Progress in Nutrition 2019; Vol.21, N. 3: in press DOI: 10.23751/pn.v21i3.7645

Original article

The effects of SNP and Some Plant Hormones on Sunflower (*Helianthus annuus L.*) seedling leaves exposed to salt sress

O.A. Kirecci[1], *F. Yurekli*[2], *O. Yilmaz*[3]

[1]Bitlis Eren University Hizan Vocational School, Bitlis, TURKEY - E-mail: kirecciogluzayhan@gmail.com; [2]Inonu University Faculty of Science Literature, Biology Dept., Malatya, TURKEY; [3]Firat University Science Faculty, Biology Dept., Elazig, TURKEY

Summary. In this study, the effects of salt stress, sodium nitoprusside (SNP) and hormones (Abscisic acid, Indol acetic acid and Gibberellic acid) applications on fatty acids concentrations of sunflower (*Helianthus annuus* L. cv. Tarsan-1018) plant leaf were investigated. *Helianthus annuss* L. cv. TARSAN - 1018 seeds were obtained through the Edirne Thrace Agricultural Research Institute, in Turkey. Following surface sterilization, the seeds were kept in water with aquarium pomp for 24 hours. The light intensity was 222 μmol / m^2s on the leaf surface. Seeds were grown in 16 hours light, 8 hours dark photoperiod. Seeds were irrigated with Hoagland culture solution for 5 weeks. At the end of the fifth week salt, SNP and hormone applications were performed with foliar application for 72 hour. At the end of 72 hours samples were taken. Fatty acid composition of leaf tissues of sunflower (*Helianthus annuus* L. cv. Tarsan-1018) were determined by using gas chromatography. 300 mM salt application caused decrease concentrations of C16:0, C17:0, C18:1 and C18:3. 100 μM sodium nitoprusside has reduced the concentrations of C16:0, C17:0, C18:1. Hormone applications. adversely affected fatty acid concentrations. The results show that salt stress, sodium nitoprusside and hormone applications have negative effects on C16:0, C17:0, C18:1 and C18.3 concentrations in Tarsan-1018 sunflower leaf tissues.

Key words*:* fatty acid, hormone, salt stress, sodium nitoprusside, sunflower

Introduction

Stress can be defined as the destabilized physiological conditions of organisms. In the biological systems, a stress type may provide stress-producing for plants or it may provide optimum conditions for plants. The most practical definition of biological stress can be defined as negative conditions that inhibit normal functions and occurrences in plants (1-3). Salinity is a type of stress that has been increasing in the last few years worldwide. Salt stress causes decrease in precipitation and increase high humidity formation, and create difficulties in achieving water and nutrients for plants. As a result, water deficiency and drought cause stressful results (4-6). High salinity has negative effects on vegetation in many ways such as water stress, ion toxicity, nutrient deficiency, metabolic process changes, membrane disorders, regression in cell division and genotoxicity (7). The increase in NaCl stress causes negatively affected significant physiological steps such as protein synthesis, photosynthesis, energy and lipid metabolism (8). The osmotic effect of NaCl stress can be observed immediately. Cell growth and division are inhibited and stomata are closed (9, 10). Many of the plants have protective or countervailing mechanisms against adverse effects of salinity. In this way, plants can struggle with stress by controlling their stomata, improving osmotically, developing photoprotective effects, providing secondary metabolite. and phytohormone production (11-14).

Plant hormones are molecules that play an important role in the growth and development of plants. When plants are exposed to abiotic stress, some endogenous plant hormones play an important role in signal transduction and regulation of gene expression (15). Plant hormones regulate cell division, differentiation

and growth (16). In addition, gibberellins, ethylene, cytokinins and brassinosteroids can regulate seed germination and development (17). Abscisic acid (ABA) plays a role in the regulation of responses to stress in various stress conditions. It regulates stomatal activity, dormancy and other plant activity in abiotic and biotic stress conditions (18-20). ABA is a vital cellular signaling molecule that mediates the expression of some stress genes (20, 21). It has been determined that Nitric oxide (NO) involved in Indol acetic acid (IAA) signal. Thus some physiological proceses are regulated (22). Gibberellic acids are a group of hormones that regulate seed germination, leaf expansion, root elongation and flow, and are related to growth and development (23, 24). It has been reported that GA regulates the amount of other plant hormones in the *Glycine max* plant and can correct the adverse effects of NaCl stress (25-27). Nitric oxide (NO) has important roles in many different physiological in plants stages such as seed germination, growth and development, senescence, stoma movements. Nitric oxide plays an important role in some physiological stages in plants, such as reduction of promoting or seed dormancy of seed development and various stress types (28-31), plant ripening and regeneration of senescence (32-34), prevention of flowering (35), provision of stoma movements (36-39). Fatty acids and lipids, which are important components of plant cells, not only provide structural integrity and energy for various metabolic processes, but also function as signal molecules (40). Researchers reported that drought stress could cause a change in fatty acid contents of different sunflower seeds (41).

Oilseed plants are located in vegetable production in Turkey and are defined as the basic necessities of vital importance in human nutrition (42). Sunflower, sesame, peanut, poppy, canola, aspir and cottonseed are cultivated in Turkey. Sunflower is in the first place in terms of production amount. Sunflower contains high vegetable oil (22-50%). For this reason it is an important plant in the production of vegetable oil.

Studies with oil plants have focused on the seeds of plants. In this research, which is a different study, the concentrations of fatty acids in sunflower plant leaves were investigated depending on salt (NaCl) stress, hormones (ABA, IAA and GA) and sodium nitoprusside (SNP) applications. The results indicate that the concentrations of fatty acid in sunflower leaves vary depending on the applications.

Material and Methods

Plant material and experimental design

Sunflower plant (*Helianthus annuss* L. cv. TARSAN - 1018) seeds were obtained through the Edirne Thrace Agricultural Research Institute. Maximum salt tolerance of plant was determined. As a result, it was determined that the concentration of 300 mM NaCl was the maximum salinity concentration and it was used to create salt stress in the study. Then, seeds were sterilized using sodium hypochloride solution (1% v/v). Followed by washing with dH_2O. Following surface sterilization, the seeds were kept in the aquarium pump for 24 hours in water. After that, pot planting process was applied. The seeds were grown at 25 ± 2 ° C in plant growth chamber with 60-65% humidity. The light intensity was 222 µmol / m^2s on the leaf surface. Seeds were grown in 16 hours light, 8 hours dark photoperiod. Hoagland culture solution was used as the main culture solution in the study. Seeds were irrigated with Hoagland solution for 5 weeks. At the end of the fifth week, salt and hormone applications were performed with foliar application for 72 hour and samples were taken at the 72nd hour. Each group has three aerated pots and 40 seeds germinated in each pot. SNP was prepared as 100 µM and the hormones were also applied as 100 µM that these applications were performed with foliar. Thus, 300 mM NaCl, 100 µM SNP, 100 µM ABA, 100 µM IAA and 100 µM GA applications and combinations were generated (43). The applications were made with the stated concentrations for 72 hours and the following 13 groups were formed:

Control, 300 mM NaCl, 100 µM SNP, 300 mM NaCl + 100 µM SNP, 100 µM ABA, 100 µM IAA,100 µM GA, 300 mM NaCl + 100 µM ABA, 300 mM NaCl + 100 µM IAA, 300 mM NaCl + 100 µM GA, 300 mM NaCl + 100 µM SNP + 100 µM ABA, 300 µM NaCl + 100 µM SNP + 100 µM IAA and 300 mM NaCl + 100 µM SNP + 100 µM GA. The samples were frozen in liquid nitrogen and stored in deep freeze at -40 ° C until analysis.

Determination of Fatty acid

Fatty acids in the lipid extracts were converted into methyl esters including 2% sulphuric acid (v/v) in methanol (44). The fatty acidmethyl esters were extracted with 5 mL n-hexane. The analysis of fatty acid methyl ester was performed in a Shimadzu GC-17A instrument gas chromatograph, equipped with a flame ionization detector (FID) and a 25mm, 0.25 mm i.d.permabond fused-silica capillary column (Macherey- Nagel, Germany). The oven temperature was programmed between 145-215°C, 4°C / min. Injector and FID temperatures were 240 and 280°C, respectively. The rate of nitrogen carrier gas was at 1 mL / min. The methyl esters of fatty acids were identified by comparison with authentic external standard mixtures analyzed under the same conditions. Class GC 10 software version 2.01 was used to process the data.

Statistical analysis

All experimental data were obtained repeatedly three times under some conditions. A comparative analysis of variance was performed between the control group and the experimental group. Stastical analyses of the data were performed by using SPSS 15.0 software program. All measurements were subjected to analysis of variance (ANOVA) to discriminate significant differences (set as P≤0.05). The data were shown as mean ± SD. Each group was compared with its own control group.

Results

Palmitic acid (C16:0) concentrations

Palmitic acid (C16:0) concentrations in leaf tissues of Tarsan-1018 sunflower plant were determined to be close to the control group in all treatment groups, except for 100 mM GA application (Table 1). When Table 1 is examined, it is understood that the many application groups result in a lower concentration of 16.0 than the control group. The lowest concentration of C16:0 was determined in 100 µM GA application (5,71±0,03 %). SNP treatment caused decrease concentration of C16:0. 100 µM IAA, 300 mM NaCl+ 100 µM GA and 300 mM NaCl+ 100 µM SNP+ 100 µM GA applications provided high concentration of C16:0 than the control group. NaCl application was almost ineffective. In the same way, 100 µM ABA application was found to be ineffective on the C16:0 concentration (Table 1).

Palmitoleic acid (C16:1) concentrations

Concentration of the Palmitoleic acid (C16:1) in leaf tissues of Tarsan-1018 sunflower plant were determined higher than control group in all applications, except for 100 mM GA and 300 mM NaCl+ 100 µM SNP applications (Table 2). Especially 100 µM ABA treatment provided the highest C16:1 concentrations (4,65±0,09 %). NaCl stress and 100 µM SNP caused increase con-

Table 1. Palmitic acid (C16:0) concentrations in leaf tissues of Tarsan-1018 sunflower plant

Treatment Groups	C16:0 Concentration (%) at 72nd Hour
Control	20,32±0,09
300 mM NaCl	19,97±0,02
100 µM SNP	15,44±0,09***
100 µM ABA	20,22±0,09
100 µM IAA	22,99±0,55**
100 µM GA	5,71±0,03***
300 mM NaCl+ 100 µM SNP	17,28±0,09**
300 mM NaCl+ 100 µM ABA	22,03±0,09**
300 mM NaCl+ 100 µM IAA	16,27±0,03***
300 mM NaCl+ 100 µM GA	22,96±0,42**
300 mM NaCl+ 100 µM SNP+ 100 µM ABA	19,69±0,07
300 mM NaCl+ 100 µM SNP+ 100 µM IAA	15,09±0,31***
300 mM NaCl+ 100 µM SNP+ 100 µM GA	21,91±0,06***

Significant differences between treatments at *** P≤0,001, ** P≤0,01 and * P≤0,05 level indicated by different.

Table 2. Palmitoleic acid (C16:1) concentrations in leaf tissues of Tarsan-1018 sunflower plant

Treatment Groups	C16:1 Concentration (%) at 72nd Hour
Control	2,61±0,07
300 mM NaCl	3,69±0,06***
100 µM SNP	3,23±0,06***
100 µM ABA	4,65±0,09***
100 µM IAA	3,14±0,05***
100 µM GA	2,38±0,09***
300 mM NaCl+ 100 µM SNP	1,46±0,09***
300 mM NaCl+ 100 µM ABA	2,89±0,06*
300 mM NaCl+ 100 µM IAA	2,75±0,03*
300 mM NaCl+ 100 µM GA	2,75±0,04*
300 mM NaCl+ 100 µM SNP+ 100 µM ABA	2,74±0,06*
300 mM NaCl+ 100 µM SNP+ 100 µM IAA	3,03±0,01**
300 mM NaCl+ 100 µM SNP+ 100 µM GA	3,46±0,06***

Significant differences between treatments at *** P≤0,001, ** P≤0,01 and * P≤0,05 level indicated by different

centraion of C16:1 than control. But 300 mM NaCl+ 100 µM SNP application reduced the concentration of C16:1 than control. Moreover, this value is the lowest value obtained from applications (1,46±0,09 %).

Heptadecanoic acid (C17:0) concentrations

Heptadecanoic acid (C17:0) concentrations were founded less than the control group in all treatment groups. These reductions were found to be serious. This reduction was about 7.5-fold in the 100 µM IAA+ 100 µM SNP+ 300 mM NaCl treatment. 100 µM IAA treatment resulted in 50% reduction compared to the control group. The concentration of C17:0 more severely decreased in 100 µM GA and 100 µM ABA applications (Table 3).

Strearic acid concentrations (C18:0)

Strearic acid concentrations (C18:0) of Tarsan-1018 leaf tissues were founded higher than the control group except for 300 mM NaCl+ 100 µM IAA, 300 mM NaCl+ 100 µM SNP+ 100 µM IAA and 100 µM GA appli-

Table 3. Heptadecanoic acid (C17:0) concentrations in leaf tissues of Tarsan-1018 sunflower plant

Treatment Groups	C17:0 Concentration (%) at 72nd Hour
Control	6,63±0,08
300 mM NaCl	2,38±0,03***
100 µM SNP	2,48±0,07***
100 µM ABA	1,55±0,08***
100 µM IAA	3,25±0,05***
100 µM GA	1,76±0,03***
300 mM NaCl+ 100 µM SNP	2,01±0,05***
300 mM NaCl+ 100 µM ABA	2,09±0,07***
300 mM NaCl+ 100 µM IAA	3,15±0,01***
300 mM NaCl+ 100 µM GA	1,65±0,02***
300 mM NaCl+ 100 µM SNP+ 100 µM ABA	1,98±0,06***
300 mM NaCl+ 100 µM SNP+ 100 µM IAA	0,89±0,01***
300 mM NaCl+ 100 µM SNP+ 100 µM GA	1,02±0,08***

Significant differences between treatments at *** P≤0,001 level indicated by different.

Table 4. Strearic acid concentrations (C18:0) in leaf tissues of Tarsan-1018 sunflower plant

Treatment Groups	C18:0 Concentration (%) at 72nd Hour
Control	2,86±0,09
300 mM NaCl	3,94±0,06***
100 µM SNP	3,25±0,08***
100 µM ABA	4,09±0,06***
100 µM IAA	3,60±0,08***
100 µM GA	2,50±0,05**
300 mM NaCl+ 100 µM SNP	3,89±0,03***
300 mM NaCl+ 100 µM ABA	4,40±0,06***
300 mM NaCl+ 100 µM IAA	2,14±0,06***
300 mM NaCl+ 100 µM GA	4,26±0,01***
300 mM NaCl+ 100 µM SNP+ 100 µM ABA	3,36±0,04***
300 mM NaCl+ 100 µM SNP+ 100 µM IAA	1,82±0,06***
300 mM NaCl+ 100 µM SNP+ 100 µM GA	3,21±0,01***

Significant differences between treatments at *** P≤0,001 and ** P≤0,01 level indicated by different.

cations. The highest concentration was detected in the 300 mM NaCl+ 100 µM ABA application (4,40±0,06 %). Only NaCl, SNP and IAA applications provided increase C18:0 concentration but their combinations caused decrease concentration of C18:0 and 100 µM GA application made a negative impact on C18:0 (Table 4).

Oleic acid (C18:1) concenration

All applications caused decrease oleic acid (C18:1) concentrations than the control except for 300 mM NaCl+ 100 µM SNP+ 100 µM ABA. The lowest concentration of C18:1 was determined in 300 mM NaCl+ 100 µM GA application (1,70±0,07 %). The lowest concentration detrmined 2.22 fold less than the control group. Interestingly, application of 300 mM NaCl + 100 µM SNP + 100 µM ABA increased the concentration. However, only NaCl, SNP or ABA application did not raise the concentration. Only IAA treatment caused decrased C18:1 concentration. Combination of IAA, SNP and NaCl provided increase concentration of C18:1 (Table 5).

Table 5. Oleic acid (C18:1) concenrations in leaf tissues of Tarsan-1018 sunflower plant

Treatment Groups	C18:1 Concentration (%) at 72nd Hour
Control	3,78±0,09
300 mM NaCl	3,05±0,03***
100 µM SNP	2,50±0,07***
100 µM ABA	2,97±0,08***
100 µM IAA	1,91±0,07***
100 µM GA	2,18±0,03***
300 mM NaCl+ 100 µM SNP	2,14±0,05***
300 mM NaCl+ 100 µM ABA	2,88±0,05***
300 mM NaCl+ 100 µM IAA	2,78±0,01***
300 mM NaCl+ 100 µM GA	1,70±0,07***
300 mM NaCl+ 100 µM SNP+ 100 µM ABA	4,18±0,09***
300 mM NaCl+ 100 µM SNP+ 100 µM IAA	1,84±0,01***
300 mM NaCl+ 100 µM SNP+ 100 µM GA	2,76±0,09***

Significant differences between treatments at *** P≤0,001 level indicated by different.

Table 6. Linoleic acid concentration (C18:2) in leaf tissues of Tarsan-1018 sunflower plant

Treatment Groups	C18:2 Concentration (%) at 72nd Hour
Control	17,44±0,08
300 mM NaCl	27,43±0,06***
100 µM SNP	23,12±0,05***
100 µM ABA	22,24±0,08***
100 µM IAA	22,88±0,04***
100 µM GA	19,01±0,04*
300 mM NaCl+ 100 µM SNP	31,47±0,06***
300 mM NaCl+ 100 µM ABA	19,88±0,07*
300 mM NaCl+ 100 µM IAA	16,45±0,01
300 mM NaCl+ 100 µM GA	23,44±0,02***
300 mM NaCl+ 100 µM SNP+ 100 µM ABA	24,18±0,02***
300 mM NaCl+ 100 µM SNP+ 100 µM IAA	27,93±0,06***
300 mM NaCl+ 100 µM SNP+ 100 µM GA	28,13±0,08***

Significant differences between treatments at *** P≤0,001 and * P≤0,05 level indicated by different.

Linoleic acid (C18:2) concentration

Linoleic acid concentration of Tarsan-1018 leaf tissues were founded higher than the control group except for 300 mM NaCl+ 100 µM IAA. Especially NaCl treatment provided an increase about 58% (Table 6). On the other hand, the combination of NaCl and SNP caused an increase approximately 80%. Only SNP treatment provided increased concentraion of C18:2. The hormones have positive effects on C18:2 concentration. When the table is examined, it is understood that the IAA application increased the concentration of 18: 2, while the combination of NaCl and IAA caused a decrease.

α-Linolenic acid (C18:3) concentration

α-Linolenic acid (C18:3) concentration reached its highest value in 100 µM ABA treatment (54,66±0,04 %) in Tarsan-1018 leaf tissues. NaCl, SNP, NaCl+SNP and NaCl+GA, NaCl+ GA applications caused decrease concentration of C18:3. ABA, IAA and GA provided high C18:3 concentration than control. The lowest concentration of C18:3 was determined in 300 mM NaCl+ 100 µM SNP application (16,79±0,06 %). SNP treatment caused decrease concentration of C18:3 (Table 7).

Discussion

In the current study, we identified fatty acid concentrations (C16:0, C16:1; C17:0, C18:0, C18:1, C18:2 and C18:3) of *Helianthus annuus* L. cv Tarsan-1018 sunflower plant leaves.

As is known, plants produce a variety of responses to abiotic and biotic stresses. Diverse studies have shown that the fatty acid content of various industrial plants changes under stress conditions. The rate of oleic / linoleic acid increased during germination at high temperature, while decreased at low temperature (45). It has been reported that the sunflower plant's concentration of palmitic acid increased and the concentration of stearic acid decreased in drought stress. The same researchers reported that drought negatively affected the oleic acid concentration, while had an enhancing effect on linoleic acid concentration (46). In a different study it has been reported that water stress causes a decrease in oleic acid content (47). It was also concluded that water stress increased oleic acid concentration and decreased stearic acid concentration (48). Our results are consistent with the literature. According to our results, the concentration of oleic acid increased in the plant due to the stress effect, which is different from the literature. This may be due to genetic differences. Because genotype is the most important factor for identifies the fatty acid composition (49).

Table 7. αLinolenic acid (C18:3) concentration in leaf tissues of Tarsan-1018 sunflower plant

Treatment Groups	C18:3 Concentration (%) at 72nd Hour
Control	34,06±0,08
300 mM NaCl	28,60±0,03***
100 µM SNP	23,12±0,05***
100 µM ABA	54,66±0,04***
100 µM IAA	37,20±0,02*
100 µM GA	39,39±0,03**
300 mM NaCl+ 100 µM SNP	16,79±0,06***
300 mM NaCl+ 100 µM ABA	37,74±0,07*
300 mM NaCl+ 100 µM IAA	39,75±0,01**
300 mM NaCl+ 100 µM GA	30,90±0,08**
300 mM NaCl+ 100 µM SNP+ 100 µM ABA	34,38±0,05
300 mM NaCl+ 100 µM SNP+ 100 µM IAA	34,79±0,02
300 mM NaCl+ 100 µM SNP+ 100 µM GA	31,34±0,08***

Significant differences between treatments at *** P≤0,001, ** P≤0,01 and * P≤0,05 level indicated by different

Literature knowledge on the effects of hormones on sunflower leaf fatty acid concentrations are limited. In a study conducted with salicylic acid (SA) application was shown that the concentration of some fatty acids (C16:0, C16:1, C18:0, C18:2 and C18:3) decreased and the concentration of C18:1 increased. In the same study it was also reported that SA treatment caused increase concentration of IAA and GA while reducing concentration of ABA (50). According to our results, ABA application increased concentrations of 16: 1, C18:0, C18:2 and C18:3. and it decreased concentrations of C17:0 and C18:1. There may be an increase or decrease in unsaturated fatty acids under different stress conditions. Due to these different reactions, the increase in unsaturated fatty acids does not provide endurance in all types of stress (51). For example, concentration of C18:3 increases in saline conditions (52) and decreases at heavy metal stress (53). However, in the present study it was determined that the concentration of C18:3 decreased under saline conditions. Of course, it is difficult to obtain same physiological responses in living organisms. There are very few studies on salinity and temperature stress that increase or no effect on fatty concentrations It is generally reported that there is a decrease of oil concentrations in saliniyt or temparature stress (54).

In our study, it was determined that concentrations of fatty acids (C16:0, C17:0, C18:1 and C18:3) decreased with application of salt stress. In a different study (55), C16:0, C18:2 and C18:3 fatty acids were identified in sunflower leaves. We have also identified C17:0, C17:1, C18:0 and C18:1 fatty acids in addition to these. Researchers reported that leaf fatty acid composition in sunflower plants showed significant changes with Cd stress and this negative effect was alleviated by salicylic acid treatment (56). Peroxidation of unsaturated lipids in biological membranes is the most obvious indication of oxidative stress in animals and plants (57). According to results, it was revealed that concentration of C18:3 decreased with salt application while it increased with hormone applications. On the other hand concentration of C18:2 increased with salt treatment. Concentration of C18:1 decreased salt, ABA, IAA ve GA applications. It was determined that the concentration of C18:0 increased with salt application. In the same way, ABA and IAA applications increased concentration of C18:0. GA application decreased C18:0 concentration. These results suggest that GA is ineffective on desaturase activity. In addition, ABA and IAA improved desaturase activity and transformation of C18:0 to C18:2 and C18:3. Studies have shown that when the plants are exposed to drought stress, the fatty acid composition may change and the content of higher unsaturated fatty acids may increase (58, 59). In addition salt stress (250 mM) caused increase concentrations of C16:0, C18:0 and

C18:2, and decrease concentration of C16:1 and C18:3 in Peanut (60). In the *Spartina patents* plant, salt sress increased contents of C16:0 and C18:0, and decreased concentrations of C16:1, C18:2 and C18:3 (61). We observed in the present study, salt stress decreased concentrations of C16:0, C17:0, C18:1 and C18:3 while increased C16:1, C18:0 and C18:2. Our results are partly consistent with studies. The reason for this may be genetic differences and different applications.

The data show that SNP application has effects on fatty acids. Researchers have reported that 10 µL/L NO application provides a significant increase in C16:1, C18:1 and C18:3 content in peach (62). They stated that a decrease occurred in content of C18:2. In the same study it was determined that 5 µL/L and 10 µL/L NO applications caused decrease the content of C18:3 but 15 µL/L NO application provided increase it. Because of these results, it has been reported that the fatty acid content depends on NO concentration. In the present study, SNP has reduced the concentrations of C16:0, C17:0, C18:1 and C18:3 fatty acids and it increased concentration of C16:1, C18:0 and C18:2 fatty acids. Apparently, our results are in contrast with the literature. These different results may be due to plants. Because genotype is the most important factor for identifies the fatty acid composition (49).

Conclusion

Fatty acids are important substances in plant tissues and are affected by a variety of factors. Also, fatty acids play role in different metabolic events in all living organizms. Omega fatty acids are effective in brain development, strengthening of the immune system and prevention of heart diseases. Ratio of unsaturated / saturated fatty acids is important in nutrients and if this rate is low, it is effective for health. Present study showed that hormone applications provided increase concentraion of unsaturated fatty acids. This is a positive result for health. Hormones at the appropriate dose can make a positive effect. In our study, it was observed that concentrations of fatty acids (C16:0, C17:0, C18:1 and C18:3) decreased with application of salt stress. NaCl stress caused increase C18:0, C18:2 and C16:1. SNP has negative effect on the concentrations of C16:0, C17:0, C18:1 and C18:3 fatty acids and it increased concentration of C16:1, C18:0 and C18:2 fatty acids.SNP has reduced the concentrations of C16:0, C17:0, C18:1 and C18:3 fatty acids and it increased concentration of C16:1, C18:0 and C18:2 fatty acids. Although nitric oxide is a signaling molecule, it has not a positive effect on all unsaturated fatty acids. This conclusion shows that the adaptation mechanism of plants to stress conditions is complicated. Hormone applications have negative effects on C16:0, C17:0, C18:1 and C18.3 concentrations. Espacially GA has very restrictive effects on the fatty acids. In conclusion, signal molecules and hormones are important for plants. The mechanism of adaptation to stress conditions is influenced by many factors. Although sunflower leaf is not consumed by humans the results suggest that attention should be paid to the consumption of nutrients.

Acknowledgments

This research was sponsored by the Bitlis Eren University Scientific Research Projects Unit (No. 2015/04).

References

1. Jones HG, Jones MB. Introduction: some terminology and common mechanisms, in: Jones HG, Flowers TJ, Jones MB (Eds.), Plants Under Stress, Cambridge university Press, Cambridge, 1989; 1-10.
2. Gaspar T, Franck T, Bisbis B, Kevers C, Jouve L, Hausman JF, Dommes J. Concepts in plant stress physiology. Application to plant tissue cultures. Plant Growth Regul 2002; 37: 263-285.
3. Jaleel AC, Manivannan P, Wahıd A, Farooq M, Al-Juburi HJ, Somasundaram R, Panneerselvam R. Drought Stress in Plants: A Review on Morphological Characteristics and Pigments Composition. Int J Agric Biol 2009; 11: 1.
4. Mahajan S, Tuteja N. Cold, salinity and drought stresses; an overview. Arch. Biochem. Biophys 2005; 444: 139158.
5. Al-Karaki GN. Nursery inoculation of tomato with arbuscular mycorrhizal fungi and subsequent performance under irrigation with saline water. Sci Hortic 2005; 109: 1-7.
6. Porcel R, Aroca R, Ruiz-Lozano JM. Salinity stress alleviation using arbuscular mycorrhizal fungi. A review. Agron Sustain Dev 2012; 32: 181-200.
7. Zhu JK. Plant Salt Stress: John Wiley & Son, Ltd 2007.
8. Parida AK, Das AB. Salt tolerance and salinity effects on plants: A review. Ecotox and Envir Safety 2005; 60: 324-349.

9. Munns R. Comparative physiology of salt and water stress. Plant Cell & Environment 2002; 25: 239-250.
10. Flowers TJ. Improving crop salt tolerance. Journal of Experimental Botany 2004; 55: 307-319.
11. Yordanov I, Velikova V, Tsonev T. Plant responses to drought, acclimatation and stress tolerance. Photosynthetica 2000; 38: 171-186.
12. Valladares F, Pearcy RW. Drought can be more critical in the shade than in the sun: a field study of carbon gain and photo-inhibition in a Californian shrub during a dry El Nino year. Plant Cell Environ 2002; 25: 749-759.
13. Martinez-Ferri E, Manrique E, Valladares F, Balaguer L. Winter photoinhibition in the field involves different processes in four co-occurring Mediterranean tree species. Tree Physiol 2004; 24: 981-990.
14. Radhakrishnan R, Lee IJ. Spermine promotes acclimation to osmotic stress by modifying antioxidant, abscisic acid, and jasmonic acid signals in soybean. J Plant Growth Regul 2013; 32: 22-30.
15. Atia A, Barhoumi Z, Debez A, Hkiri S, Abdely C, Smaoui A, Haouari CC, Gouia H. Plant Hormones: Potent targets for engineering salinity tolerance in plants. Salinity Responses and Tolerance in Plants 2018, 1: 159-184
16. Hooley R. Gibberellins: perception, transduction and responses. Plant Mol Biol 1994; 26: 1529-1555.
17. Kucera B, Cohn MA, Leubner-Metzger G. Plant hormone interactions during seed dormancy release and germination. Seed Sci Res 2005; 15: 281-307.
18. Moore TC. Biochemistry and Physiology of Plant Hormones, 2nd edn. Springer-Verlag, New York, U.S.A, 1989.
19. Davies WJ, Jones HG. Abscisic acid: physiology, biochemistry. BIOS. Scientific Publishers Ltd, Cambridge, UK, 1991.
20. Basu S, Rabara R. Abscisic acid — An enigma in the abiotic stress tolerance of crop plants. Plant Gene 2017; 11(B): 90-98.
21. Hasanuzzaman M, Nahar K, Fujita M. Plant Response to Salt Stress and Role of Exogenous Protectants to Mitigate Salt-Induced Damages. In: Ahmad P, Azooz M, Prasad M. (eds) Ecophysiology and Responses of Plants under Salt Stress. Springer, New York, 2013; pp.53- 54.
22. Yadav S, David A, Baluska F, Bhatla SC. Rapid auxin-induced nitric oxide accumulation and subsequent tyrosine nitration of proteins during adventitious root formation in sunflower hypocotyls. Plant Signal Behav 2013; 8: 231-96.
23. Magome H, Yamaguchi S, Hanada A, Kamiya Y, Odadoi K. Dwarf and delayed- flowering 1, a novel Arabidopsis mutant deficient in gibberellins biosynthesis because of overexpression of a putative AP2 transcription factor. Plant J 2004; 37: 720-729.
24. Kim SG, Park CM. Gibberellic acid-mediated salt signaling in seed germination. Plant Signal Behav 2008; 3: 877-879.
25. Hisamatsu T, Koshioka M, Kubota S, Fujime Y, King RW, Mander LN. The role of gibberellin in the control of growth and flowering in Matthiola incana. Physiolgia Plant 2000; 109: 97-105.
26. Hamayun M, Khan SA, Khan AL, Shin JH, Ahmad B, Shin DH, Lee IJ. Exogenous gibberellic acid reprograms soybean to higher growth and salt stress tolerance. Journal of Agricultural and Food Chemistry 2010; 58: 7226-7232.
27. Iqbal N, Nazar R, Khan MIR, Masood A, Khan NA. Role of gibberellins in regulation of source sink relations under optimal and limiting environmental conditions. Current Science 2011; 100: 998-1007.
28. Corpas FJ, Palma JM. Assessing nitric oxide (NO) in higher plants: An outline. Nitrogen 2018; 1(1): 12-20.
29. Desikan R, Cheung MK, Bright J, Henson D, Hancock JT, Neill SJ. ABA, hydrogen peroxide and nitric oxide signalling in stomatal guard cells. J Exp Bot 2004; 55: 205-212.
30. Bright J, Desikan R, Hancock JT, Weir IS, Neill SJ. ABA induced NO generation and stomatal closure in Arabidopsis are dependent on H2O2 synthesis. Plant J 2006; 45: 113-122.
31. Garcia-Mata C, Lamattina L. Abscisic acid (ABA) inhibits lightinduced stomatal opening through calcium- and nitric oxide-mediated signaling pathways. Nitric Oxide 2007; 17: 143-151.
32. Neill SJ, Desikan R, Clarke A, Hancock JT. Nitric oxide is a novel component of abscisic acid signaling in stomatal guard cells. Plant Physiol 2002; 128: 13- 16.
33. Guo FQ, Crawford NM. Arabidopsis nitric oxide synthase1 is targeted to mitochondria and protects against oxidative damage and dark-induced senescence. Plant Cell 2005; 17: 3436-3450.
34. Floryszak-Wieczorek J, Arasimowicz M, Milczarek G, Jelen H, Jackowiak H. Only an early nitric oxide burst and the following wave of secondary nitric oxide generation enhanced effective defense responses of pelargonium to a necrotrophic pathogen. New Phytol 2007; 175: 718-730.
35. Zhao MG, Zhao X, Wu YX, Zhang LX. Enhanced sensitivity to oxidative stress in Arabidopsis nitric oxide synthesis mutant. J Plant Physiol 2007a; 164: 737-745.
36. Uchida A, Jagendorf AT, Hibino T, Takabe T. Effects of hydrogen peroxide and nitric oxide on both salt and heat stres tolerance in rice. Plant Sci 2002; 163: 515-523.
37. Zhao L, Zhang F, Guo J, Yang Y, Li B, Zhang L. Nitric oxide functions as a signal in salt resistance in the calluses from two ecotypes of reed. Plant Physiol 2004; 134: 849-857.
38. Modolo LV, Augusto O, Almeida IM, Magalhaes JR, Salgado I. Nitrite as the major source of nitric oxide production by Arabidopsis thaliana in response to Pseudomonas syringae. FEBS Lett 2005; 579: 3814-3820.
39. Zhao MG, Tian QY, Zhang WH. Nitric oxide synthase dependent nitric oxide production is associated with salt tolerance in Arabidopsis. Plant Physiol 2007b; 144: 206-217.
40. Lim GH, Singhal R, Kachroo A, Kachroo P. Fatty acid and lipid mediated signaling in plant defense. Annual Review of Phytopathology 2017; 55: 505-536.
41. Ali Q, Ashraf M, Anwar F. Physico-chemical attributes of seed oil from drought stressed sunflower (Helianthus annuus L.) plants. Grases Y Aceites 2009; 60: 475-481.
42. Yurdagul M, Ersoy U. The Fats and Oils Market In Turkey With Special Emphasis To Its Export. AOCS, The World Oil Conference, İstanbul, 1997.

43. Yurekli F, Kirecci OA. The relationship between nitric oxide and plant hormones in snp administrated sunflower plants under salt stress condition. Acta Sci Pol Hortorum Cultus 2016; 15, 6: 177-191.
44. Christie WW. Preparation of methyl esters- Part 1. Lipid Technol 1990; 2: 48-49.
45. Tremolieres A, Dubacq JP, Drapier D. Unsaturated fatty acids in maturing seeds of sunflower and rape: regulation by temperature and light intensity. Phytochemistry 1982; 21: 41- 45.
46. Petcu E, Arsintescu A, Stanciu D. The effect of drought stress on fatty acıd composıtıon ın some romanıan sunflower hybrıds. Romanian Agricultural Research 2000; 15: 39- 42
47. Baldini M, Giovanardi R, Vannozzi GP. Effect of different water availability on fatty acid compos ition of the oil in standard and high oleic sunflower hybrids. In Proceedings of 15th International Sunflower Conference, A.79-A.84. Toulouse, France, 12-15 June, 2000.
48. Mckeon TA, Stumpf PK. Purification and characterization of the stearoil-acyl carrier protein desaturase and the acyl-acyl protein thioesterase from mature seeds of sunflower. The Journal of Bioch 1982; 257: 12141 - 12147.
49. Dawood MG, Sadak MS, Hozayen M. Physiological role of salicylic acid ın ımproving performance, yield and some biochemical aspects of sunflower plant grown under newly reclaimed sandy soil. Aust J of Basic and App Sci 2012; 6: 82- 89.
50. Upchurch RG. Fatty acid unsaturation, mobilization, and regulation in the response of plant sress. Biotecnol Lett 2008; 30: 967- 977.
51. Zhang M, Barg R, Yin M, Gueta-Dahan Y, Leikin-Frenkel A, Salts Y, Shabtai S, Ben-Hayyim G. Modulated fatty acid desaturation via overexpression of two distinct x-3 desaturases differentially alters tolerance to various abiotic stresses in transgenic tobacco cells and plants. Plant J 2005; 44: 361-371.
52. Howlett NG, Avery SV. Induction of lipid peroxidation during heavy metal stress in Saccharomyces cerevisiae and influence of plasma membrane fatty acid unsaturation. Appl Environ Microbiol 1997; 63: 2971-2976.
53. Wang Y, Frei M. Stressed Food - The Impact of Abiotic Environmental Stresses on Crop Quality. Agric Ecosyst Environ 2011; 141: 271-286.
54. Sabudak T. Seren G, Kaykioglu G, Dincer AR. Determination of trace elements in soil and sunflower (Helianthus annuus L.) Plant parts. Fresenius Environmental Bull 2007; 16: 1274-1278.
55. Moradkhani S, Nejad RAK, Dilmaghani K, Chaparzadeh N. Effect of salicylic acid treatment on cadmium toxicity and leaf lipid composition in sunflower. J of Stress Physiol & Biochem 2012; 8: 78-89.
56. Cho UH, Seo NH. Oxidative stress in Arabidopsis thaliana exposed to cadmium is due to hydrogen peroxide accumulation. Plant Sci 2005; 168: 113-120.
57. Zhong DH, Du HM, Wang ZL, Huang BR. Genotypic variation in fatty acid composition and unsaturation levels in bermudagrass associated with leaf dehydration tolerance. J Am Soc Hortic Sci 2011; 136: 35- 40.
58. Knowles PF. Recent advances in oil crops breeding. Applewhite TH. Proceeding of the World Conference on Biotechnology for the Fats and Oil Industry 35- 38. Ed. American Oil Chemists Society, 1988.
59. Xu L, Han L, Huang B. Membrane fatty acid composition and saturation levels associated with leaf dehydration tolerance and post-drought rehydration in Kentucky Bluegrass. Crop Sci 51: 273.
60. Sui N, Wang Y, Liu S, Wang F, Wan S. transcriptomic and physiological evidence for the relationship between unsaturated fatty acid and salt stress in Peanut. Frontier in Plant Sci 2018; 9:7.
61. Duarte B, Matos AR, Margues JC, Cacador I. Leaf fatty acid remodeling in the salt-excreting halophytic grass Spartina patens along a salinity gradient. Plant Phys and Biochem 2018; 124: 112-116.
62. Zhu Z, Zhou J 2006. Effects of nitric oxide on fatty acid composition in peach fruits during storage. J Agrc Food Chem 2011; 54: 9447- 9452.

Correspondence:
Oguz Ayhan Kirecci
Bitlis Eren University Hizan Vocational School, Bitlis, Turkey
Phone: +90434 2220000/9320
E-mail: kireccioguzayhan@gmail.com