of either *A. cerealis* or salinity. Statistical analysis showed dramatically increased with increasing the incubation periods in combined stress of *A. cerealis* infection and salinity (2 ds m^{-1}), whereas after 2 and 24 h the total flavonoids content was increased steadily in 4 and 6 ds m^{-1} and decreased after 48 h **(Figure 1).**

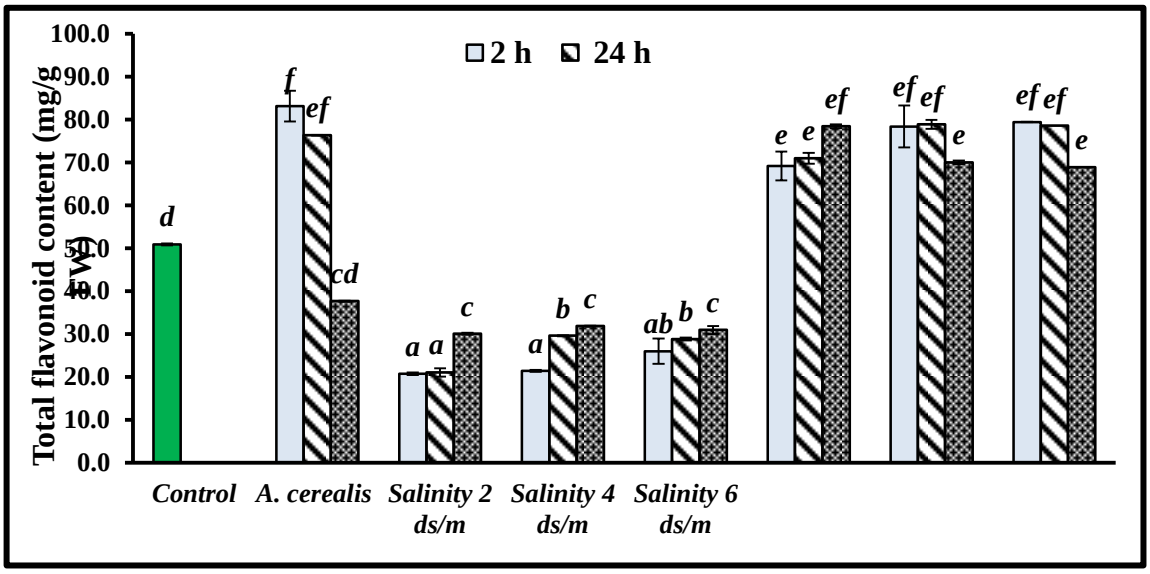

Figure 1: Effect of *Alternaria cerealis* (MT808477) and different salinity levels on total flavonoids content. Data are means ± SD (n = 3) with statistically significant differences (P < 0.05).

Total terpenoids

Results associated with the effects of *A. cerealis* or different salinity levels on the total terpenoids of tomato leaves were depicted in **figure (2)**. There are increasing in total terpenoids contents in tomato plants infected only with *A. cerealis*, 26.65± 2.11 mg/g FW after 24 h, over the control (9.63 ± 0.03 mg/g FW). For instance, salinity treatments showed a noticeable rise in the total terpenoids content by 27.67±1.78 mg/g FW and 38.21±0.51 mg/g FW enhancement relative to the control at 4 ds m^{-1} and 8 ds m^{-1}, respectively, whereas the combined stress of *A. cerealis* infection and different levels of salinity treatments exhibited increase in the total terpenoids content after different infection periods. The highest concentration of total terpenoids was found after 48 h by 36.42 ± 0.10, 36.00± 1.06 and 42.79± 0.12 mg/g FW at 2 ds m^{-1}, 4 ds m^{-1} and 6 ds m^{-1}, respectively.

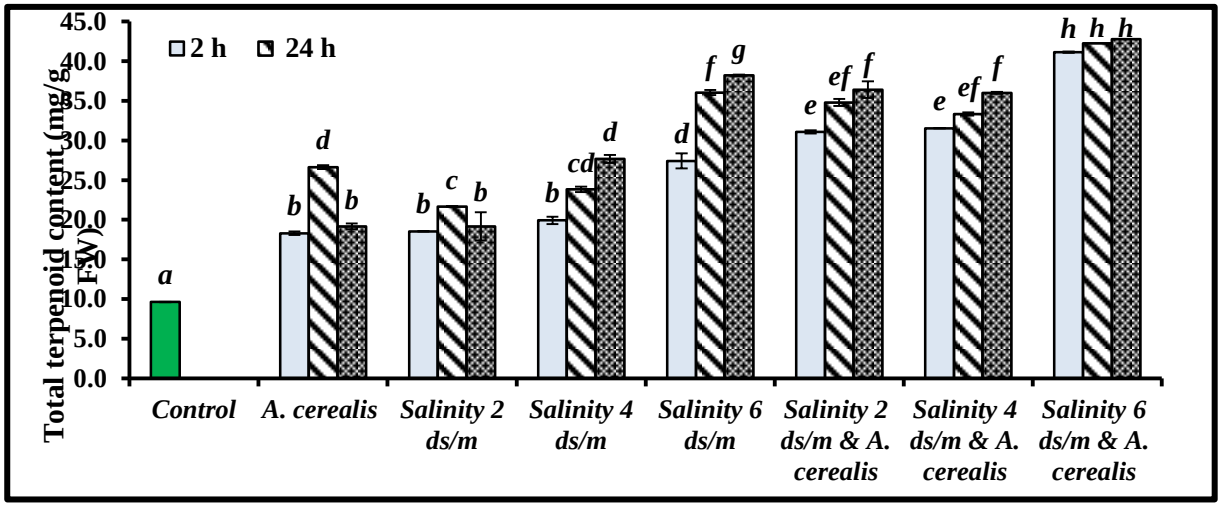

Figure 2: Effect of *Alternaria cerealis* (MT808477) and different salinity levels on total terpenoid content. Data are means ± SD (n = 3) with statistically significant differences ($P < 0.05$).

Total antioxidants

The total antioxidant was determined in tomato plants subjected to *A. cerealis* or different salinity treatments to assess the quantity of ROS scavenged. As shown in **figure (3),** there was an elevation in the total antioxidant content with increasing incubation periods compared to the control, a high significant increase in the total antioxidant content was observed after 2 h (51.05 ± 5.64 mg/g FW). However, plants treated with different levels of salinity stress (2, 4 and 6 ds m^{-1}) were significantly rise in all treatment periods in total antioxidant content in tomato plants by 48.41± 0.00, 46.65± 3.18, 41.07± 4.60 mg/g FW after 2 h, respectively. The data additionally disclosed that there was an increase in total antioxidant content at the combination stress of both *A. cerealis* infection and different levels of salinity after 2 h.

Soluble proteins

Proteins are functionally versatile macromolecules that represent the main workhorses of living cells. Therefore, in this investigation, the result of assorted *A. cerealis* and salinity treatments on the content of soluble proteins in tomato leaves was followed **(Figure 4).** The soluble proteins production was stimulated in tomato leaves with increasing incubation periods (2, 24 and 48 h) in all treatments. The result indicated that the soluble protein contents was significantly increased in infected plants after 24 and 48 h by 15.98 ± 0.39 and 16.05 ± 0.35 mg/g FW, respectively. Similarly, the soluble proteins production was increased significantly in the tomato plants treated with different levels of salinity stress (2, 4 and 6 ds m^{-1}) with increase incubation time. Also, increase in soluble proteins contents in combination of stress *A. cerealis* and different levels of salinity after 48 h was reported.

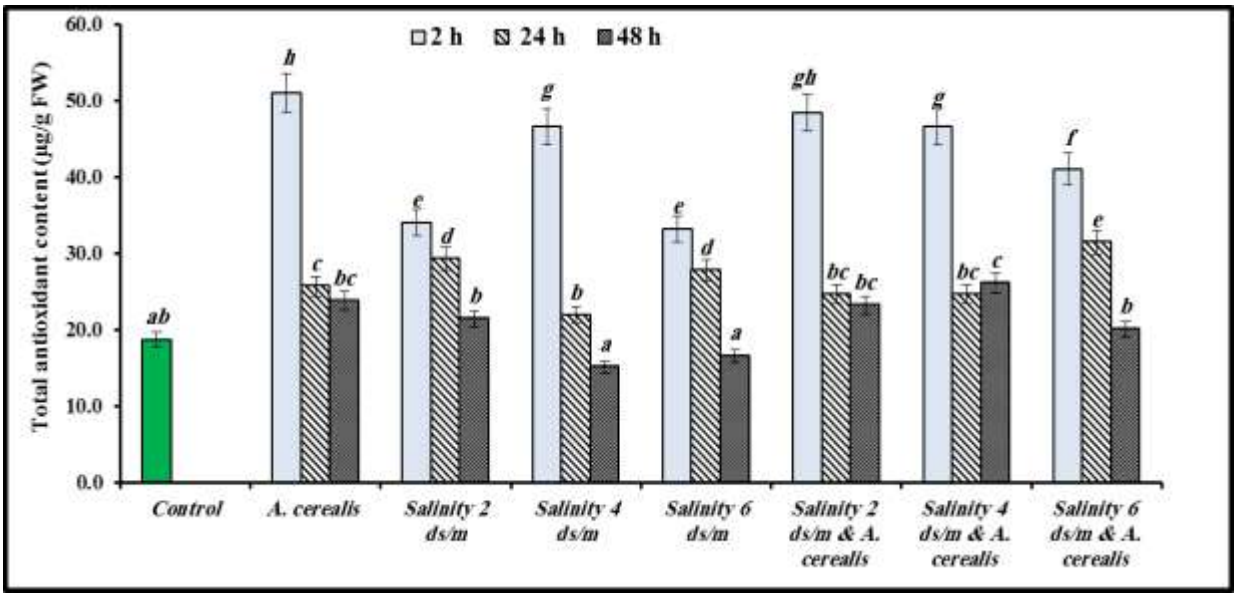

Figure 3: Effect of *Alternaria cerealis* (MT808477) and different salinity levels on total antioxidant content. Data are means ± SD (n = 3), with statistically significant differences (P < 0.

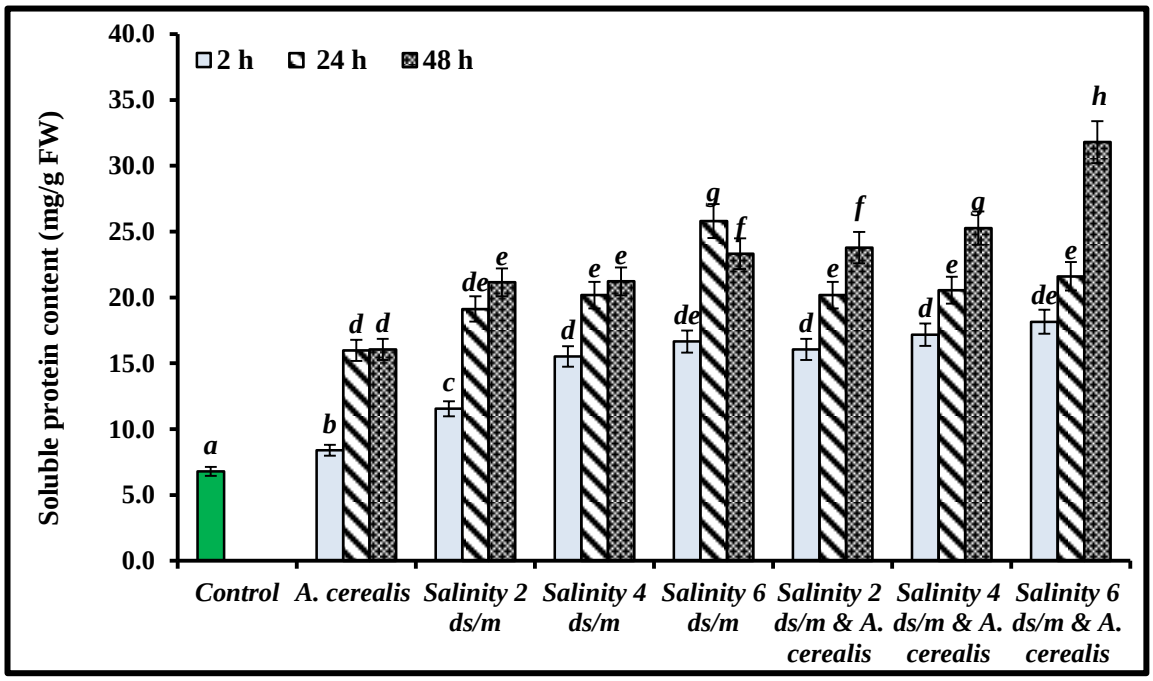

Figure 4: Effect of *Alternaria cerealis* (MT808477) and different salinity levels on soluble proteins content. Data are means ± SD (n = 3) with statistically significant differences (P < 0.05).

Lipid peroxidation

The content of lipid peroxidation was determined in tomato plants exposed to various treatments to assess the degree of membrane damage resulted from *A. cerealis* and salinity stress (**Figure 5**). The results demonstrated that lipid peroxidation of the tomato leaves was raised gradually with rising incubation period of plants treated with *A. cerealis* or different levels of salinity stress. The *A. cerealis* and salinity levels increased the lipid peroxidation content in tomato plants by 351.47± 2.56 mg/g FW and 418.13 ± 1.60 mg/g FW at 6 ds m^{-1} after 48 h, respectively, as compared with the control (132.33 ± 14.76 mg/g FW).

Hydrogen peroxide (H_2O_2)

Hydrogen peroxide is considered as an important signal molecule that mediates many physiological and biochemical processes in plants. The data herein obtained clearly demonstrated that the H_2O_2 content in tomato plants was considerably enhanced with the rise of incubation periods in infected tomato plants with *A. cerealis* **(Figure 6).** The *A. cerealis* infection enhanced the H_2O_2 content in tomato leaves by 2.54 ± 0.12 mg/g FW) after 48 h, over the control (0.36 ± 0.01 mg/g FW). In contrast, an insignificant decrease of the H_2O_2 content was observed in different levels of salinity (2, 4 and 6 ds m^{-1}) treated tomato plants. A further increase in H_2O_2 content was observed with increasing salinity levels in combination with *A. cerealis* infection and incubation periods in stress treatment with 2.19±0.12 at 2 ds m^{-1}, 2.58±0.01 at 4 ds m^{-1} and 2.77±0.05 at 6 ds m^{-1}, respectively, relative to the untreated plants (control).

Catalase (CAT) activity

Catalase catalyzes the dismutation of H_2O_2 into water and oxygen. The CAT activity was increased in tomato plants infected with *A. cerealis* after different infection times (2, 24 and 48 h) (**Figure 7**). The highest concentration of CAT activity was shown in tomato plant after 48 h (16.25±0.20 mg protein^{-1} min^{-1}) as compared with the control (0.01±0.00 mg protein^{-1} min^{-1}). In addition, the result of this study elucidated that, the CAT activity in case of different levels of salinity (2, 4 and 6 ds m^{-1}) represented insignificant decrease correlation between CAT activity and salinity concentrations in tomato plants. Under the combined stress of salinity and *A. cerealis* infection, the CAT activity was drastically decreased in all concentration of salinity stress. The data additionally disclosed that, there was an increase in CAT activity after 2 h only.

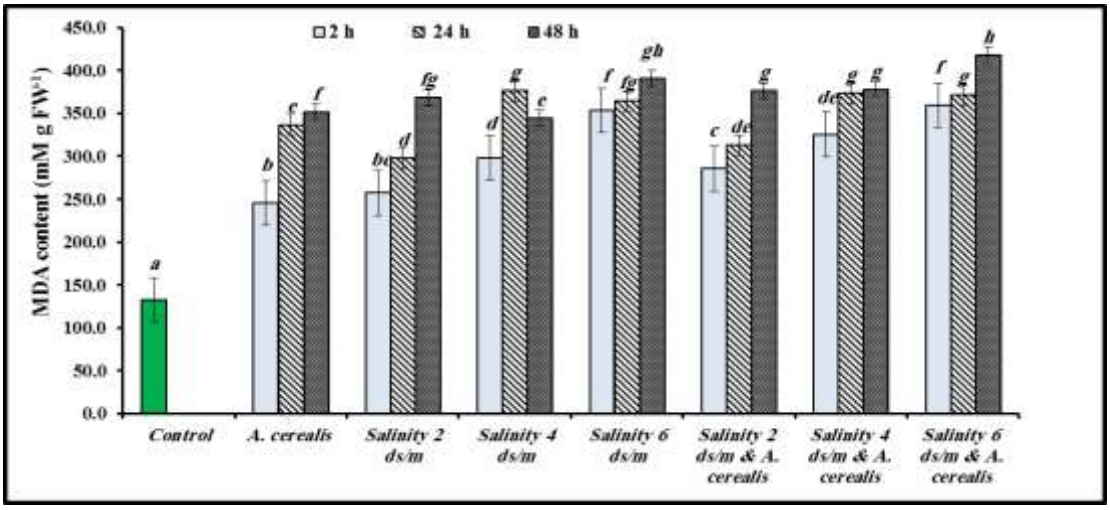

Figure 5: Effect of *Alternaria cerealis* (MT808477) and different salinity levels on MDA content. Data are means ± SD (n = 3) with statistically significant differences (P < 0.05).

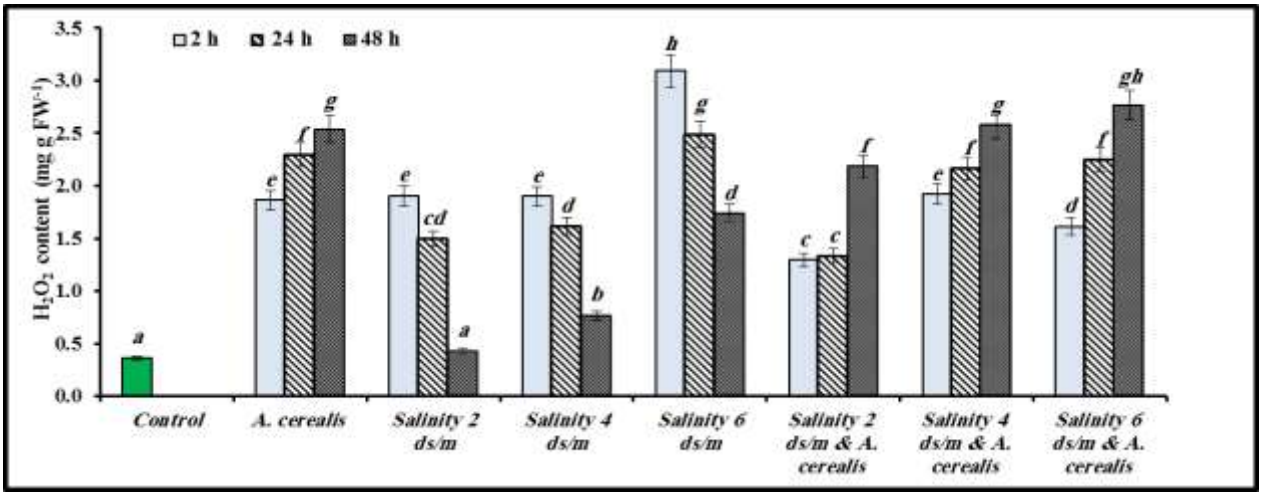

Figure 6: Effect of *Alternaria cerealis* (MT808477) and different salinity levels on H_2O_2 content. Data are means ± SD (n = 3) with statistically significant differences (P < 0.05).

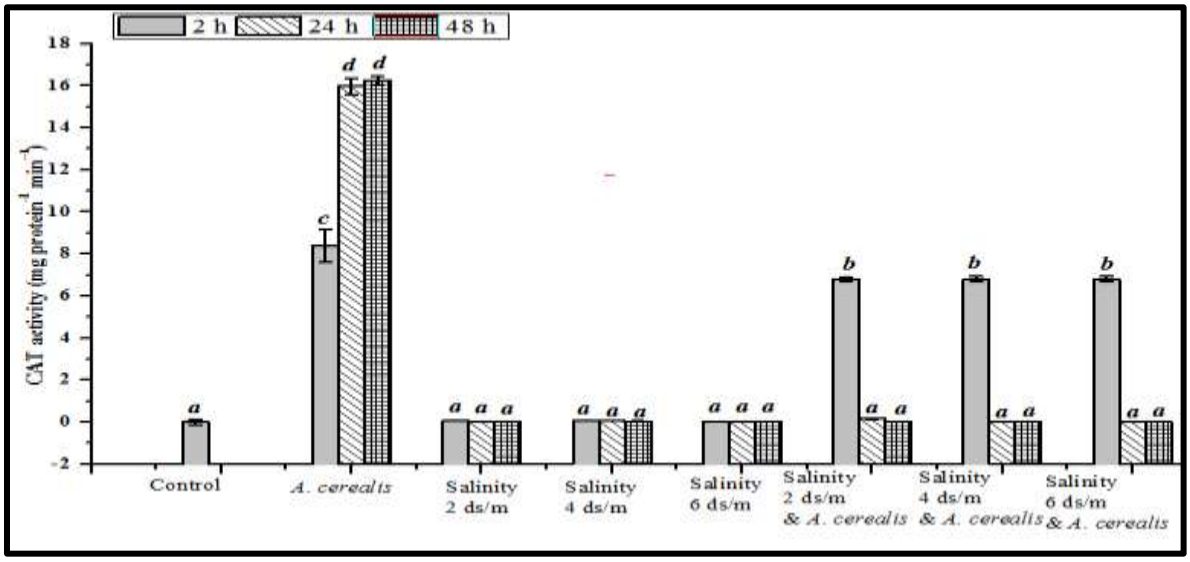

Figure 7: Effect of Alternaria cerealis (MT808477) and different salinity levels on CAT activity. Data are means ± SD (n = 3) with statistically significant differences (P < 0.05).

Discussion

Tomato (*Solanum lycopersicum* L.) is a wonderful fruit that is enhanced with safe phytochemicals and helps prevent major chronic degenerative diseases (**Chaudhary *et al.* 2018).** Several phytopathogenic fungi of tomatoes attributed to the action of mainly biological and physical damage factors that affect the morphology of the fruit or its taste and smell such as *Alternaria alternata*, *Fusarium moniliforme*, *F. oxysporum*, *Phytophthora* spp, *Rhizopus stolonifer* and *Penicillium waksmanii* **(Takam *et al.* 2019, Zakawa *et al.* 2019 and Hao *et al.* 2020).** Among these pathogens, *Alternaria* can trigger disease symptoms in all parts of the plant (leaf blight, stem lesions and rotting fruits) and result in acute damage at all stages of the plant development **(Abada *et al.* 2008).**

In the present study, *Alternaria cerealis* MT808477 was isolated from infected tomato leaves after two weeks of infection**.** Different physiological parameters (total flavonoids content, total terpenoids and total antioxidants) of the infected tomato plants showed a remarkable decline. *Alternaria cerealis* has been known

to cause serious diseases that tend to decrease the plant growth and biomass**. Das and Roychoudhury (2014)** noted that overproduction of ROS in infected plants by fungi can effect on root growth and leaves by increasing damage to membranes, protein, carbohydrate, nucleic acid and different physiological parameters, thereby affecting the physiological and developmental aspects. *Alternaria* blight infection caused increase in proline, total protein, total amino acid levels along with simultaneous reduction in total sugar, chlorophyll, and relative water content levels **(Mallick *et al.* 2015).**

The current results indicated that total flavonoids content in tomato plant treated with different levels of salinity (2, 4 and 6 ds m^{-1}) individually was significantly decreased in all treatment periods. In this respect, **Shahid *et al*. (2012)** reported that the reduction of plant biomass under salt stress may be related to many events, including lack of bulk maintenance, sodium/chloride toxicity and metabolic pathway interference. The combined stress of *A. cerealis* infection and different levels of salinity showed an increase in total flavonoids content in all concentrations and incubation periods compared to individual stress of *A. cerealis* or salinity. These results are in harmony with the finding of **Shoaib *et al*. (2018)**. They reported that in individual stress of salinity or *Fusarium oxysporum*, and combined stress of *Fusarium oxysporum* and salinity showed increased disease severity, with the highest disease occurrence and highly deteriorated bulb morphology in onion plants.

Terpenoids can act as antioxidants to protect cells from oxidative damage **(Kim et al. 2020**). In current results, there are an increasing in total terpenoids contents in tomato plants infected with *A. cerealis*. These results are in agreement with the findings of **Elgersma (1980)** who showed that the accumulation of terpenoids (rishitin) occurred in susceptible and resistant tomato plants after inoculation with *Verticillium albo-atrum*. Also, total terpenoids content in tomato plants treated with the salinity or combined stress with *A. cerealis* infection was significantly increased in all treatment periods. Similar results were reported by **Valifard *et al.* (2019)**. They showed an increase in the amount of major terpenoids in *Salvia mirzayanii* plants exposure to different levels of salinity stress (25, 50, 75, and 100 mM NaCl).

Also, salt stress increases the content of natural antioxidants in plants (**Petropoulos *et al.* 2017**). The results indicated that total antioxidant content in tomato plants was significantly rising in all treatments periods and concentrations. In this instance, total antioxidant compounds have a protective effect on reactive oxygen species (ROS) produced during biotic or abiotic stresses, which are increase in plants under stress **(Jaleel *et al.* 2009). Ahmed and Gabr (2012)** showed that after subculturing with different concentrations of NaCl (60 and 90 mM NaCl) for 6 weeks, the antioxidant activity in the methanol extract of cress and bean sprouts was relatively high.

In the present study, the results indicated that soluble proteins contents were significantly increased in infected plants after 24 and 48 h by 15.98 ± 0.39 and 16.05 ± 0.35 mg/g FW, respectively. The results are greatly similar to the results obtained by **Mallick *et al.* (2015),** who demonstrated the increasing of total soluble protein and proline contents under *Alternaria* blight infection stress in oil of mustard genotypes. In tomato plants, the soluble proteins production was significantly increased with different levels of salinity stress (2, 4 and 6 ds m^{-1}) with increase incubation time. **Sarker *et al.* (2018**) found that salt stress significantly increased protein, total flavonoid content, total antioxidant at 50 mM and 100 mM NaCl concentrations in *Amaranthus tricolor* leaves. **Petropoulos *et al.* (2017**) showed increase in protein and carbohydrates content in *Cichorium spinosum* plants under salinity stress.

When the polyunsaturated fatty acids of the plasma membrane are peroxidized, malondialdehyde is produced, which indicates the expression of oxidative damage. The present results indicated that MDA content

was significantly increased in infected plants or treated with different levels of salinity or both and dramatically increased with increasing the incubation periods. Our results are greatly in consistent with the results obtained by **Zehra *et al.* (2017),** who showed that the MDA content was gradually increased in tomato plants infected with *Fusarium oxysporum*. This result was similar to the finding of **Carrasco-Ríos and Pinto (2014)** who showed that the MDA content in corn varieties was increased with increasing salinity. Several studies have shown that salt stress can cause changes in the structure and composition of plasma membrane lipids, such as increasing saturation of free fatty acids and free sterols, resulting in decreasing fluidity of cell membranes **(Mansour *et al.* 2005)**.

Hydrogen peroxide (H_2O_2) is one of the most common and stable structure. It regulates a number of metabolic pathways as molecular signals in defense and development processes **(Slesak *et al.* 2007).** Our result demonstrated that H_2O_2 content in tomato plants was considerably enhanced with the rise of incubation periods in infected tomato plants with *A. cerealis***.** These results are in harmony with the results of **Zhou *et al.* (2019).** They showed that H_2O_2 contents of two tomato cultivars were remarkably increased following 3–6 and 4–6 days of drought treatment. **Das and Roychoudhury (2014)** reported that induced ROS in infected plants had an effect on physiological and developmental aspects by raising membrane damage. **Carrasco-Ríos and Pinto (2014)** indicated that salinity induced the activity of H_2O_2, which was double that control at intermediate salinity in corn varieties.

Plants have antioxidant pathways that can mitigate the negative effects of salinity, such as catalase (CAT). Cell damage caused by the accumulation of free oxygen and free radicals has been identified as a result of cell membrane changes caused by the oxidation of lipid bilayer acids. This causes changes in the chemical composition and ultrastructure of cell membranes, resulting in decreased fluidity, altered permeability, and inactivation of enzymes and membrane-linked receptors **(Mansour and Salama 2004)**.

In the present results, the CAT activity was increased in tomato plants infected with *A. cerealis* after all infection times (2, 24 and 48 h). The increase of CAT in tomato plants infected with *A. cerealis* agrees with the results of **Del Río and López-Huertas (2016).** They found that H_2O_2 induces peroxisome gene biogenesis in plant cells and proposed that the proliferation of peroxisomes generated to restore the cell's redox equilibrium can mitigate a variety of stress situations that trigger H_2O_2 formation. In the current study, the result elucidated that the CAT activity decreased in tomato plants in case of treatment with different levels of salinity (2, 4 and 6 ds m^{-1}). Our results are greatly in harmony with the results obtained by **Shoaib *et al.* (2018)** who showed that the CAT activity was gradually decreased drastically with increased soil salinity levels in onion plants. CAT activity may be decreased as a result of increasing of H_2O_2 content, redox imbalance, and catalase deactivation due to the prevention of new enzyme synthesis under high salinity stress **(Yamane *et al.* 2010).** Under the combined stress of salinity and *A. cerealis* infection in tomato plants, the CAT activity gradually decreased drastically in all concentration of salinity stress. Similar results were obtained by **Shoaib *et al.* (2018)** who demonstrated decreasing production of CAT activity in onion plants under the combined stress of salinity and *Fusarium oxysporum* infection.

Conclusion

Under the combined stress of salinity and *A. cerealis* infection, the overall increase trend of the studied physiological and enzyme parameters is approximately the same as that observed under the stress of *A. cerealis* infection or salinity alone. Consequently, this characteristic may be considered to be a valuable defense mechanism which contributes to the tolerance of the oxidative effect of salinity.

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