THE EFFECTS OF DROUGHT STRESS ON CORN (*Zea mays* L. *indentata*) ANATOMY

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Abstract. The summer crop corn under arid condition was cultivated by applying drip irrigation system in Mazıdağı, Mardin, Türkiye. Arid condition (50%) was identified as an issue of irrigation. For anatomical analysis, cross sections of the cortex and xylem vessel in the root; cuticle, epidermis, and xylem vessel in the stem; midrib region, mesophyll, bundles, bullate, upper and lower epidermis, xylem vessel, and cuticle in the leaf were examined by microscopy research techniques. As a result, some anatomical characteristics of corn differed from full-irrigation condition to arid condition depending on drought. However, the corn cultivated under arid condition anatomically adapted to the condition having drought stress and did not have anatomical anomaly. In conclusion, especially for varieties adapting to drought, it is suggested that studies of improvement should be carried out after determining anatomical features in crop cultivation. The study will pave the way for cultivation and other studies which will be carried out by using various abiotic factors in plants.
Keywords: *ecological need, irrigation application, plant histology, plant ultrastructure, water deficit*

Introduction

One of the assurances of economic and social systems in society is fresh water resources. Limited and dispersed fresh water resources in Turkey and in the world have been easily used by human beings for ages. However, global warming due to global climate changes has had a negative effect on water resources. It has also affected the selection of methods and systems in agricultural irrigation.

Today, the usage of new irrigation technologies protecting soil and water resources in agricultural irrigation, pressurized irrigation systems which have especially high irrigation efficiency, distribute water homogeneously and need less labor have become widespread (Demirok and Tuylu, 2017). The drip irrigation system or the sprinkler irrigation system has been widely applied in cultivation in the provinces in the South Eastern Anatolia Region, Türkiye depending on drought. The summer crop corn is cultivated in Mazıdağı, Türkiye by using the systems mentioned. The production of corn cultivated was 3569 ton and the yield of corn is 880 kg da^{-1} in Mazıdağı in 2018 (Anonymous, 2019).

Plants grow in the biotic and abiotic conditions they need. The fact that these conditions are more or less causes stress in plants. As stated in Korkmaz and Durmaz (2017), plants undergo changes in terms of quality of stress factor and genetical, and ontogenetic features of plants. In this way, plants conform with the environment where they live by means of the changes.

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It is known that there are specific critical periods which are sensitive to stress in process of plant growth. When the plant is exposed to water deficit in the periods in question, it is physiologically affected in a negative way and the yield decreases considerably. The fact that considering the periods when the plant is affected by stress specifically in the places in which there is shortage of water is significant for irrigation management (Yazar, 1990). Stress reactions can be observed in some characteristics of plants depending on drought. One of these characteristics is Plant Anatomy.

In the study, it was aimed to contribute to determine the accurate ecological need in terms of the irrigation strategy of the corn variety by examining structures of cell, tissue and organ. When the characteristics mentioned under arid condition are considered, it can be decided if the plant conforms with the limited water applied for growth. At the same time, the relationship between the amount of irrigation water and plant anatomy can be understood.

Materials and methods

The study was carried out in Mazıdağı (37° 28’ 37” N; 40° 29’ 41” E) in 2015. Mazıdağı is located at 1030-1090 m from the sea level, 47 km to northwest of Mardin in the South Eastern Anatolia Region, Türkiye. Plant cultivation has been performed by applying irrigation and nonirrigation in the province. The climate is hot and dry in summers and cold and rainy in winters in the province. The average rain fall has been 667.4 mm and July has been the hottest month for years (Anonymous, 2017). Some climatic data belonging to the cultivation area and the period (from July 15 to November 15, 2015) is given in *Table 1*. The soil in Mazıdağı is medium-textured and contains sand, silt, and clay (*Table 2*).

Table 1. *Some climatic data of the study area in 2015 (Anonymous, 2017)*

Climatic data		Maximum temperature (°C)	Minimum temperature (°C)	Evaporation (mm)	Relative moisture (%)	Wind speed (m sn^{-1})	Sunshine (h)	Rainfall (mm)
Months	Decades							
June	1	30.4	16.5	22.5	32.8	1.9	10.6	2.0
	2	31.4	16.5	23.8	33.2	1.9	13.0	0.0
	3	32.6	17.8	27.8	32.0	1.9	12.5	0.0
July	1	37.0	20.5	17.3	23.9	1.8	12.4	0.0
	2	38.0	23.5	8.7	22.7	2.4	12.0	0.0
	3	38.5	22.9	14.2	18.0	1.6	12.0	0.0
August	1	37.8	22.2	19.2	24.0	1.8	11.7	0.0
	2	37.0	21.7	24.5	29.9	1.8	12.2	0.0
	3	34.2	20.3	32.3	27.3	1.8	11.3	0.0
September	1	35.0	20.3	19.3	24.4	1.5	9.8	0.0
	2	34.6	20.1	27.2	21.0	1.4	10.1	0.0
	3	30.6	17.2	26.7	33.1	1.6	10.8	0.0
October	1	25.2	13.6	28.4	56.4	1.4	7.9	11.4
	2	25.2	12.0	33.0	45.8	1.2	9.5	0.3
	3	19.3	11.1	25.7	84.9	1.1	4.2	63.6
November	1	16.3	5.8	24.4	67.2	1.1	6.9	13.8
	2	14.0	4.9	21.7	59.6	1.4	7.4	22.8
	3	14.7	3.6	26.5	64.2	1.0	6.2	0.7
Year	2015	21.2	9.7	821.1	55.9	1.6	94.3	431.9

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Table 2. *Soil properties of study area*

	Field capacity (%)	Wilting point (%)	Bulk density (g cm^{-3})	Infiltration (mm h^{-1})	pH	Texture		
						Sand (%)	Silty (%)	Clay (%)
0-90	36.2	18.5	1.285	3.3	7.6	34.4	30.6	35.0

Offspring F_1 included in the group of Ventoruli Italian hybrid FAO 600 (the 120-day) of corn (*Zea mays* L. *indentata*) was selected as the research material. It is cultivated as the summer crop in Mazıdağı. The time of seed planting is July 15th on average. In the study area, the irrigated parcels were arranged in a completely randomized experimental design with irrigation treatment replicated three times. Each parcel was 7.28 m^2, and seeds of corn were planted as 16 × 70 cm and 5 sequenced. Two sequences were separated as border effect in the evaluation. Irrigation water was applied by drip irrigation systems. Irrigation interval was selected as a 6-day period due to the conditions of the farmers in the region. The source of underground water was used in irrigation and the water quality was C_2S_1 class. Irrigation issues were designed according to Class A Pan method (Demirok and Tuylu, 2017; Kırnak et al., 2003). The control group under full-irrigation condition (I_1) was the same as the one under full-irrigation condition determined in Tuylu (2018a). Class A Pan Coefficient (kcp) was obtained from the different irrigation applications in the preliminary tests (kcp = 1) in Tuylu (2018a). The present study was carried out together with Tuylu (2018a) under the same conditions and the same period. Arid condition (I_2) was created by reducing 50% of the full-irrigation issue and 352 mm irrigation water was applied in the present study. Base fertilizer, N, and P_2O_5 were evenly applied to the parcels for both conditions (5 kg da^{-1}). Fighting against diseases was not required and weeds were cleared by hand.

The samples of root, stem and leaf belongs to corn cultivated vegetatively and generatively under I_2 condition were kept in alcohol 70%, they were protected, and anatomically examined. The tiny pieces of the samples which were taken from lower, middle, and upper parts of the roots, stems, and leaves were fixed at +4°C using 3% glutaraldehyde (with 0.1 M Na-P buffer solution) and 1% osmium tetroxide (with 0.1 M Na-P buffer solution) respectively. After dehydration and saturation, the samples were embedded in epoxy resin (Luft, 1961; Tuylu et al., 2017, 2019). The blocks were kept in incubator at 30°C for 1 night, at 45°C for 1 day and at 60°C for 1 night to be polymerized. Semithins and ultrathins were taken in cross section from the blocks trimmed using Reichert OMU-4 ultra-microtome. The thickness of semithins was 0.5-1 µm and the thickness of ultrathins was 60-100 nm. Semithins were stained by toluidine blue and were examined by light microscope Leica 1000, the results were photographed by digital camera Leica EC3, and biometric measurements were performed by Las v4.3 software. The total number of cross sections taken from the plants and examined was 90 on 9 preparats for 3 plants in each replication and a total of 270 measurement values were obtained by taking 3 from each section. The arithmetic means of the measurement values and mean standard error were calculated using basic statistical methods in Excel computer software and the results were explained. After ultrathins were stained by uranyl acetate and lead citrate (Stempak and Ward, 1964; Tuylu, 2015, 2018a), they were examined by JEOL CX-100 transmission electron microscopy (TEM) and micrographed. The total number of ultrathins examined in each replication was 27 in 9 grids for cytological evaluations. All the photos were completely original.

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Results

Roots

Vascular bundles surrounded pith like a ring in the roots cultivated under both conditions (I_1 and I_2). A lot of respiration spaces were observed in cortex under I_2. (*Fig. 1A, B, C*). One layered pericycle, and one layered endodermis surrounded the bundle (*Fig. 1B*). Starch grains were clearly observed in roots under I_2 (*Fig. 1D*). Lipids were seen in both roots under I_1 (Tuylu, 2018a) and I_2, but the distribution of lipid in the root cultivated under I_1 was denser. When they were compared, lipids were more electron-dense than starch grains in both roots (*Fig. 1D*). Cortex was formed by thin-walled parenchyma cells which could obviously be seen. Electron density was low in parenchyma cells and xylem vessels (*Fig. 1E*).

According to the results of the biometric measurements, a linear relationship was determined between the amount of irrigation water and the thickness of cortex ($p < 0.05$). The diameter of xylem vessel was not significantly affected ($p > 0.05$). For the hybrid of corn examined, the root reduced the thickness of cortex by being exposed to drought when it was cultivated by 50% water deficit. Thus, the root cultivated under arid condition adapted to the condition and did not have anatomical anomaly (*Graph 1*), ($p < 0.01$: highly significant, $p < 0.05$: significant, $p > 0.05$: no significant).

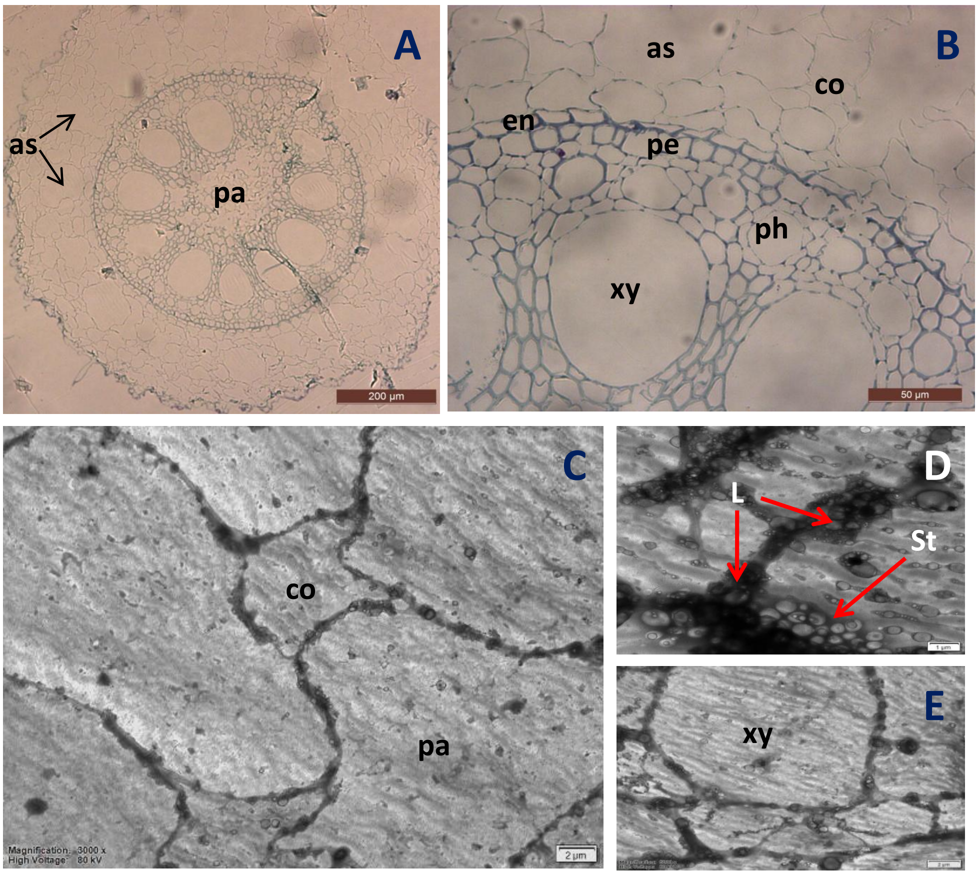

Figure 1. *Histological and cytological structure of root in Zea mays L. indentata under I_2 (cross section). A. air space (as), paranchyma (pa), bar = 200 µm, B. cortex paranchyma (co), air space (as), endodermis (en), pericycle (pe), phloem (ph), xylem (xy), bar = 50 µm, C. cortex paranchyma (co), paranchyma cell (pa), bar = 2 µm (micrograph), D. lipid (L), starch (St), bar = 2 µm (micrograph), E. xylem (xy), bar = 2 µm (micrograph)*

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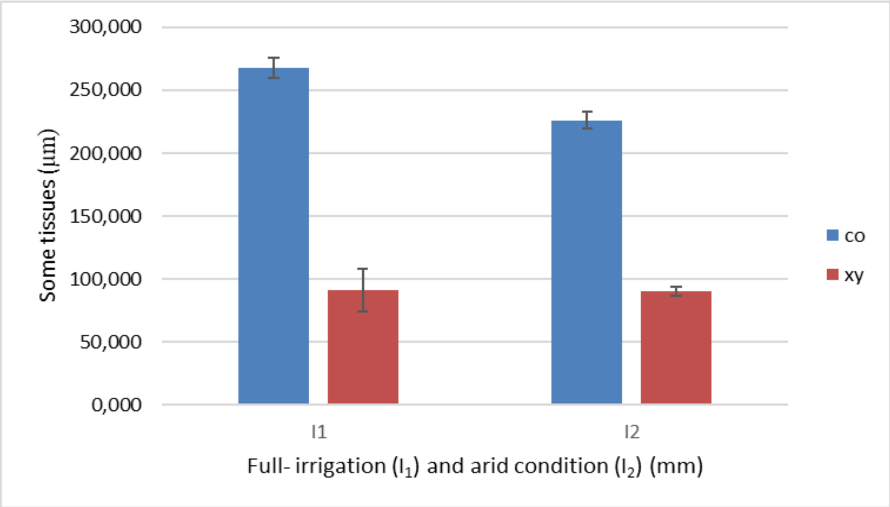

Graph 1. *The relationship between amount of irrigation water and measurements of some tissues in roots of Zea mays L. indentata under I_1 and I_2. co: the thickness of cortex, xy: the diameter of xylem vessel (p<0,01: very significant; p<0,05: significant; p>0,05: no significant).*

Stems

The stems cultivated under both conditions (I_1 and I_2) were surrounded by one layered epidermis. Stomate was rarely seen (*Fig. 2B, C*). Starch sheath was formed by large cells after cortex parenchyma from the outside towards the inside (*Fig. 2A, B*). Vascular bundles were collateral. Xylem, phloem, lacuna and vascular bundles formed by air spaces were generally surrounded by bundle sheath (*Fig. 2B, D, E, F*). A few layered sclerenchyma outward-facing supported xylem and phloem (*Fig. 2B*). The vascular bundle in the stem under I_2 was rare without lacuna and air space (*Fig. 2C*). The pith was parenchymatic. Cortex cells were cytologically large and thin-walled. (*Fig. 2F*). In Tuylu (2018a), starch and lipids were generally observed in parenchyma cells in the stem under I_1. Furthermore, starch grains were more electron-dense than lipids under I_1. Starch and lipid were rarely observed in the stem under I_2.

According to the results of the biometric measurements, the thickness of cuticle was not significantly changed ($p > 0.05$) under I_2. It was observed that the relationship between the amount of irrigation water and the thickness of epidermis ($p < 0.05$) was linear inverse while there was a linear relationship between the amount of irrigation water and the diameter of xylem vessel ($p < 0.05$). The stem cultivated under I_2 adapted to drought by thickening epidermis and reducing xylem vessels and did not have anatomical anomaly (***Graph 2***).

Leaves

The leaves cultivated under the conditions (I_1 and I_2) were unifacial and amphistomatic, and stomate was in the type of Gramineae. A great number of bullate cells with various sizes were observed in epidermis. Big and small vascular bundles were collateral. Big bundle similar to the one in the stem in midrib region was surrounded by bundle sheath and supported by sclerenchyma on both sides. Supporting tissue increased in the midrib region in the leaf cultivated under I_2. While the distance between small bundles were close to each other in the leaf under I_1 (Tuylu, 2018a), they

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increased the distance in the leaf under I_2 (*Fig. 3A, B, C*). It was observed that mesophyll cells under I_1 were cytologically oval or round and regular, but the cells under I_2 were more irregular (*Fig. 3F*). Vascular bundles and bundle sheath cells around them under I_2 were more electron-dense (*Fig. 3D, E*) than the bundles under I_1. Starch and lipid were observed in the leaf under I_2. Lipids were more electron-dense than starch grains (*Fig. 3D, E*). Starch and lipid were rarely observed in the leaf under I_1.

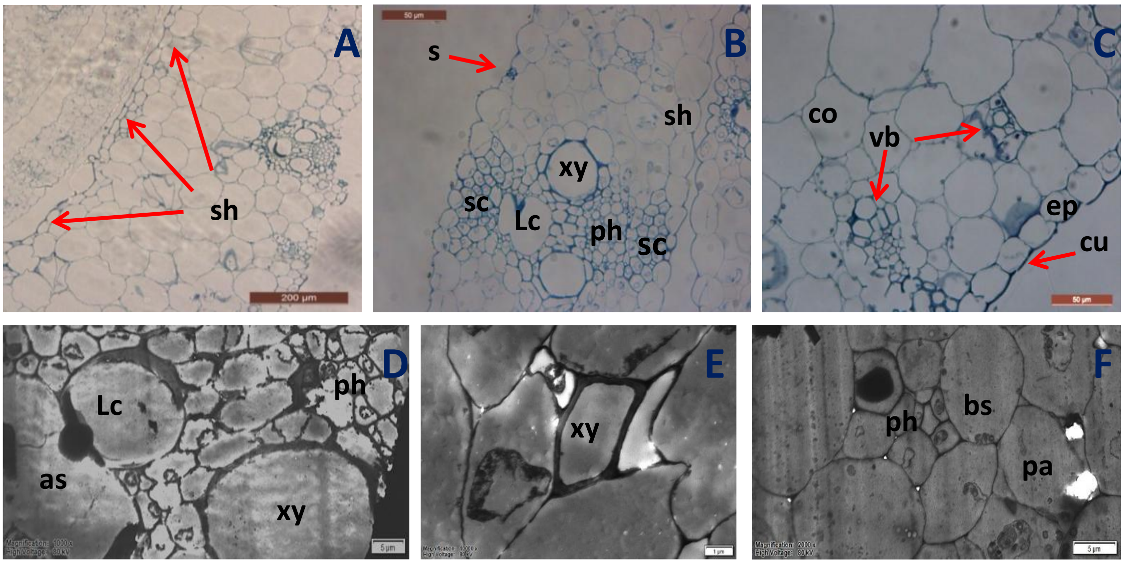
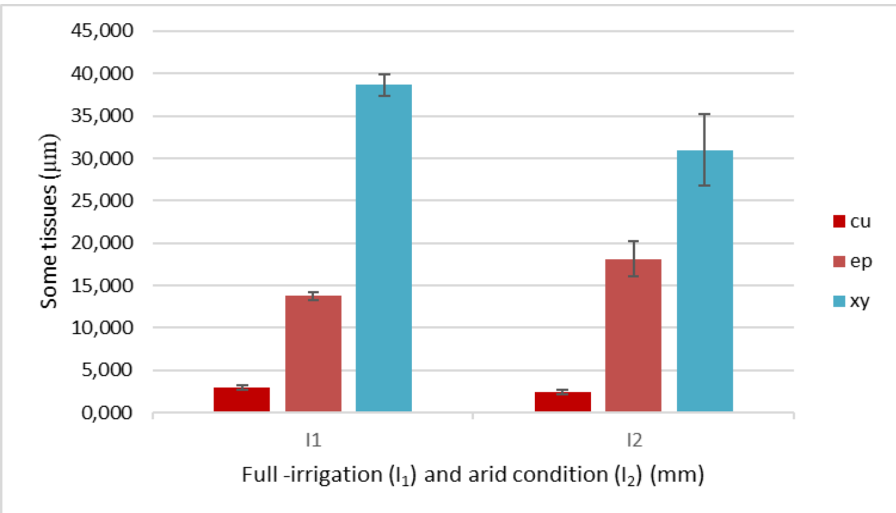


Figure 2. *Histological and cytological structure of stem in Zea mays L. indentata under I_2 (cross section). A. starch sheath (sh), bar = 200 µm, B. stomate (s), sclerenchyma (sc), phloem (ph), xylem (xy), lacuna (Lc), sheath (sh), bar = 50 µm, C. cuticle (cu), epidermis (ep), vascular bundle (vb), cortex paranchyma (co), bar = 50 µm, D. phloem (ph), xylem (xy), lacuna (Lc), air space (as), bar = 5 µm (micrograph), E. xylem (xy), bar = 1 µm (micrograph), F. phloem (ph), bundle sheath (bs), paranchyma cell (pa), bar = 5 µm (micrograph)*



Graph 2. *The relationship between amount of irrigation water and measurements of some tissues in stems of Zea mays L. indentata under I_1 and I_2. cu: the thickness of cuticle, ep: the thickness of epidermis, xy: the diameter of xylem vessel (p<0,01: very significant; p<0,05: significant; p>0,05: no significant).*

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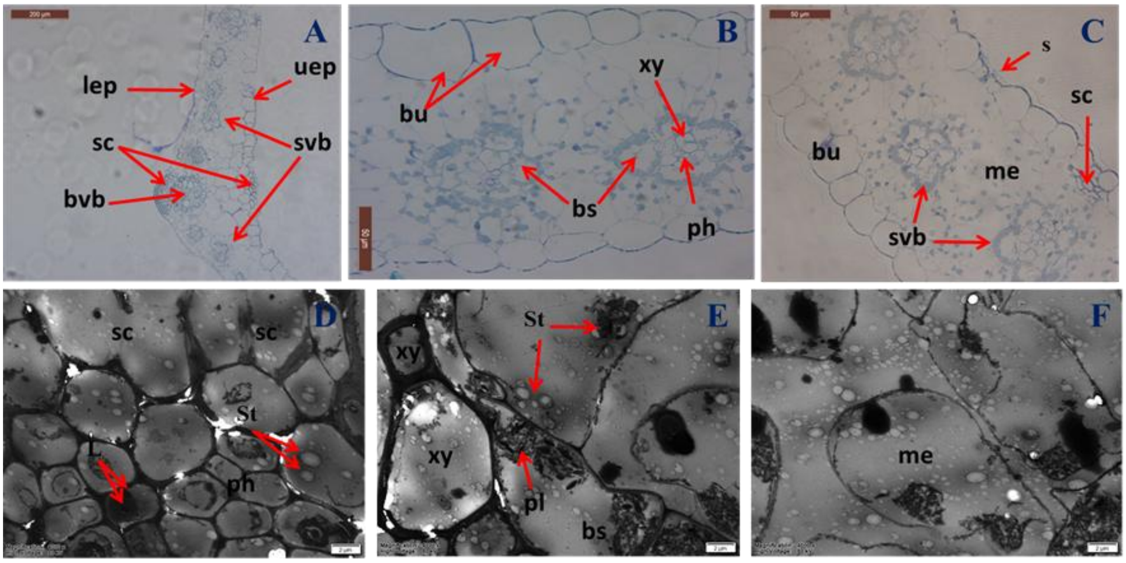

Figure 3. *Histological and cytological structure of leaf in Zea mays L. indentata under I_2 (cross section). A. upper epidermis, (uep), lower epidermis (lep), sclerenchyma (sc), big vascular bundle (bvb), small vascular bundle (svb), bar = 200 µm, B. bullate cell (bu), bundle sheath (bs), xylem (xy), phloem (ph), bar = 50 µm, C. stomate (s), bullate cell (bu), small vascular bundle (svb), sclerenchyma (sc), mesophyll (me), bar = 50 µm, D. sclerenchyma cells (sc), starch (St), lipid (L), phloem cells (ph), bar = 2 µm (micrograph), E. xylem (xy), starch (St), bundle sheath (bs), plastid (pl), bar = 2 µm (micrograph), F. mesophyll cell (me), bar = 2 µm (micrograph)*

According to the results of the biometric measurements; a linear relationship between the amount of irrigation water and the diameter of xylem vessel ($p < 0.01$), and a linear relationship between the amount of irrigation water and the width of midrib region ($p < 0.05$) were determined. A linear inverse relationship between the amount of irrigation water and the thickness of midrib region ($p < 0.01$), a linear inverse relationship between the amount of irrigation water and the thickness of upper and lower epidermis ($p < 0.05$), a linear inverse relationship between the amount of irrigation water and the width of mesophyll ($p < 0.05$), a linear inverse relationship between the amount of irrigation water and the width of bullate ($p < 0.01$), and a linear inverse relationship between the amount of irrigation water and the distance of bundles ($p < 0.05$) were obtained. The thickness of cuticle ($p > 0.05$) and the length of bullate ($p > 0,05$) were not significantly changed under I_2. The leaf cultivated under I_2 adapted to drought by reducing the diameter of xylem vessel and the width of midrib region, and increasing all the other tissues measured except for the thickness of cuticle and the length of bullate, and did not have anatomical anomaly (***Graphs 3* and *4***).

Discussion

All the plants examined were similar to the ones which were mentioned in Metcalfe (1960) and Tuylu (2018a) in terms of general anatomical characteristics. Air spaces were quite a lot in cortex in the root cultivated under I_2 and the aeranchymatic property was dominant. The thickness of the cortex decreased in the root under I_2. According to the results in the same variety of corn in Tuylu (2018a), it was determined that the thickness of

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cortex increased when the plant was irrigated more or less than its optimum water need. Additionally, it was stated that the air gaps under over-irrigation and limited irrigation conditions were much more than the ones under optimum irrigation condition. In another study carried out by Tuylu (2018b), it was mentioned that the thickness of cortex in the root was changed by water stress in two cultivars of tomato when they were anatomically compared. In the study carried out by Tuylu et al. (2018), a cultivar of tomato was examined and they stated that the cortex was thicker in the root under water stress than the one in the root cultivated under perlite. The increasing of cortex thickness was related to water stress under hydroponic culture. The studies mentioned and the present study showed that cortex in root can give anatomical reactions under drought and water stress. In Tuylu (2018a, b) and Tuylu et al. (2018) when the roots were exposed by excess water, they reacted anatomically in a similar way. In Tuylu (2018a), the cortex increased in the root in the same variety of corn under the condition created by reducing the amount of full-irrigation water by 25%. On the other hand, in the present study, the thickness of cortex decreased under I_2 created by reducing the amount of full-irrigation water by 50%.

Electron-density was low in parenchymatic tissue and xylem vessels in the root under I_1 and I_2. The fact that the lowness of electron density in the root under I_2 was similar to the one under I_1 can be anatomically associated with increasing air spaces under drought stress. Thus, the root under stress could lead to osmotic balance and tolerate negative water potential, as well. Otherwise, the cells in the root under stress would have been electron-dense due to increasing concentration of protoplasm. In the roots under both conditions in the present study and the ones under three conditions in Tuylu (2018a), lipid was densely observed in the root cultivated under full-irrigation condition while starch grains were clearly observed under all conditions. Lipid was rarely seen under the other conditions in the two studies.

It was observed that the stem cultivated under I_2 adapted to the stress condition by thickening epidermis and reducing xylem vessel. However, cuticle was not significantly changed under I_2. While the reactions of cuticle and epidermis conformed with the ones which were exposed to drought, the reaction of xylem vessel was not parallel with the one under the same condition in Tuylu (2018a). Furthermore, in the same study, it was pointed that the diameter of xylem vessel changed highly significantly as long as irrigation water was reduced. In Tuylu et al. (2018), it was stated that when the stems under hydroponic and perlite conditions were compared, cuticle was not affected, epidermis thickened and xylem vessel narrowed under water stress. Under full-irrigation condition in the present study and under optimum condition mentioned in Tuylu (2018a), starch and lipid were generally observed in parenchymatic tissue. However, starch and lipid were rarely seen under stress in the two studies.

It was observed that the cuticle, upper epidermis and lower epidermis in leaves under I_2 were thicker than the ones grown under I_1. In Tuylu (2018a), it was stated that the thickness of cuticle reduced highly significantly under stress conditions. The result mentioned was opposed to the present study. The same study pointed out the increase of the thickness of upper and lower epidermis under limited irrigation. The result conformed with the present study. The anatomical reactions of the three tissues mentioned under over-irrigation condition differed from the ones under limited irrigation conditions. The width of bullate cells with characteristics of storing water in the epidermis of the leaf increased under I_2. The result was similar to the one in Tuylu (2018a), but the increase of the length of bullate cell mentioned in the study was not affected in the present study.

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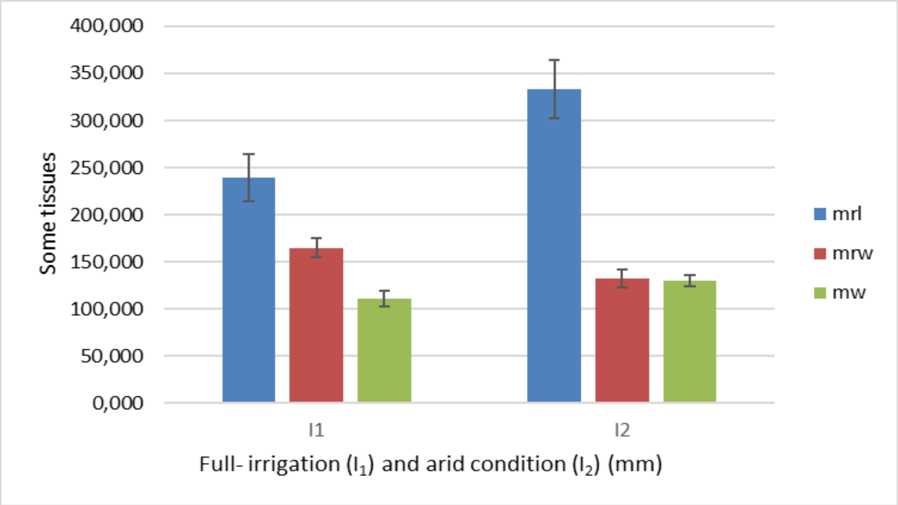
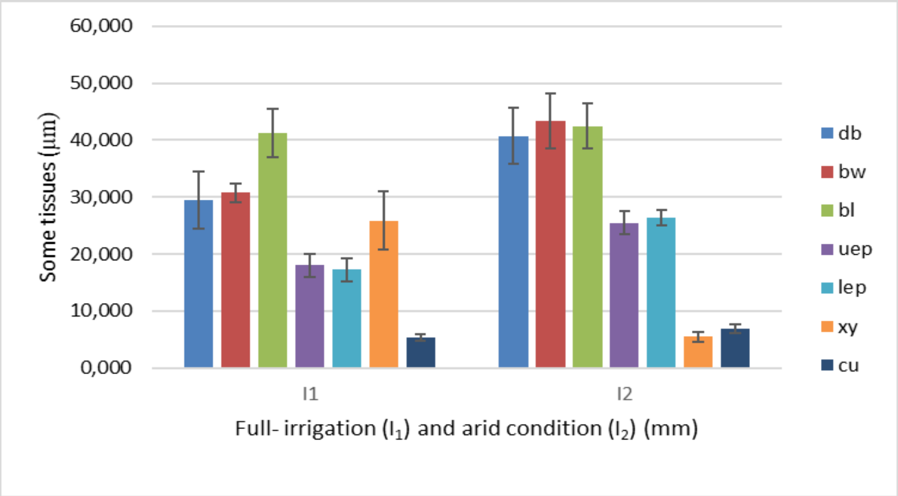


Graph 3. *The relationship between amount of irrigation water and measurements of some tissues in leaves of Zea mays L. indentata under I_1 and I_2 A. mrl: the thickness of midrib region, mrw: the width of midrib region, mw: the width of mesophyll (p<0,01: very significant; p<0,05: significant; p>0,05: no significant).*



Graph 4. *The relationship between amount of irrigation water and measurements of some tissues in leaves of Zea mays L. indentata under I_1 and I_2 B. db: the distance of bundles, bw: the width of bullate, bl: the length of bullate, uep: the thickness of upper epidermis, lep: the thickness of lower epidermis, xy: the diameter of xylem vessel, cu: the thickness of cuticle (p<0,01: very significant; p<0,05: significant; p>0,05: no significant).*

Mesophyll in the leaf under I_2 widened more than the one under I_1. Tomás et al. (2014) studied on mesophyll tissues in the grapevine cultivars exposed to stress and stated that the thickness of leaf was affected under water stress. In the present study, both epidermis tissues and mesophyll layer thickened. The result expressed that the leaf thickened and it conformed with Tomás et al. (2014). Additionally, the leaf thickness in the present study could be related to mesophyll conductance under stress condition as stated in the study. In Tuylu (2018a), it was pointed out that the width of mesophyll under over-irrigation condition was distinctly increased, but it was slightly

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increased under limited irrigation condition. Sclerenchyma increased in midrib region in the leaf under I_2. The fact that the thickness of midrib region increased, its width reduced, and mesophyll widened as well can anatomically explain that the leaf under stress curled up. In Terzi and Kadıoğlu (2006), it was stated that the responds to drought stress were quite related to anatomical and morphological changes such as the curling in the leaf. In Tuylu (2018a), it was stated that the thickness of midrib region and the width of midrib region changed under stress effect. Similarly, in Tuylu (2018b), it was pointed out that the width of mesophyll in cv. Ceren increased more clearly than the one in cv. Panda. Furthermore, it was added that the length of big vascular bundle in midrib region increased and its width reduced in cv. Ceren. The two varieties of tomato were compared in terms of measurements of mesophyll and midrib region under water stress condition. It was remarked that the measurements of the tissues mentioned had difference between two cultivars under the same stress condition in Tuylu (2018b). In Tuylu et al. (2018), the midrib region was wider and big vascular bundles were larger than the ones under perlite due to water stress. When the results in the studies were evaluated together, under stress effect the width of mesophyll, the thickness of midrib region, and the width of midrib region reacted were important anatomical parameters.

While mesophyll cells under I_1 were oval or round and more regular, mesophyll cells under I_2 were irregular. In addition, starch and lipid molecules were generally observed in mesophyll cells under I_2 while they were rarely seen in mesophyll cells under I_1. These results conformed with Utrillas and Alegre (1997)'s study carried on in C. *dactylon*. They stated that mesophyll cells exposed to drought were more irregular than the ones under well-watered condition and starch was observed in mesophyll chloroplasts under stress in C. *dactylon*. Similarly, in Tuylu (2018a), it was cytologically seen that the mesophyll cells were oval or round and regular under optimum condition, but they were irregular under stress effects. Furthermore, in Tuylu (2018a), it was stated that starch and lipid were observed in the leaves under stress conditions.

The diameter of xylem vessels reduced in direct proportion to amount of decreasing irrigation water in the present study. These results conformed with Tuylu (2018a). When the results were evaluated together, it could be explained that the diameter of xylem vessel was directly affected under drought or water stress. Additionally, the distance between small vascular bundles increased under I_2. Bundle sheath cells and the other tissues were generally cytologically electron-dense in the leaf under I_2. These results conformed with the results mentioned in Tuylu (2018a).

Finally, some tissues of corn cultivated were evaluated by performing biometric measurements. No clear anatomical difference was observed in the plants cultivated under the both conditions. No abnormal changes were seen in development of basic tissues. To sum up, some characteristics such as length, thickness, distance, and diameter in various tissues of the variety of corn examined showed changes due to adaptation to drought. The thickness of cortex in the root, the thickness of epidermis, and the diameter of xylem vessel in the stem, the thickness of upper and lower epidermis, the width of mesophyll, the width of midrib region and the distance of bundles in the leaf changed significantly under drought stress. The diameter of xylem vessel, the thickness of midrib region, and the width of bullate in the leaf reacted highly significantly anatomically under drought stress.

Conclusions

As a result, it was figured out that the cultivar of corn examined was histologically and ultrastructural suitable for cultivation by limited irrigation. In the study carried out by Biber and Kara (2006), they stated that there would be some yield decrease related to water deficit. However, the decrease in the ratio of yield was not equal to percentage of water deficit. To determine the accurate irrigation strategy in cultivation of corn cultivar studied, the properties of the fruit of the plant should be considered in terms of the yield and quality parameters to be able to apply limited irrigation creating by 50% water deficit in the province. In addition, in the present study, while starch grains and lipids were rarely seen in the stem under I_2, they were generally observed in the stem under I_1. Therefore, it could be expressed that the stem cultivated under full-irrigation condition was more acceptable to feed animals after harvest. According to the results for the leaf, while starch and lipid in the leaf under arid condition were observed, they were rarely seen in the leaf under full-irrigation condition. Thus, when the leaf in the cultivar studied was irrigated by 50% water deficit it could be nutritious for animals after harvest. However, the results for the stem and the leaf should be supported by evaluation of plant physiology.

It is suggested that all the characteristics of plants (morphological, anatomical, physiological, etc.) should be examined together in similar studies. Thus, accurate methods of improvement to be applied to reduce drought stress on plant can be clearly determined. In addition, producers can be efficiently guided to get high amounts of yield.

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REFERENCES

[1] Anonymous (2017): Mardin Climate Values (Mardin İklim değerleri). – Turkish State Meteorological Service (Meteoroloji Genel Müdürlüğü), Ankara (personally received).

[2] Anonymous (2019): Report about Corn (Mısır Raporu). – https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr.

[3] Biber, Ç., Kara, T. (2006): Evaporatranspiration and restricted irrigation applications of corn (Mısır Bitkisinin Bitki Su Tüketimi ve Kısıtlı Sulama Uygulamaları). – Journal of Faculty of Agriculture OMU 21(1): 140-146.

[4] Demirok, A., Tuylu, G. İ. (2017): Evaluation of planning and actual irrigation time scheduling for the maize (*Zea mays* L.) plant in Harran plain (Harran Ovası'nda Mısır Bitkisi (*Zea mays* L.) için Planlanan ve Gerçekleşen Sulama Zamanı Programının Değerlendirilmesi). – Harran Journal of Agricultural and Food Science (Harran Tarım ve Gıda Bilimleri Dergisi) 21(1): 84-90.

[5] Kırnak, H., Gençoğlan, C., and Değirmenci, V. (2003): Effect of deficit irrigation on yield and growth of second crop corn in harran plain conditions (Harran Ovası

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_11291140

Koşullarında Kısıntılı Sulamanın II. Ürün Mısır Verimine ve Bitki Gelişimine Etkisi). – Journal of the Faculty of Agriculture (Atatürk Üniversitesi Ziraat Fakültesi Dergisi) 34(2): 117-123.

[6] Korkmaz, H., Durmaz, A. (2017): Responses of plants to abiotic stress factors Bitkilerin (Abiyotik Stres Faktörlerine Verdiği Cevaplar). – GUFBED 7(2): 192-207.

[7] Luft, J. H. (1961): Improvements in epoxy resin embedding methods. – J. Biophys Biocha Cytol. 9(2): 409-412.

[8] Metcalfe, C. R. (1960): Anatomy of Monocotyledons. – Clarendon Press, Oxford, pp. 532-536.

[9] Stempak, J. G., Ward, R. T. (1964): An improved staining method for electron microscopy. – J. Cell Biol. 22.

[10] Terzi, R., Kadıoğlu, A. (2006): Drought stress tolerance and the antioxidant enzyme system in Ctenanthe setosa. – Acta Biologica Cracoviensia Series Botanica 48(2): 89-96.

[11] Tomás, M., Medrano, H., Brugnoli, E., Escalona, J. M., Martorell, S., Pou, A., Ribas-Carbó, M., Flexas, J. (2014): Variability of mesophyll conductance in grapevine cultivars under water stress conditions in relation to leaf anatomy and water use efficiency. – Australian J. of Grape and Wine Research 20: 272-280.

[12] Tuylu, G. İ. (2018a): Effect of ecological conditions created by over-irrigation and limited irrigation on the anatomy of corn. – AEER 16(6): 7619-7634.

[13] Tuylu, M. (2015): Leaf and stem anatomy, histology, cytology of several Marrubium L. (Lamiaceae) taxons (Bazı Marrubium L. (Lamiaceae) Taksonlarının Yaprak ve Gövde Anatomisi, Histolojisi, Sitolojisi). – University of Süleyman Demirel Institute of Science (Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü). Phd. Thesis (Doktora tezi), Isparta, Türkiye.

[14] Tuylu, M. (2018b): Examination of anatomical features of tomato (Lycopersicon esculentum Mill.) varieties cultivated under hydroponic system. – AEER 16(3): 3381-3391.

[15] Tuylu, M., Büyükkartal, H. N., Akgül, G., and Kalyoncu, H. (2017): Comparing stem and leaf anatomy of *Marrubium lutescens* Boiss. and *M. cephalanthum* Boiss. & Noë subsp. *akdaghicum* (Lamiaceae) (Marrubium lutescens Boiss. ve M. cephalanthum Boiss. & Noë subsp. akdaghicum (Lamiaceae)' un Gövde ve Yaprak Özelliklerinin Anatomik Olarak Karşılaştırılması). – Süleyman Demirel Unv. J. of Natural and Applied Sciences (Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi) 21(1): 113- 117.

[16] Tuylu, M., Tuylu, G. İ., Söylemez, S., Büyükkartal, H. N. (2018): Comparing some anatomical features of tomato (Lycopersicon esculentum Mill. cv. Kurucaova) cultivated under perlite and hydroponic culture (Perlit ve Su Kültürü Ortamlarında Yetiştirilen Domates (Lycopersicon esculentum Mill. cv. Kurucaova) Bitkisinin Bazı Anatomik Özelliklerinin Karşılaştırılması). – Süleyman Demirel Unv. J. of Natural and Applied Sciences (Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi) 22(2): 1104-1109.

[17] Tuylu, M., Büyükkartal, H. N., Kalyoncu, H., Akgül, G. (2019): Comparing stem and leaf anatomy of Marrubium trachyticum Boiss. and Marrubium globosum subsp. micranthum Montbret & Aucher ex Benth. (Lamiaceae). – Fresenius Environmental Bulletin 28(7): 5083-5089.

[18] Utrillas, M. J., Alegre, L. (1997): Impact of water stress on leaf anatomy and ultrastructure in *Cynodon dactylon* (L.) Pers. under natural conditions. – International J. of Plant Sciences 158(3): 313-324.

[19] Yazar, A. (1990): Utilization of infrared thermometry technique for assessing crop water stress and irrigation scheduling for soybean. – Doğa Tr.d. of Agriculture and Forestry 14: 517-533.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_11291140