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Biochemical Effects of Drought Stress in Some Strawberry Cultivars

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ABSTRACT

This research was 2016-2017 years of the Selcuk University Faculty of Agriculture Department of Horticulture Research and practice was carried out in the greenhouse. Study the Yalova Atatürk Central Horticultural Research Institute, Ata-77, Bolverim-77, Doruk-77, Dorukhan-77, Eren-77, Erenoğlu-77, and Hilal-77 strawberry varieties. After the planted strawberry seedlings reached the 5-6 leaf stage, after irrigation at field capacity, drought application was made until the plants lost their leaf turgor. After implementation of the varieties of drought with healing and drought period of watering again losses to determine.

In strawberry cultivars, significant decreases occurred in the amount of protein with the application of drought. In the recovery period after the drought, the protein amounts increased again. Drought treatment significantly increased proline content in all cultivars compared to control. Catalase enzyme activity in all strawberry cultivars increased significantly as a result of drought application in both years. There was a slight decrease in the recovery period. In both years of the study, drought application increased the peroxidase enzyme activity in all strawberry cultivars compared to the control, and a slight decrease occurred in the recovery period compared to the drought application. Drought application in cultivars increased the superoxide dismutase enzyme activity a little compared to the control, while the activity decreased to the control level during the recovery period.

1. Introduction

Strawberry is one of the important fruit species grown commercially in the world and Turkey, and this importance is increasing. Strawberry is a type of fruit that can easily adapt to different ecological conditions and climate types. It can be grown in different ecological conditions from Siberia to Ecuador, from places with high altitudes to places at sea level. Therefore, it can be grown in almost every region in Turkey (Geçer and Yılmaz, 2011). Strawberry is produced mostly in the Mediterranean and Aegean regions in Turkey, and it has started to be grown in the inner regions over time. In the world, China, the USA, Mexico, Turkey, Spain, and Egypt are important strawberry producer countries (FAO, 2021).

Today, drought has reached social and economic dimensions that threaten the environment with the increase in the world population, climate changes, deforestation, and global warming. Drought is one of the natural disasters that cause the most damage to people and the environment and cause great losses. It is predicted that Turkey is among the countries in a high-risk group in terms of the possible effects of global warming and that the Mediterranean and Central Anatolia regions will be more affected by climate change in the future. Climate elements and especially the precipitation factor, which has the greatest effect on production, show great changes in time and space. Although the annual precipitation average in Turkey is around 640 mm, water shortage and drought are experienced in many regions due to the irregularity of the precipitation distribution (Özcan et al., 2004). Atmospheric conditions, physical geography factors, and climatic conditions are among the main factors affecting drought in Turkey. Drought stress is caused by the lack of moisture required for the plant to grow normally and complete its life cycle; It is common in regions where rainfall is irregular and irrigation is insufficient (Sircelj et al., 2007). Drought is a meteorological phenomenon in general terms, and it is defined as the period when there is no precipitation until the water

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content of the soil and plant growth decreases significantly and the amount of water shortage is sufficient to suffer (Özcan et al., 2004). In drought conditions, the water potential of the soil and then the plant decreases. Then, low turgor pressure, closure of stomata, decrease in leaf growth, and decrease in photosynthesis occurs. Plants exposed to drought stress have limited growth, lower dry matter production, increased susceptibility to diseases and pests and decreased product quality and quantity (Monti, 1987).

Stress is defined as the force physically applied to an object. However, the calculation of the biological stress force is quite difficult. Because while biological conditions cause stress in one plant species, they may be normal for another species (Mahajan et al., 2005). Practically, biological stress is a counterforce and is defined as the inability of plants to perform their biological functions and the deterioration of their systems (Jones, 1990). Plants encounter many stress factors throughout their lives, and these factors can be examined into two groups abiotic and biotic. These stress factors reduce the biosynthetic capacity of plants and change their normal functions and cause damage that will lead to death (Ekmekçi and Kalefetoğlu, 2005). Abiotic stress contains significant threats in terms of aquaculture with the deterioration of environmental factors, and it causes negative changes in plants in morphological, physiological, biochemical, and molecular directions, leading to more than 50% of product loss and low yield in the world (Wang et al., 2003).

Plants to drought stress; respond with the changes they show in morphological, biochemical, and metabolic processes. As a result, plants exposed to water scarcity are more sensitive to other biotic and abiotic stresses (Caruso et al., 2008). Stress tolerance; is the ability of plants to survive against adverse environmental conditions. Plants form a two-way defense mechanism against drought stress, either by avoiding stress or by developing stress tolerance (Mundree et al., 2002). Drought tolerance is species-specific and even cultivar-specific, and it is of great importance to determine the stress avoidance abilities of plants in terms of determining their tolerance (Özcan et al., 2004). In addition to the tolerance mechanisms created against the mechanical damage caused by drought, plants have also developed various enzymatic defense systems against oxidative stress (Bian and Jiang, 2009). High levels of antioxidative enzyme activity in plants significantly reduce oxidative damage in drought tolerance (Sharma and Dubey, 2005). However, the activity of these antioxidant enzymes produced during drought varies according to the plant type, variety, stress intensity, and duration (Bian and Jiang, 2009).

Global warming, which is seen as a potential threat to agricultural production in the future and whose effect is felt increasingly day by day, will require the determination of drought tolerance of cultivated plants and the cultivation of new drought-tolerant genotypes. For this purpose, in this study, a total of 7 domestic short-day strawberry cultivars, Bolverim-77, Hilal-77, Doruk-77, Dorukhan-77, Ata-77, Eren-77, Erenoğlu-77, bred in Yalova Horticultural Institute.

2. Materials and Methods

Materials

This research was carried out in the greenhouse of the Department of Horticulture, Faculty of Agriculture, Selcuk University in 2016-2017. In the research, a total of 7 strawberry cultivars, Bolverim-77, Hilal-77, Doruk-77, Dorukhan-77, Ata-77, Eren-77, Erenoğlu-77, were bred in Yalova Horticultural Central Research Institute, were used.

Characteristics of the strawberry cultivars used

ATA-77: Tioga x Cruz hybrid. Its fruits are medium-sized, the outer color of the fruit is bright red, the fruit is easy to break from the stem, the fruit flesh is hard, the fruit is heart-shaped, and the taste and smell are very good. Although it is table quality, it is also suitable for the food industry (Anonymous, 2017).

BOLVERİM-77: Tioga x Yalova-104 hybrid. The fruits are large, the outer color of the fruit is bright light red, the fruit is easy to break from the stem, the hardness of the fruit is medium, the shape is flattened, and the fruit taste is medium. It is suitable for the food industry (Anonymous, 2017).

DORUK-77: Tufts x Cruz hybrid. The fruits are small, the outer color of the fruit is bright red, the fruit is easy to break from the stem, and the fruit flesh is quite hard. It is suitable for the food industry and can also be used as a table (Anonymous, 2017).

DORUKHAN-77: Tufts x Cruz hybrid. The fruits are medium-large, the outer color of the fruit is bright red, the fruit is easy to break from the stem, and the fruit flesh is hard. It is quite efficient. Although it is table quality, it is also suitable for the food industry (Anonymous, 2017).

EREN-77: Ottoman x Tufts hybrid. Its fruits are medium-large, conical in shape, the outer color of the fruit is bright red, the fruit is easy to break from the stem, the taste and smell are very good, the fruit quality is good and the fruit flesh is hard. It is a table variety suitable for the food industry (Anonymous, 2017).

ERENOĞLU-77: Cruz x Tioga hybrid. The fruits are large, the outer color of the fruit is bright red, the fruit is easy to break from the stem, and the fruit flesh is medium hard. The taste and smell are very good, heart-shaped, and very easy to break from the stem. Fruit quality is very good (Anonymous, 2017).

HİLAL-77: Ottoman x Tufts hybrid. The fruits are medium-large, heart-shaped, the outer color of the fruit is bright red, the fruit is very easy to break from the stem, the taste and smell are very good, the fruit quality is good and the fruit flesh is hard. It is a table variety suitable for the food industry (Anonymous, 2017).

Methods

In the study, frigo strawberry seedlings were planted in 3-liter pots filled with peat. After the seedlings are planted, the flowers and branches are plucked until they reach the 5-6 leaf stage, and vegetative development of the plants is ensured. The seedlings, whose development was completed, were irrigated at the field capacity level and no irrigation was applied until the first sign of drought (withering of the leaves). After the first sign of drought, the plants started to be watered again and the recovery vitality was maintained. In the research, biochemical analyzes were made on plants during the drought application and during the re-irrigation phase.

The study was planned on 7 strawberry cultivars with a 15-day drought application followed by re-irrigation and the recovery of the plants. In the study, there were 3 replications and 3 plants in each replication.

Biochemical Analysis

Protein determination in plants under stress was made according to the "Bradford" method using 0.5 g plant samples. Results were calculated in terms of “mg protein/g” of fresh tissue (Bradford, 1976).

Proline determination was made spectrophotometrically by the acid-ninhydrin method (Bates et al., 1973).

While the activity of catalase (CAT) enables the conversion of H2O2 to oxygen and water in the environment, it is based on monitoring the absorbance change at 240 nm (Havir and Mchale, 1987).

Peroxidase (POD) activity determination is based on monitoring the absorbance increase at 470 nm caused by the colored compound, which is the product of the reaction in which guaiacol and H_2O_2 are substrates (Angelini and Federico, 1989).

Superoxide dismutase activity is based on the spectrophotometric determination of the inhibition of the photochemical reduction reaction of nitro blue tetrazolium (NBT) with superoxide radicals to the blue-colored formazone by the SOD enzyme (Agarwal and Pandey, 2004).

3. Results and Discussion

Results

The effect of drought stress on the amount of soluble protein in strawberry cultivars

Significant decreases in protein amount occurred with the application of drought in strawberry cultivars. In the recovery period after the drought, the protein amounts increased again. However, with these increases, the protein level did not increase to the control level in cultivars except Doruk-77 (Table 1.).

Table 1
The effect of drought stress on the amount of soluble protein (μg g^{-1} TA) in strawberry cultivars.

Cultivars	2016				2017			
	0-day	15th-day control	15th-day drought	7th-day recovery	0-day	15th-day control	15th-day drought	7th-day recovery
Doruk-77	33.91 a	34.32 a	19.59 a	34.03 a	34.92 a	35.63 a	21.94 a	34.83 a
Dorukhan-77	29.36 b	31.10 b	14.74 bd	23.08 b	29.80 b	31.23 b	16.51 c	23.66 b
Hilal-77	22.86 d	23.33 c	13.15 d	16.59 e	23.56 e	23.00 e	15.10 e	17.00 e
Bolverim-77	28.62 b	29.00 b	14.28 c	18.17 d	28.91 b	29.42 b	15.70 d	18.62 d
Eren-77	26.00 c	25.45 c	15.22 b	19.44 c	26.39 c	26.12 c	17.50 b	19.93 c
Erenoğlu-77	24.50 cd	24.16 c	12.49 e	17.57 de	25.26 cd	24.75 d	14.36 f	18.00 de
Ata-77	23.17 d	22.84 c	13.25 d	17.56 de	23.63 de	24.36 de	14.57 ef	18.00 e
LSD	2.32	2.80	0.77	1.57	2.39	2.41	0.85	1.61

*: There is no difference between the averages shown with the same letter in the same column

As a result of our study, the amount of protein decreased with the application of drought in strawberry cultivars. This result was similar to Brito et al. (2003), olive, Behnamnia et al. (2009)'s tomato, and Zanjani et al. (2012) zucchini. Drought stress causes a disturbance in the protein metabolism of the plant. This disorder is seen as the breakdown of proteins and decreased protein synthesis (Kutlu, 2010).

Effect of drought stress on proline amount in strawberry cultivars

Drought treatment significantly increased proline content in all cultivars compared to control. In the recovery period after the drought, a decrease was detected in the proline content, but with these decreases, the proline content remained above the control level (Table 2).

Table 2
Effect of drought stress on proline amount (μg g^{-1} TA) in strawberry cultivars.

Cultivars	2016				2017			
	0-day	15th-day control	15th-day drought	7th-day recovery	0-day	15th-day control	15th-day drought	7th-day recovery
Doruk-77	15.86 e	15.78 d	29.16 d	19.35 f	19.23 e	21.63 e	26.10 f	22.63 e
Dorukhan-77	29.69 b	27.61 b	40.85 c	34.68 b	20.96 d	22.12 de	27.75 e	22.33 e
Hilal-77	23.14 cd	2300 c	44.94 b	31.38 c	28.43 b	31.24 b	38.47 b	31.08 b
Bolverim-77	29.63 b	27.56 b	28.35 de	38.81 a	24.39 c	26.86 c	38.97 b	28.94 c
Eren-77	31.11 a	32.18 a	27.30 e	34.79 b	23.43 c	24.50 cd	31.08 d	27.11 d
Erenoğlu-77	22.29 d	23.14 c	49.99 a	24.45 e	33.29 a	36.78 a	44.27 a	38.66 a
Ata-77	24.30 c	24.50 c	42.02 c	27.24 d	21.44 d	24.96 c	35.89 c	27.13 d
LSD	1.82	2.56	2.47	1.07	1.51	2.89	2.01	1.08

*: There is no difference between the averages shown with the same letter in the same column

Proline is a water-soluble amino acid that generally accumulates under stress conditions and acts as an indicator in terms of providing the plant's resistance ability (Bian et al., 1988). Besides serving as an osmolyte, it is an effective substance in stabilizing cells, adjusting cytosolic pH, and regulating hydroxyl radicals (Matysik et al., 2002). Plants exposed to stress accumulate various soluble substances in their cytoplasm and organelles to maintain osmotic balance. Apart from providing a positive effect on enzymes, these substances also play a role in ensuring osmotic regulation in plants under stress by maintaining membrane integrity (Ashraf and Foolad, 2007). In our study, it was determined that the amount of proline increased in strawberry plants under drought stress. Similarly, Alizadeh et al. (2011) on different apple rootstocks, Abbaspour et al. (2012) In Pistachio, Karimi et al. (2012) almond and GF 677 rootstock, Rostami and Rahemi (2013) fig, Bolat et al. (2014) found that drought stress caused increases in proline amounts in apple and pear, İpek (2015) on Myrobolan and Garnem rootstocks.

Effect of drought stress on Catalase (CAT) enzyme activity in strawberry cultivars

Catalase enzyme activity in all of the strawberry cultivars we used increased significantly as a result of drought application in both years. There was a slight decrease in the recovery period. In 2016, the cultivar with the highest catalase enzyme activity was Doruk-77, and in 2017, Erenoğlu-77 was found (Table 3).

Catalase is one of the most important enzymatic antioxidants that catalyzes the direct reduction of high concentration H_2O_2 to water and oxygen by using its 2 electrons (Dionisio-Sese and Tobita, 1998). When the genes encoding different catalase isozymes in many plants under stress were examined, it was observed that the expression levels of the genes encoding this enzyme increased in relation to stress (Millar et al., 2003). In our study, significant increases in catalase enzyme activity were detected in strawberry plants kept under drought stress. These results we obtained are also compatible with drought stress studies on different plants (Reddy et al., 2004; Chai et al., 2005; Moussa and Abdel-Aziz, 2008).

Effect of drought stress on peroxidase (POD) activity in strawberry cultivars

In both years of the study, drought application increased the peroxidase enzyme activity in all strawberry varieties compared to the control, and a slight decrease occurred in the recovery period compared to the drought application (Table 4).

Table 3
Effect of drought stress on Catalase (CAT) enzyme activity (EU g^{-1} TA) in strawberry cultivars

Cultivars	2016				2017			
	0-day	15th-day control	15th-day drought	7th-day recovery	0-day	15th-day control	15th-day drought	7th-day recovery
Doruk-77	161.83 e	155.01 g	783.83 a	402.17 e	143.00 e	145.36 f	508.17 b	377.83 c
Dorukhan-77	192.50 d	191.30 f	722.17 b	491.00 c	203.17 d	197.65 e	412.33 d	259.83 e
Hilal-77	362.51 a	345.36 a	442.62 d	426.33 d	387.67 a	380.25 b	476.00 c	401.00 b
Bolverim-77	204.50 d	200.36 e	701.83 b	477.50 c	266.17 c	271.36 d	358.83 e	327.50 d
Eren-77	231.33 c	236.75 d	691.67 b	528.17 b	294.17 b	290.01 c	425.67 d	329.00 d
Erenoğlu-77	301.33 b	289.63 b	466.67 d	391.17 e	398.00 a	387.34 a	624.33 a	455.67 a
Ata-77	248.00 c	255.02 c	575.33 c	555.17 a	383.33 a	380.69 b	470.67 c	450.67 a
LSD	31.24	2.80	54.19	24.76	38.34	2.38	25.93	26.29

*: There is no difference between the averages shown with the same letter in the same column

Table 4
Effect of drought stress on peroxidase (POD) enzyme activity (EU g^{-1} TA) in strawberry cultivars.

Cultivars	2016				2017			
	0-day	15th-day control	15th-day drought	7th-day recovery	0-day	15th-day control	15th-day drought	7th-day recovery
Doruk-77	406.53 a	400.01 a	1050.80 a	637.60 a	479.67 a	470.85 a	1054.80 a	623.33 a
Dorukhan-77	355.33 b	359.33 b	520.53 c	444.24 c	388.00 b	384.00 b	768.13 b	480.33 b
Hilal-77	192.53 g	187.44 g	333.33 e	316.80 f	288.00 e	280.01 e	488.80 d	374.33 c
Bolverim-77	294.40 c	290.18 c	637.86 b	549.87 b	323.00 c	326.00 c	467.46 e	362.33 c
Eren-77	225.20 e	229.66 e	358.13 e	313.80 f	245.66 f	240.23 f	492.80 d	301.66 d
Erenoğlu-77	266.13 d	270.61 d	475.60 d	347.60 e	301.33 d	299.63 d	595.73 c	387.33 c
Ata-77	207.80 f	205.36 f	440.00 d	276.40 d	233.33 g	230.14 g	426.80 f	383.33 c
LSD	5.02	2.44	55.73	10.19	4.21	3.08	6.54	54.82

*: There is no difference between the averages shown with the same letter in the same column

It has been reported that high POD activity is associated with drought tolerance of plants and an increase in POD activity may contribute to drought stress tolerance (Sairam and Srivastava, 2000). In our study, POD activity increased in all cultivars under drought stress. Similar results were obtained in studies on this subject. Tanaka et al. (1990) reported that POD activity increased in spinach leaves under water stress. Similarly, Bolat et al. (2014) in apple and pear, Patel et al. (2011) reported an increase in POD activity under drought stress in chickpea.

Effect of drought stress on superoxide dismutase (SOD) activity in strawberry cultivars

Drought application in cultivars increased the activity of superoxide dismutase enzyme slightly compared to the control, while the activity decreased to the control level during the recovery period (Table 5).

Table 5
Effect of drought stress on superoxide dismutase (SOD) enzyme activity (EU g^{-1} TA) in strawberry cultivars

Cultivars	2016				2017			
	0-day	15th-day control	15th-day drought	7th-day recovery	0-day	15th-day control	15th-day drought	7th-day recovery
Doruk-77	465.59 c	460.13 d	624.69 a	404.76 d	479.35 a	480.00 a	540.64 bc	418.06 f
Dorukhan-77	444.26 d	440.01 e	572.15 c	403.89 d	435.12 c	438.12 c	549.25 b	428.42 e
Hilal-77	503.51 a	505.78 a	542.54 f	463.65 a	423.51 c	420.00 f	483.44 e	443.44 d
Bolverim-77	423.08 f	420.52 g	567.56 d	418.35 c	438.99 c	443.11 b	514.84 d	484.98 b
Eren-77	434.55 e	436.99 f	557.69 e	423.62 b	435.91 b	428.36 d	529.60 cd	414.69 f
Erenoğlu-77	507.13 a	50.15 b	604.33 b	407.09 d	419.49 c	425.19 e	585.80 a	457.92 c
Ata-77	473.19 b	470.32 c	556.06 e	424.84 b	417.63 c	427.85 de	543.30 bc	505.59 a
LSD	7.72	3.20	4.49	6.34	30.16	2.92	22.76	7.06

*: There is no difference between the averages shown with the same letter in the same column

Oxidative stress in plants under drought stress causes the formation of reactive oxygen species (ROS) in cells. Plants use antioxidant enzymes such as SOD, GR, CAT, and APX to neutralize these radicals. The superoxide anion (O_2^-) is converted to H_2O_2 by the SOD enzyme in the cells and H_2O_2; other enzymatic systems are broken down into HO and O_2 by POD, APX, and GR (Bian and Jiang, 2009).

In our study, an increase in superoxide dismutase enzyme activity was detected in all cultivars during the drought period. Many researchers have examined the SOD enzyme activity in different plants under different stress conditions. Gong et al. (2005) stated that the SOD enzyme activity in wheat was lower under drought conditions, while Yediyıldız (2008) determined that there were no significant differences in SOD activity of wheat varieties under salt and drought stress compared to the control. Rahman et al. (2002) determined that the SOD enzyme reached the highest level at the end of the stress in tomato plants under drought stress. Reddy et al. (2004) mulberry, Cai et al. (2005) in coffee, and Sivritepe et al. (2008) found an increase in SOD enzyme activity in Gisela-5 rootstock grown in vitro.

4. Conclusions

It occurs when the usable water in the soil decreases in plants and water is lost by transpiration or evaporation due to atmospheric conditions (Jaleel et al., 2009). Drought stress is one of the most important stresses affecting plant growth and yield, and it affects many physiological, biochemical, and molecular properties in plants (Özfidan, 2010). Therefore, understanding the physiological and biochemical responses of plants in resistance to drought stress will be useful in identifying species and varieties that are resistant to drought conditions. In this context, in our study on newly bred strawberry cultivars, it was determined that the responses of cultivars to drought stress differ.

Factors that inhibit plant growth are called stress. Stress caused by drought, salinity, high and low temperatures, and heavy metals is common in many agricultural parts of the world. In recent years, with the effect of global warming, the importance of water has started to be felt more and more with agricultural drought. Plants develop tolerance mechanisms to adapt to environmental conditions like physiological, biochemical, and molecular responses to drought stress (İpek, 2015). Decrease in the amount of protein in varieties with drought application; proline, catalase, peroxidase, and superoxide dismutase enzyme activities increased.

In plants in general, the continuation of growth and development depends on the preservation of the water content of the cell. The lack of water in the plant causes a decrease in photosynthesis and thus a slowdown in development and, as a result, a decrease in yield and quality. As a result, irrigation systems have been emphasized and new methods have been developed to combat drought. However, nowadays, these are insufficient with the decrease in irrigation water. In this context, the selection of resistant plants should be emphasized to obtain drought-resistant plants. In addition, elucidating the drought stress mechanism will help to develop drought stress-resistant plants.

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