J. Agr. Sci. Tech. (2019) Vol. 21(5): 1341-1352

Yield and Quality Compounds of White Cabbage (*Brassica oleracea* L. cv. Capitata) under Different Irrigation Levels

O. Erken[*1], and M. Yildirim[1]

ABSTRACT

This study was conducted in field conditions to determine the response of cabbage to four different irrigation levels, from 2015 to 2016. The experiment was laid out in randomized block design. Plots were irrigated using a drip irrigation system and the irrigation interval was fixed as 4 days for all treatments. Evaporation was determined by Class-A pan. Six organic acids (ascorbic, tartaric, lactic, citric, malic and oxalic) were identified and quantified by HPLC-UV. White cabbage yields were significantly increased by water applications, but deficit irrigation produced negative results. Maximum amounts of ascorbic, lactic, tartaric and malic acids were found in the low water content treatment, while reducing sugar and total sugar increased in the full irrigation treatment. In the study, supplying different amounts of irrigation water caused changes in the growth and quality of white cabbage (*Brassica oleracea* L.cv. Capitata). When water stress in cabbage production exceeded more than 30%, the yield and, especially, the quality of cabbage decreased significantly. The results revealed evidence that different soil moisture content in the root depth affected the yield, organic acids, and sugar content.

Keywords: Abiotic stress, Drip irrigation levels, Organic acids, Water stress.

[DOR: 20.1001.1.16807073.2019.21.5.7.4]

INTRODUCTION

Water is an important resource and recent studies have focused on optimum water use in farming rather than obtaining the highest yield for sustainable agriculture. The shortage of good quality water in coastal areas occasionally necessitates the use of saline water for irrigation (Yildirim, 2010). A reduction in fresh water sources forces agricultural producers to use poor quality or contaminated water (Bustan *et al*., 2005).

Climate change is already prevailing and represents one of the greatest environmental threats to our planet (Anon., 2010). This will affect agriculture by further endangering food security, causing a rise in sea level and accelerating erosion, especially in coastal areas Kadıoglu (2010). There is an apparent decreasing trend in winter precipitation all over Turkey, whereas a generally increasing trend is dominant in the precipitation at some stations in spring, summer, and autumn (Turkes, 1996; Turkes *et al*., 2008).

Water is the most important factor influencing crop development and production (Nyatuame *et al*., 2013). Irrigation management could play a key role in sustainable agriculture by avoiding nitrate leaching causing ground-water pollution and excess water application. These circumstances exert significant stress on the limited supply of water resources, especially during the irrigation season in summer (Yildirim and Bahar, 2017).

In recent years, during the summer, especially in arid and semi-arid regions, the required amount of water necessary for agricultural crops could not be met due to erratic rainfall and water shortages have

[1] Department of Irrigation and Farm Structures, Faculty of Agriculture, Canakkale Onsekiz Mart University, Canakkale 17100, Turkey.
*Corresponding author; e-mail: oerken@comu.edu.tr

caused a significant loss of crops. For this reason, identification of drought-resistant varieties of all crops has become an important issue (Kusvuran and Abak, 2012).

The benefits of irrigation scheduling may be grouped under three factors: increase in irrigation efficiency, reduced cost of irrigation, and saving water resources. Cabbage as a vegetable requires water throughout its growing season (Nyatuame *et al*., 2013). Brassica species are reported to exhibit cancer preventive alkaloid called glucosinolates and their derived properties (Vaughan and Geissler, 1997). Consumers globally are aware of the need for a constant supply of phytochemical-containing plants to obtain optimal nutritional benefits. For health reasons, brassica vegetables are very popular, being consumed in enourmous quantities all over the world (Sousa *et al*., 2005). Many research studies have recently been carried out to determine their bioactive components since it was reported that broccoli may also prevent chronic disease. Some nutrients in broccoli play a dual role in human health and plant metabolism (Jeffery *et al*., 2003).

Research carried out so far on the irrigation of cabbage has resulted in discrepancies and focused mainly on yield (Xu and Leskovar, 2014), without considering how organic compounds change under different irrigation levels. The present experiment was undertaken to reveal the influence of irrigation through the drip irrigation system on yield and to evaluate the influence of different irrigation regimes on the organic acids of cabbage leaves.

MATERIALS AND METHODS

Experimental Site and Soil

This experiment was conducted at the Agricultural Research Station of Canakkale Onsekiz Mart University, Turkey. Experimental site is along the coast of the Dardanelles in Canakkale province, located between latitude 40^0 06’ N and longitude 26^0 24’ E in NW Turkey, with an average elevation of 5 m. The climate is warm and there is almost no rainfall between May and September. The average annual precipitation of 650 mm, which falls mostly between November and March in the autumn and winter months. The soil was clay loam with an available soil moisture holding capacity of 36.6% (P_w) or 167.7 mm at depths between 0 and 90 cm. Cabbage seedlings (*Brassica oleracea* L.cv. Capitata) were transplanted on 10 July and harvested on 12 November in 2015, and on 18 July and 2 November in 2016, respectively. The climate parameters (temperature (°C) and relative humidity (%) at the site were measured above the canopy of the plants by a mini-weather station with HOBO U12 including sensors and data logger). Rainfall data were taken from the meteorological station 10 km from the site, as given in Table 1.

Irrigation Management

Each plot in the experiment took the same amount of fertilizer, including N (20%), Ammonium NH_4-N (3.4%), Nitric NH_3-N (5.3%), Ureic NH_2-N (11.3%), P_2O_5 (water soluble) (20%), K_2O (water soluble) (20%),

Table 1. Meteorological data for period of experiment: Temperatures, air relative humidity, and rainfall.

2015			2016		
Cumulative temperature (°C)	Cumulative rainfall (mm)	Mean relative humidity (%)	Cumulative temperature (°C)	Cumulative rainfall (mm)	Mean relative humidity (%)
2797.2	67.8	57.9	2378.4	19.3	54.2

[DOR: 20.1001.1.16807073.2019.21.5.7.4]

B (0.01%), Cu (0.01%), Fe (0.05%), Mn (0.02%), Mo (0.001%), and Zn (0.02%). The total amount of fertilizer was applied three times, first at planting, then at 15 and 20-day intervals.

The irrigation treatments included four irrigation levels from full water to severe water stress. Only in the full Irrigation ($I_{1.0}$) was water refilled in the root zone up to field capacity at 4-day intervals. In the deficit treatments, water was applied at 70 ($I_{0.7}$), 30 ($I_{0.3}$), and 0% (I_0) of full irrigation. All treatments were equally irrigated for 20 days after transplanting in order to establish the root development of all plants then water was applied according to the irrigation treatments. A Class-A pan was installed next to the experimental plot. The amount of 4-day irrigation water was estimated based on cumulative evaporation from the class-A pan, as per Ertek and Kanber (2000). All amounts of evaporation from the class-A pan throughout the growing season were measured every 4 days for the entire growing period.

$$I= A\times E_{pan}\times Kc\times Kp\times P \quad (1)$$

Where, *I* is the amount of Irrigation water applied (mm), A is the plot Area, E_{pan} is the cumulative Evaporation at irrigation interval (mm), *Kc* is the crop coefficient, *Kp* is the pan coefficient, and *P* is the Percentage of wetted area (%) . Irrigation Water Use Efficiency (IWUE, kg m^{-3}) was estimated according to Howell (2001), as:

$$IWUE= Y/ I \quad (2)$$

Where, *Y* is Yield (kg ha^{-1}), and *I* is the applied Irrigation water (mm).

Plant and Fruit Quality Parameters

Leaf area was determined by a CI-202 Portable Laser area meter (CID, Inc., USA) as cm^2, all leaves of each plant were collected in all treatments. All plant weights (stem, leaf, and head) were determined using a digital balance (±0.01 g) and diameters were measured with a digital clipper (±0.01 mm). Fresh weights (stem, leaf and head) were determined separately by weighing. After this, they were all oven-dried to a constant weight at about 70°C for two days to determine the dry weight of the whole plants in each treatment.

Sugar Content

Carbohydrate (CH) content of the leaves as reducing sugar and total sugar concentration (glucose+sucrose+fructose) was determined by the dinitrophenol method (Ross, 1959). Plants were seperated into leaves, stalks, and roots, and then dried at 70°C for 48 hours to reach a constant weight. Dried leaves were extracted with 15% potassium hegzasiyanoferrat, 30% $ZnSO_3$ and 6 mL dinitrophenol. Readings were taken using a T70 +UV spectrophotometer (PG Instruments, UK). The concentration of sugar (g 100 g^{-1}) was calculated according to Ross (1959).

Organic Acid Extraction and Analysis with HPLC

Cabbage pulp (3 g) was extracted by stiring with 30 mL of metaphosphoric acid for 15 minutes, then mixed with distillated water to 50 mL and subsequently filtered through Whatman no.4 paper (Vazquez *et al*.,1994). The volume was adjusted to 10 mL and passed through a 0.45 µm filter before examination. The process was performed for each sample using a HPLC system with a UV/VIS detector. The simultaneous determination of oxalic, tartaric, malic, malonoic, lactic, citric, and ascorbic acids using liquid chromatography was carried out according to Arnetoli *et al*. (2008). The chromatography analysis was performed using a HPLC system (Shimadzu, Japan). The equipments of the HPLC system consisted of a LC-20AD pump, SIL-20AC Auto sampler, CBM-20A system controller, SPD-M20A Prominence DAD detector (190-800 nm), CTO-20AC column oven and LC solution (version: 1.23 sp1) software. An Inertsil ODS-III C18 column (4.6x250 ID, 5 µm particle size) was used for the chromatographic separation. The mobile phase was carried out with 125 mM KH_2PO_4 adjusted to pH 2.5 with o-phosphoric acid. The flow rate of the mobile phase and temperature of the column oven were 1.4 mL min^{-1} and 40°C, respectively. The detection wavelengths were performed at 210 nm for oxalic, tartaric, malic, lactic, acetic and citric acids, and at 254 nm for ascorbic acid (Figure 1).

The retention times of each organic acid to prepare single standard solution at 25 µg mL^{-1} concentrations was determined before being calibrated with a mixed solution of all organic acids for simultaneous determination. Afterwards, standard mixed solution of organic acids was prepared by using oxalic acid (Sigma, 99.0%), tartaric acid (Sigma, 99.5%), malic acid (Sigma, 99.0%), lactic acid (Sigma, 98.0%), acetic acid (Sigma, 99.0%), citric acid (Sigma, 99.5%), and ascorbic acid (Sigma, purity g 99.0%). Then, the equipment was calibrated with a mixed solution of all organic acids at different concentrations. Unless otherwise stated, all procedures were done in triplicate.

Statistical Analysis

The experiment was laid out using a randomized block design. Transplanting was done at a distance of 0.6 m between rows and 0.4 m between the plants in each row. In each plot, there were 40 plants. All growth and physiological variables, yield, and growth characteristics data were subjected to Analysis Of Variance (ANOVA) and Duncan test using SPSS. Mean differences between irrigation levels and the amount of organic acids, however, were determined according to the Tukey range test, since the variances were homogeneous.

RESULTS AND DISCUSSION

Irrigation Water and Yield

The Irrigation amounts (I) and yield values for both years in the experiment are given in Table 2. Different irrigation treatments in both years had a significant effect on the yields and vegetative development of the cabbage.

Cabbage is classified as intermediately susceptible to water stress (Nortje and Henrico, 1988). Cabbage production during fall and winter mainly depends on supplemental irrigation Xu and Leskovar (2014) and (Sivanappan and Padmakumari 1998) recommended drip irrigation for cabbage production to save water without any loss of yield. Many researchers indicate that cabbage is sensitive to water stress and recommend that cabbage be supplied with irrigation water throughout its growing season. In the present experiment, the amount of water applied in 2015 fluctuated on average from 48 mm in the severe stress treatment ($I_{0.0}$) to 373.6 mm in the full water

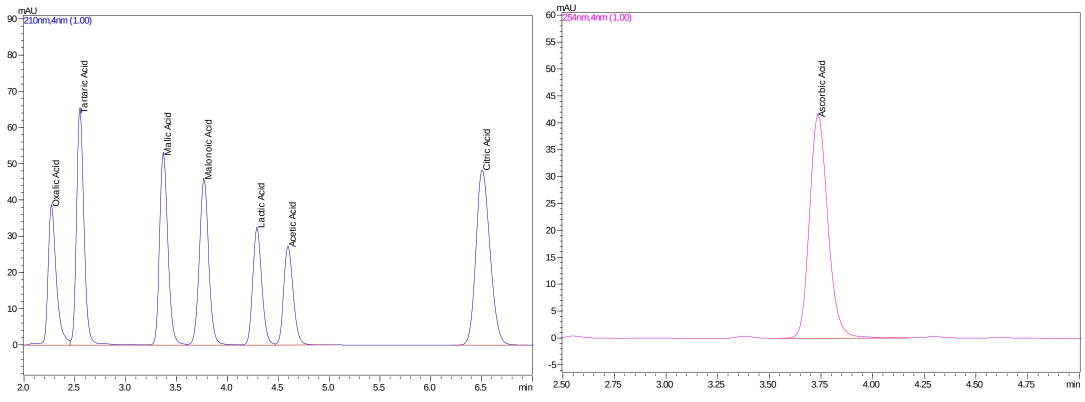

Figure 1. Chromatography spectrum of organic acid (210 nm) and ascorbic acid (254 nm).

[DOR: 20.1001.1.16807073.2019.21.5.7.4]

application ($I_{1.0}$), but increased from 70.6 mm to 448.7 mm in 2016. Therefore, an increment in yield was observed with increased amount of irrigation water in $I_{1.0}$ and $I_{0.7}$. The highest yield was obtained when the total water requirement of cabbage was fully covered in the $I_{1.0}$ treatment. The yield results, especially for treatments $I_{1.0}$ and $I_{0.7}$ in the present study, agreed well with findings in the literature. Tiwari *et al*. (2003) recommended that 400 mm of water is enough for the average seasonal water requirement of cabbage and they obtained the highest yield of cabbage (106 t ha^{-1}) when full water demand was compensated by a drip irrigation system. Also, 20 and 40% of water deficit decreased the yield to 105.5 and 101.45 t ha^{-1}, respectively.

In both years of our experiment, total precipitation was lower than the average evapotranspiration during the growing period. Hence, it is clear that supplemental irrigation is unavoidable under semi-arid climatic conditions, and the cabbage may even be considered a cool season crop. Irrigation water should be applied throughout the growing season to achieve an economic yield and prevent cracking of the heads of cabbage. Yield components were significantly reduced by deficit irrigation. In 2015, the amount of rain that fell was rather higher than the second year. Hence, this probably increased the yield, especially in the severe stress treatments ($I_{0.3}$ and $I_{0.0}$) as seen in Table 2. Therefore, yield in the severe stress treatment ($I_{0.0}$) was 34,667 kg ha^{-1}, which was probably due to the high rainfall in the first year. In 2016, it decreased to 19,250 kg ha^{-1} since there was low rainfall and the cabbage could not meet its water need.

The yields in both years were on par in the $I_{0.3}$ treatment; even though the applied water in the second year was very high. In this case, it can be said that irrigation water applied between 112 and 224 mm does not make much difference in yield. However, the treatments of full ($I_{1.0}$) and moderate ($I_{0.7}$) water application indicated that more than 261.5 mm should increase the yield of cabbage; in other words, they will give a higher yield per unit increment of water. While the yield in $I_{0.7}$ was 73,625 kg ha^{-1}, when the irrigation water applied was 261 mm, the yield went up to 80,458 kg ha^{-1} by applying 314.1mm irrigation water. This is even clearer in the full water application, since when the amount of applied irrigation water was increased from 373.6 to 448.7 mm, the yield increased to 139,875 kg ha^{-1}.

The amount of rainfall had a significant positive effect on the *IWUE*. Rainfall caused the *IWUE* in $I_{0.3}$ to be higher than other treatments in the first year. However, the effect of applied rainfall water on *IWUE* presents a clearer picture, since there was almost no irrigation throughout the growing period. *IWUE* increased as the applied water decreased according to the irrigation treatments, which may be due to rainfall, since water in the form of rain during the growing season increased the yield in the severe stress treatments ($I_{0.3}$ and $I_{0.0}$), though only to a very small degree. However, in 2016, the amount of irrigation water had a significant positive effect on the *IWUE*, and even made the *IWUE* in $I_{1.0}$ higher than the other treatments. These findings agree with researchers such as Sezen *et al*. (2006) and (Yıldırım *and* Bahar, 2017). These results

Table 2. Irrigation depth, yield and IWUE.

Treatments/Years	Irrigation depth (mm)		Yield [a] (kg ha^{-1})		IWUE (kg m^{-3})	
	2015	2016	2015	2016	2015	2016
$I_{1.0}$	373.6	448.7	86375^a	139875^a	23.0	31.2
$I_{0.7}$	261.5	314.1	73625^a	80458^b	28.2	25.6
$I_{0.3}$	112.1	224.4	48500^b	49583^c	43.3	22.1
$I_{0.0}$	48	70.6	34667^b	19250^c	36.1	27.2

[a] Numbers indicated by different letters are significantly different by the Duncan test at $P < 0.001$.

[DOR: 20.1001.1.16807073.2019.21.5.7.4]

may be due to rainfall occurring throughout the growing season.

Deficit irrigation management is very important, especially in arid and semi-arid climates (Xu and Leskovar, 2014). However, leaf vegetables as compared with fruit trees seem to be less adapted to deficit irrigation (Costa *et al*., 2007). As seen in the present study, when water resources are scarce, a water deficit of 30% will not result in significant reduction in yield. In this case, on average, seasonal irrigation water of 288 mm appears to be enough to achieve an economical yield without any loss.

Quality Parameters

Yield components were significantly reduced by deficit irrigation. In the first year, except for the leaf area, there was no statistical significant difference between the full ($I_{1.0}$) and moderate stress ($I_{0.7}$) treatments and their values decreased considerably in the severe stress treatments ($I_{0.3}$ and $I_{0.0}$), as seen in Table 3. The amount of rainfall reduced the difference in quality parameters between the full and moderate stress treatments, in the first year. In the second year, however, the difference in quality parameters between full and moderate stress treatments was statistically important.

Parameters related to plant development (fresh head weight, diameter, height, leaf area) were negatively affected as the amount of water decreased from 261 to 48 mm in 2015 and from 314.1 to 70.6 mm in 2016. In the second year, irrigation at 70% Evapotranspiration (ETc) significantly reduced fresh head weight, width, height, and leaf area. In the $I_{0.7}$ treatment, economic yield and quality could be achieved with a water saving of 30%, but irrigation water less than 261.5 mm reduced yield and quality significantly. Therefore, deficit irrigation at 70% *ETc* can be considered as the threshold level in terms of both yield and quality to obtain an economical yield.

The taste of a vegetable is determined by its sugar and organic acid content (Majkowska-Gadomska and Wierzbicka, 2008). In our study, significant differences were found in the content of total sugars and monosaccharides, which agrees well with the results of Majkowska-Gadomska and Wierzbicka (2008). Primary metabolites such as sugars, proteins, lipids, and starch are of prime importance, and essentially for the growth of plants. Sugar providing energy and glucose is the main source of energy because the most complex sugars and carbonhydrates breakdown into glucose. The leaves, as compared with the stem and root of cabbage, contain the maximum concentration of metabolites (Santhi *et al*., 2011).

In the first year of our experiment, the total sugar content was highest in the $I_{1.0}$ and $I_{0.7}$ treatments (Table 4). Results in other treatments were very close, which means that cabbage attempts to retain sugar, one of the primary metabolites, at a certain level, even if water is applied in very small quantities, as in treatment $I_{0.3}$. But, in the second year, different irrigation treatments had no significant effect on the total sugar content of cabbage. However, content of reducing sugar was significantly affected by different irrigation treatments in both years, and its content in the full and moderate stress treatment was the highest according to the stress treatments of $I_{0.3}$ and $I_{0.0}$.

Sharma and Rao (2013) determined the sugar content as 4.00±0.65 gm g^{-1} dw in normal leaves, and in pest-infected leaves of cabbage, it increased to 4.98±0.46 gm g^{-1} dw. This increment was most likely due to the stress created by pests on the cabbage. In another study, the nutritional sugar content in 13 different types of cabbage ranged from 3.83 to 0.83 g per 100 g. Cabbage in its raw state contains 3.90 g of sugar per 100 g (Anonymous, 2017). In the present experiment, the highest sugar content was 5.27 mg per 100 g. Therefore, regular irrigation practices in all treatments may have caused the sugar content in the cabbage to increase. As the average of both years, it was 4.58 mg per 100 g fresh weight. Majkowska-Gadomska and Wierzbicka (2008) obtained sugar content and organic acid at the highest level in var. HacoPOL as

[DOR: 20.1001.1.16807073.2019.21.5.7.4]

Table 3. Effect of different treatments on diameter in x and y directions, head height (cm), and leaf area (cm^2).

Treatments	2015					2016				
	Head [a]					Head [a]				
	Weight (g head^{-1})	Dia- x (cm)	Dia- y (cm)	Height (cm)	Leaf area (cm^2)	Weight (g head^{-1})	Dia- x (cm)	Dia- y (cm)	Height (cm)	Leaf area (cm^2)
$I_{1.0}$	2073,0 ± 140^a	20.10±0.64^a	19.21±0.45^a	12.56 ±0.37^a	15407 ± 267^a	3357 ± 256^a	26.07 ±1.27^a	24.53 ±1.43^a	20.87 ± 2.37^a	19522 ± 370^a
$I_{0.7}$	1766.9 ± 38.2^a	19.77±0.13^a	18.55±0.10^a	12.38 ± 0.13^a	14249 ± 146^b	1931 ± 117^b	19.07 ±0.64^b	18.60 ± 0.12^b	16.53 ± 0.57^{ab}	12738 ± 816^b
$I_{0.3}$	1163.5 ± 48.3^b	16.89±0.23^b	16.27±0.02^b	9.05 ± 0.5^b	5257 ± 66^c	1120 ± 86^c	16.40 ±1.15^b	16.07 ± 1.16^b	13.93 ± 0.70^b	5410 ± 310^c
$I_{0.0}$	832.3 ± 65.8^b	9.32±0.33^c	9.59± 0.51^c	5.39 ± 0.27^c	759 ± 92^d	462 ± 58^c	11.80 ±0.61^c	11.60 ±0.40^c	7.40 ± 0.20^c	969 ± 76^d

[a] Numbers indicated by different letters are significantly different by the Duncan test at $P< 0.05$. Dia : Siameter.

Table 4. The amounts of reducing sugar, total sugar, and sucrose (g 100 g^{-1}).

Treatments	2015 [a]			2016 [a]		
	Reducing sugar	Total sugar	Sucrose	Reducing sugar	Total sugar*	Sucrose
$I_{1.0}$	4.245 ± 0.09^a	5.270 ± 0.20^a	0.970 ± 0.15^{ns}	3.659 ± 0.09^a	4.352 ± 0.10^{ns}	0.658 ± 0.06^c
$I_{0.7}$	4.227 ± 0.10^a	5.277 ± 0.22^a	0.998 ± 0.12^{ns}	3.475 ± 0.09^{ab}	4.089 ± 0.03^{ns}	0.850 ± 0.04^{bc}
$I_{0.3}$	3.673 ± 0.05^b	4.779 ± 0.06^{ab}	1.051 ± 0.11^{ns}	3.138 ± 0.07^b	3.913± 0.10^{ns}	1.169 ± 0.11^{ab}
$I_{0.0}$	3.323 ± 0.08^b	4.432 ± 0.09^b	1.054 ± 0.02^{ns}	2.697 ± 0.10^c	4.540 ± 0.43^{ns}	2.186 ± 0.12^a

[a] Numbers indicated by different letters are significantly different by the Duncan test at $P< 0.05$

3.66 g per 100 g and 2.35 g per 100 g, and the lowest level in var. Kada as 2.17 g per 100 g and 0.89 g per 100 g, respectively.

Organic Acids

Organic acids are principally employed to determine fruit maturity (Philip and Nelson, 1973; Lamikanra *et al*., 1995). Cabbage is a good source of beta-carotene, vitamin C, and fiber. It is a cruciferous vegetable and has been shown to reduce the risk of some cancers, especially those in the colorectal group. This is probably due to either the glucosinolates found in cole crops, which serve as metabolic detoxicants, or to the sulphoraphane content, also responsible for metabolic anticarcinogenic activity (Sharma and Rao, 2013). Organic acids have important functions as flavor enhancers and natural antimicrobial agents. Organic acids also influence the color of vegetables since many pigments are natural pH indicators (Sinha *et al*., 2011).

The organic acids (ascorbic, tartaric, lactic, citric, malic and oxalic) in cabbage (*Brassica oleracea* L.cv. Capitata) are given in Tables 5 and 6. In our experiment, the organic acid contents of cabbage in $I_{1.0}$ varied from 31.22 to 48.50 mg g^{-1}, in 2016. As seen in the Tables 5 and 6, the amount of total organic acid increased when the level of water stress increased. The increase in organic acids in 2016 may be due to the amount of rainfall during the development period. The dominant organic acids were ascorbic and oxalic. Ascorbic acid exhibited the highest content compared with other organic acids, in both years. In 2015, ascorbic acid ranged from 14.69 mg $g\text{-}^{1}$ in $I_{1.0}$ to 20.26 mg $g\text{-}^{1}$ in the severe stress treatment, which accounted for almost 46.30% of the total organic acid content. Oxalic acid was 29.60%. The minor organic acids were malic, citric, lactic, and tartaric and these accounted for 6.04% of the total acids. In 2016, irrigation treatments led to the same trend in organic acids. Fluctuation in ascorbic acid content was much greater between different irrigation treatments.

Ascorbic acid ranged from 17.56 mg g^{-1} in the $I_{1.0}$ treatment (55.80% of total organic acids) to 32.15 mg $g\text{-}^{1}$ in the $I_{0.0}$ treatment (66.30% of total organic acids). However, the amount of ascorbic acid was close in the treatments $I_{0.7}$ (20.69 mg $g\text{-}^{1}$) and $I_{0.3}$ (24.33 mg $g\text{-}^{1}$). Majkowska-Gadomska and Wierzbicka (2008) determined the content of L-ascorbic acid in varieties Kissendrup and HacoPOL as 36.38 and 31.57 mg 100 g^{-1}, respectively. In both years of our study, the content of each individual organic acid increased with increasing water stress. Ascorbic acid, known as Vitamin C, is an organic acid with antioxidant properties. Vitamin C is involved in the absorption of iron and calcium. Majkowska-Gadomska and Wierzbicka (2008) found the content of copper and iron in the edible parts of red head cabbage to range from 3.57 to 6.83 mg kg^{-1} and from 52 to 50 mg kg^{-1} dry matter, respectively. Singh *et al*. (2006) reported that vitamin C content of 18 different cabbage cultivars on a fresh weight basis ranged from 5.70 to 23.5 mg 100 g^{-1}. They also determined that ascorbic acid content of white cabbage cv. Taler was higher compared to the 18 cabbage cultivars, and higher in comparison with other Brassica vegetables such as cauliflower, brussels sprouts, and Chinese cabbage, but lower compared with broccoli. Sousa *et al*. (2005) identified six organic acids from tronchuda cabbage; aconitic, citric, ascorbic, malic, shikimic, and fumaric, which ranged from 11 to 87 g kg^{-1}. They also indicated that the amount of organic acids could change according to the harvesting time. In the internal leaves, even though malic acid was the major compound until December and accounted for 43-87% of the total identified compounds, ascorbic acid became the main compound in January, corresponding to 57-69% of total acids. Ascorbic acid assists in the healing of wounds and burns, in preventing blood clotting, and in strengthening the walls of capillaries (Carr and Frei, 1999). Therefore, cabbage can be

[DOR: 20.1001.1.16807073.2019.21.5.7.4]

Table 5. Fluctuations in organic acids under different irrigation levels, in 2015 (mg g^{-1}).

Treatments	2015 [a]						Total
	Ascorbic	Tartaric	Lactic	Citric	Malic	Oxalic	
$I_{1.0}$	14,69 ± 0.11 [b]	0.91 ± 0.04 [c]	0.88 ± 0.08 [c]	1.86 ± 0.46 [a]	1.43 ± 1.20 [ns]	11.45 ± 0.05 [ns]	31.22
$I_{0.7}$	14.20 ± 0.41 [b]	1.09 ± 0.06 [bc]	3.33 ± 0.26 [bc]	1.64 ± 0.80 [ab]	1.72 ± 0.71 [ns]	11.34 ± 0.08 [ns]	33.32
$I_{0.3}$	15.23 ± 0.95 [b]	1.37 ± 0.10 [b]	5.29 ± 0.80 [ab]	1.38 ± 0.41 [b]	1.60 ± 0.99 [ns]	9.15 ± 0.05 [ns]	34.02
$I_{0.0}$	20.26 ± 1.13 [a]	1.70 ± 0.07 [a]	6.41 ± 0,.0 [a]	1.30 ± 0.45 [b]	1.637 ± 0.63 [ns]	9.14 ± 0.04 [ns]	40.45

[a] Numbers indicated by different letters are significantly different by the Tukey range test at $P< 0.05$. [ns]: Not significant.

Table 6. Fluctuations in organic acids under different irrigation levels, in 2016 (mg g^{-1}).

Treatments	2016						Total
	Ascorbic	Tartaric	Lactic	Citric	Malic	Oxalic	
$I_{1.0}$	17.56 ± 0.46 [c]	0.04 ± 0.003 [c]	0.100 ± 0.09 [b]	1.22 ± 0.08 a	1.54 ± 0.13 [a]	10.99 ± 0.08 [ns]	31.45
$I_{0.7}$	20.69 ± 0.84 [bc]	0.07 ± 0.01 [bc]	1.24 ± 0.16 [b]	1.14 ± 0,05 [ab]	1.72 ± 0.15 [a]	13.56 ± 2,72 [ns]	38.42
$I_{0.3}$	24.33 ± 1.52 [b]	0.13 ± 0.02 [ab]	4.89 ± 0.42 [a]	1.10 ± 0.06 [ab]	1.21 ± 0.07 [ab]	10.86 ± 0.08 [ns]	42.52
$I_{0.0}$	32.15 ± 1.25 [a]	0.18 ± 0.03 [a]	5.64 ± 0.47 [a]	0.95 ± 0.03 [b]	1.01 ± 0.07 [b]	8.57 ± 0,23 [ns]	48.50

[a] Numbers indicated by different letters are significantly different by the Tukey range test at $P< 0.05$. [ns]: Not significant.

considered as a good source of ascorbic acid and also includes the greatest quantities of macro elements, especially in the leaves.

In fruits, the total acid content generally reaches a maximum during growth and decreases during ripening (Eskin *et al*., 1971). Although having the same genotype, grapes harvested in different climates have different organic acid contents (Fuleki *et al*., 1993). Furthermore, the amount of ascorbic acid may change according to the growing season. Martinez-Villaluenga *et al*. (2009) indicated that Vitamin C content in raw white cabbage was higher in cabbage cultivated in summer (373.33 mg 100 g^{-1} dry weight, equivalent to 37.30 mg 100 g^{-1} fresh weight) than that cultivated in winter (302.96 mg 100 g^{-1} dry weight, equivalent to 27.90 mg 100 g^{-1} fresh weight). For these reasons (climate, season, etc.), many researchers have reported different amounts of organic acids for cabbage.

CONCLUSIONS

In the present study, white cabbage (*Brassica oleracea* L.cv. Capitata) showed itself to be a plant sensitive to water shortage. On average, 411.2 mm of irrigation water applied for the whole growing season increased the yield of cabbage. Furthermore, 287.3 mm of irrigation water resulted in better preservation of yield. In this study, water-stressed cabbage in the more severe stress conditions was negatively affected in terms of morphology and yield. Soil water content in the field capacity maintained an economical yield according to its capacity. Also, the quantity and time of rainfall affected the yield of cabbage. Therefore, yield in the severe stress treatment in 2015 was almost 40% higher than the yield obtained in 2016.

In the moderate stress treatment, as the average of both years, irrigation water of 287.3 mm was the threshold level for conservation of yield, but irrigation water of 168.2 mm ***was less*** effective in preventing yield and quality losses in white cabbage. Organic acid content highly correlated with the amount of irrigation water and was lower when the full water requirement of cabbage was met.

In summary, preservation of yield was achieved by providing an amount of irrigation water of not less than 411.2 mm. On the other hand, organic acid content was higher in cabbage cultivated under low soil water content. These results concerning primary organic acids and sugar content are of commercial importance and may be of interest in plants pharmaceuticals sector. They can also be considered as a strategy for water management in white cabbage (*Brassica oleracea* L.cv. Capitata) irrigated under semi-arid conditions

ACKNOWLEDGEMENTS

The authors wish to thank Canakkale Onsekiz Mart University Agricultural Experiment Station for their assistance in this research and we are also grateful to Mr. G. H. Lee for proof-reading the manuscript.

REFERENCES

1. Anonymous. 2010. *Climate Change.* http://ec.europa.eu/environment/climat/home_en.htm (Accessed on 6 December 2010).
2. Anonymous. 2017. *Diet and Fitness Today*. http://www.dietandfitnesstoday.com/sugar-in-cabbage.php. (Accessed on 25 August 2017).
3. Arnetoli, M., Montegrossi, G., Buccıant A. and Gonnelli, C. 2008. Determination of Organic Acids in Plants of Silene Paradoxa L. by HPLC. *J. Agric. Food Chem*., **56:** 789–795.
4. Bustan, A., Cohen, S., Malach, De Y., Zimmermann, P., Golan, R., Sagi, M. and Pasternak, D. 2005. Effects of Timing and Duration of Brackish Irrigation Water on Fruit Yield and Quality of Late Summer Melons. *Agric. Water Manage.,* **74:** 123-134.
5. Carr, A. C. and Frei, B. 1999. Toward a New Recommended Dietary Allowance for Vitamin C Based on Antioxidant and Health Effects in Human. *Am. J. Clin. Nutr.,* **69:** 1086-1107.

6. Cheney, G. 1950. Anti-Peptic Ulcer Dietary Factor. *J. Am. Diet. Assoc.,* **26:** 668–672.
7. Costa, M., Ortuna, M. F. and Chaves, M. M. 2007. Deficit Irrigation as a Strategy to Save Water: Physiology and Potential Application to Horticulture. *J. Integr. Plant Biol.,* **49:** 1421-1434.
8. Ertek, A. and Kanber, R. 2000. Pamukta Uygun Sulama Dozu ve Aralığının Pan-Evaporasyon Yöntemiyle Belirlenmesi. *Turk, J. Agric. F.*, **24:** 293-300. (in Turkish)
9. Eskin, N. A. M., Henderson, H. M. and Townsend, R. J. 1971. Organic Acids. In: "*Biochemistry of Foods*", (Ed.): Eskin, N. A. M. Academic Press, New York, PP.31-63.
10. Fuleki, T., Pelayo, E. and Palabay, R. 1993. Carboxylic Acid Composition of Authentic Varietal and Commercial Grape Juices. *J. AOAC Int.,* **76:** 591-600.
11. Howell, T. 2001. Enhancing Water Use Efficiency in Irrigated Agriculture. *Argon. J.,* **93:** 281-289.
12. Jeffery, E. H., Brown, A. F., Kurilich, A. C., Keck, A. S., Matusheski, N., Klein, B. P. and Juvik, J. A. 2003. Variation in Content of Bioactive Components in Broccoli. *J. Food Compos. Anal.,* **16:** 323-330.
13. Kadıoglu, M. 2010. *Climate Change and Turkey*. http://www.tuba.gov.tr (Accessed on 6 December 2010).
14. Kusvuran, S. and Abak, K. 2012. Kavun Genotiplerinin Kuraklık Stresine Tepkileri. *Ç. Ü. Fen ve Müh. Bil. Der.,* **28 (5):** 78-87. (in Turkish)
15. Lamikanra, O., Inyang, I. and Leong, S. 1995. Distribution and Effect of Grape Maturity on Organic Acid Content of Red Muscadine Grapes. *J. Agric. Food Chem.,* **43:** 3026-3028.
16. Martinez-Villaluenga, C., Penas, E., Frias, J., Ciska, E., Hanke, J., Piskula, M. K., Kozlowska, H. and Vidal-Valverde, C. 2009. Influence of Fermentation Conditions on Glucosinolates, Ascorbigen and Ascorbic Acid Content in White Cabbage (*Brassica oleracea* var. Capitata cv. Taler) Cultivated in Different Seasons. *J. Food Sci.,* **74:** 62-66.
17. Majkowska-Gadomska, J. and Wierzbicka, B. 2008. Content of Basic Nutrients and Minerals in Heads of Selected Varieties of Red Cabbage (Brassica oleracea var.capitata f.rubra). *Polish J. Environ.,* **17(2):** 295-298.
18. Nortje, P. F. and Henrico, P. J. 1988. The Effect of Suboptimal Irrigation and Intra-row Spacing on the Yield and Quality of Cabbages. *Acra Hort.,* **228:** 163-170.
19. Nyatuame, M., Ampraw, F., Owusu-Gyimah, V. and Ibrahim, B. M. 2013. Irrigation Scheduling and Water Use Efficiency on Cabbage Yield. *Inter. J. Agro. Agric. Res.* **3:** 29-35.
20. Philip, T. and Nelson, F. E. 1973. Aprocedure for Quantitative Estimation of Malic Acid and Tartaric Acids of Grape Juices. *J. Food Sci.,* **38:** 18-20.
21. Ross, A. F. 1959. *Dinitrophenol Method for Reducing Sugar in Potato Processing.* (Eds.): Tulburt, W. F. and Smith, O.. Tavi Publishing Co. Westport, Connecticut, PP. 469-470.
22. Santhi, R., Lakshmi, G., Priyadarshani, A. M., and Anandaraj, A. L. 2011. Phytochemical Screening of Nerium Oleander Leaves and Momordica Charantia Leaves. *Inter. Res. J. Phar.,* **2(1):** 131-135.
23. Sezen, S. M., Yazar, A. and Eker, S. 2006. Effect of Drip Irrigation Regimes on Yield and Quality of Field Grown Bell Pepper. *Agric. Water Manage.,* **81:** 115–131.
24. Sharma, D. and Rao, D. V. 2013. Biochemical Analysis of Cabbage (Brassica oleracea) after Infection of Pest. *Inter. Res. J. Phar.,* **4:(6)** 127-130.
25. Singh, J., Upadhyay, A. K., Bahadur, A., Singh, B. and Singh, K. P. 2006. Antioxidant Phytochemicals in Cabbage (*Brassica oleracea* L. var. Capitata). *Sci. Hort.,* **108:** 233-237.
26. Sinha, N. K., Hui, Y. H., Evranuz, E. O., Siddiq, M. and Ahmad, J. 2011. Handbook of Vegetables and Vegetable Processing. Willey-Black Well Publication, Blackwell Publishing Ltd, Printed in Singapore. Chapter II. pp.35–36.
27. Sivanappan, R. K. and Padmakumari, O. 1980. *Drip Irrigation: SVNP Report.* 2 March, Tamil Nadu Agricultural University, Coimbatore, India, PP. E3-E10.
28. Sousa, C., Valentao, P., Rangel, J., Lopes, G., Pereira, J. A., Ferreres, F., Seabra, R. M. and Andrade, P. B. 2005. Influence of Two Fertilization Regimes on the Amounts of Organic Acids and Phenolic Compounds of Tronchuda Cabbage (*Brassica oleracea* L. var. Costata DC). *J. Agric. Food Chem.,* **53:** 9128-9132.
29. Tiwari, K. N., Singh, A. and Mal, P. K. 2003. Effect of Drip Irrigation on Yield of Cabbage (*Brassica oleracea* L. var. Capitata) under Mulch and Non-mulch Conditions. *Agric. Water Manage.,* **58:** 19-28.

[DOR: 20.1001.1.16807073.2019.21.5.7.4]

30. Xu, C. and Leskovar, D. I. 2014. Growth, Physiology and Yield Responses of Cabbage to Deficit Irrigation. *Hort. Sci.(Prague),* **41(3):** 138-146.
31. Turkes, M. 1996. Meteorological Drought in Turkey: A Historical Perspective, 1930-1993. Drought Network News, *Inter. Drought Inf. Cent.*, University of Nebraska, **8:** 17-21
32. Turkes, M., Koc, T. and Saris, F. 2008. Spatiotemporal Variability of Precipitation Total Series over Turkey. *Inter. J. Clim.*, DOI: 10.1002/joc.1768
33. Vaughan, L. G. and Geissler, C. A. 1997. *The New Oxford Book of Food Plants*. Oxford University Press, New York, PP. 166-169.
34. Vazquez, O. M. L., Vazquez, B. M. E., Lopez, H. J., Simal, L. J. and Romero, R. M. A. 1994. Simultaneous Determination of Organic Acids and Vitamin C in Green Beans by Liquid Chromatography. *JAOAC,* **77:** 1056–1105.
35. Yildirim, M. 2010. Water Management in Coastal Areas with Low Quality Irrigation Water for Pepper Growth. *J. Coastal Res.*, **26(5):** 2010
36. Yildirim, M. and Bahar, E. 2017. Water and Radiation Use-Efficiencies of Tomato (*Lycopersicum esculentum* L.) At Three Different Planting Densities in Open Field. *Med. Agric. Sci.,* **30(1):** 39-45.

عملکرد و ترکیبات کیفی کلم سفید (*Brassica oleracea* L. cv. Capitata) در سطوح مختلف آبیاری

و. ارکن، و م. ایلدیریم

چکیده

این پژوهش در شرایط مزرعه با هدف تعیین واکنش کلم سفید به ۴ سطح مختلف آبیاری در سال های ۲۰۱۵ و ۲۰۱۶ اجرا شد.آزمایش با طرح بلوک های تصادفی پیاده شد. کرت ها با استفاده از سامانه قطره ای و دور آبیاری ثابت ۴ روزه برای همه تیمارها آبیاری شد. تبخیر با استفاده از طشت تبخیر کلاس Aتعیین می شد. شش اسید آلی (اسکربیک، تارتاریک، لاکتیک، سیتریک، مالیک واگزالیک) شناسایی شد و با استفاده از دستگاه HPLC-UVمقدارشان تعیین شد. عملکردهای کلم سفید در اثر آبیاری به طور معناداری افزایش یافت ولی کم آبیاری نتایج منفی داد. مقدار بیشینه اسید اسکربیک، اسیدلاکتیک، اسید تارتاریک، و اسید مالیک در تیمارهای دارای محتوای کم آب مشاهده شد در حالیکه قندهای احیاکننده و قند کل در تیمار آبیاری کامل افزایش نشان دادند. در این پژوهش، تامین مقادیر متفاوت آب آبیاری باعث تغییراتی در رشد و کیفیت کلم سفید (*Brassica oleracea* L.cv. Capitata) شد. هنگامی که تنش آبی در تولید کلم سفید بیش از ۳۰٪ شد، عملکرد، و به ویژه کیفیت کلم، به طور معناداری کاهش یافت. نتایج آشکار ساخت که عملکرد، اسیدهای آلی، و محتوای قند تحت تاثیر مقادیر مختلف رطوبت خاک در عمق ریشه قرار گرفته بود.

[DOR: 20.1001.1.16807073.2019.21.5.7.4]