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EFFICACY OF SINGLE DRIP LATERAL DESIGN FOR TWO PLANT ROWS OF GRAIN MAIZE IN KONYA-KADINHANI-KOLUKISA PROVINCE, TURKEY

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Keywords:*Trickle Irrigation System, Corn Grain Yield, Lateral Tube Design, Soil Wetting*

ABSTRACT

The purpose of this research was to evaluate the effectiveness of trickle irrigation on grain-corn production as well as soil wetting geometry under single drip lateral design for two plants rows at Konya-Kadınhanı-Kolukısa province of Turkey under farmer's practices. The seasonal applied water varied from 416.78 to 441.98 mm in research farms. The grain yield was found between 14200 and 16750 kg/ha in those study farms. Irrigation Water Use Efficiency, IWUE, varied from 3.21 and 3.93 kg/m^3. The both the lateral and vertical wetting front was around 50 cm under 140 cm lateral space. The field inspection clearly showed that it is impossible to obtain sufficient wetted soil volume by use of one trickle lateral design, 140 cm, for two plant rows so one drip lateral design,70 cm, for each crop row was strongly recommended for facilitating better wetted soil volume within plant rooting depth consequently increasing grain production. Maize plant is very sensitive to the water deficiency so water amount should be met enough in soil rooting environment during the whole plant growing cycles.

INTRODUCTION

The maize production has been used in 35% for humanity and 65% for animal consumption in Turkey. Recent years, feed industry has been expanded due to gradual increase in animal population in Konya plain of Turkey although the region is suffering from the water scarcity problem. In that regard, both the grain and silage maize demand has increased day by day in feed suppliers (Ak, 2017). In the semiarid Konya plain, farmers cannot achieve sustainable yields without irrigation, especially for summer crops. Sugar beet, maize, carrot, and maize crops are known as high water consumption crops. In the past, furrow irrigation was commonly used for growing maize plant. Poor water application to plants, as well as other challenges during irrigation operations including high labour need and time-consuming, are the primary drawbacks of using surface irrigation systems. In recent years, due to the introducing drip irrigation system, both the grain and silage corn has been irrigated with drip irrigation in the Konya plain. The farmers are well knowledgeable in all facets of farming, particularly irrigation so they have adopted drip irrigation for their maize crops with remarkable rapidity.

Beside the performing proper cultural practices, possibly application of irrigation water with pressurized irrigation systems to the crops with necessary amount is the main reason of the maximal crop yield and quality. Those systems, drip or sprinkler, are getting the popularity particularly in water-starved regions due to the many advantages such as improving water savings (Acar et al. 2014; Musa et al. 2014).

There is no doubt that water application efficiency of drip irrigation system is high so it is strongly recommended for areas having limited water resources (Irfan et al. 2014; Acar, 2020; Asres, 2023). The applied water should meet whole crop water consumption within the crop rooting depth for maximal crop yield (Amer et al. 2010). The pressure variations at outlets of the drippers should be as minimum as possible for more uniform water applications to the whole cropped lands (Mohanty et al. 2016). As known, sustainable agriculture relies heavily on efficient water usage which is especially challenging in dry and semiarid environments (Cavero et al. 2000). By comparison to the farming performed at none-irrigated (rain-fed) condition, drip system may allow around increment in 20-80% in crop yield and 30-70% in water saving (Shamshery et al. 2017). Crop nutrients are applied directly through the rooting parts with liquid form by this system so almost all fertilizers are taken by crops so it is also one of the reasons behind high crop production (Santana Junior et al. 2020). In accordance of our observation in region, the grain and silage yields are around 16-20 t/ha and 70-90 t/ha, respectively. Correct agricultural water management is the backbone of the achievement high yield and quality.

The water withdrawal in irrigation is greater than 75% in Konya plain (Yavuz et al. 2015) and is higher than 85% in western part of USA and water scarcity has very serious environmental problem in region (Munoz-Perea et al. 2006). Farmers of Konya plain have focused on lowering the irrigation number due to water shortage in region and reducing irrigation energy cost in all summer crops. Since this strategy is very important particularly for high water consuming crops even deficit irrigation was suggested for some field crops including maize (Yavuz et al. 2021). In common practice two lateral lines for one crop row has been used in the our region namely Konya plain, Turkey.

One of the most important information needed in irrigation scheduling is effective root depth, plants taking around 80% of their water requirement, and is upper part of the rooting systems where roots are being dense. The rooting depths depend on type of the plant, soil properties, water status in soil profile and crop growing stage. The maximal rooting depth for maize crop can be assumed as 1.00 m (Ibrahim & Ibrahim, 2020).

The applied water for surface irrigated-grain maize was found as 375-555 mm under full irrigation status at Pingtung province, located at Southern part of Taiwan (Greaves & Wang, 2017). In South-eastern Anatolia region of Turkey, irrigation water for drip-irrigated silage maize was reported as 590.8-614.3 mm for full irrigation treatment (Tarı, 2022). This value was determined as 344 mm for grain maize at Al-Qassim province of Saudi Arabia (Khan et al. 2021). The grain yields of maize under lysimeter condition of Yangling, Guanzhong plain, semi-arid environment, of China were stated as 7994 kg/ha and 8401 kg/ha for 2012 and 2013, respectively under full watered treatment (Yufeng et al. 2021). In other study (Camporese et al. 2021) performed at Albettone, Northern part of Italy, the grain yield of sprinkler-irrigated corn was as an average of 18375 kg/ha. Another study conducted by Tariq & Usman (2009) at Takht-i Bhai, Mardan province of Pakistan, the irrigation water and maximal grain yield of corn were reported as 661.44 mm and 2993 kg/ha, respectively. Similarly those values were stated as 486.8 mm and 3777 kg/ha, respectively for Metekel province of Benishangul, Ethiopia (Tefera &

Mitku, 2017). In Bursa province of Turkey, applied water, Evapotranspiration (ETc), grain yield for full irrigation treatment, water productivity (WP), and irrigation water productivity (IWP) were found as 863.5 mm, 974.5 mm, 16200 kg/ha, 1.44-1.90 kg/m^3, and 0.46-1.705 kg/m^3, respectively for drip irrigated maize plant (Kuscu et al. 2013). In Faisalabad province of Pakistan, grain yield and WP values varied from 4200 kg/ha to 10100 kg/ha, and from 10.29 to 15.46 kg/ha/mm, respectively for surface irrigation corn plant (Ashraf et al. 2016). Yield performance of drip-irrigated grain maize under different water applications was studied at Xinjiang province of China (Liu et al. 2022). The irrigation levels were as follows; 420 mm (I1), 480 mm (I2), 540 mm (I3) and 600 mm (I4). The lateral space was 110 cm in this research. The grain yields as an average of 9-year (2013-2021) for I1, I2, I3 and I4 treatments were found 10537.40, 14593.92, 16570.28 and 14892.37 kg/ha, respectively.

The correct design of laterals in trickle irrigation system has maximum effect on sufficient water distribution both the horizontally and vertically in soil profile. Maximal crop performance is obtained under well drip trickle system.

The uniform water distribution of drip irrigation system within soil rooting depth depends on a lot of factors such as working pressure, dripper space, land slope, design of the water delivery pipes, variation in dripper discharge, dripper quality, partial or complete blockage of drippers and aging of the drip irrigation systems components (Ardey, 2021; Raphael et al. 2018). The wetting front of soil, wetted soil being above boundary of field capacity of soil moisture content (Acar et al. 2009), is highly affected from soil properties, dripper or lateral tube spacing, dripper flow rate, and irrigation interval. The size or shape (like a cut ellipsoid) of the wetted volume refers to the amount of water needed to wet rooting depth (Bajpai & Kaushal, 2020).

The performance of drip irrigation systems for irrigating grain-maize under field circumstances has not been thoroughly studied in the literature. The research, therefore, aimed to identify irrigation scheduling for drip-irrigated grain corn plant under farmer’s practices in semi-arid Konya plain of Turkey. Beside that whether single drip lateral design for two crop rows is an efficient practice or not for adequate water distribution within the soil rooting systems.

MATERIAL AND METHODS

The research was conducted during the corn growing season of 2022 in semi-arid Konya-Kadınhanı-Kolukısa province, Turkey (Figure 1).

Figure 1. Study site within Konya map

The study farms are about 85 kilometers from Konya's downtown and 993 meters above sea level. The soils within research sites are either clay or loam properties. A total of 62.2 mm of precipitation fell during the crop vegetative period (30.20 mm in May and 32.00 mm in June) of 2022. The maize cultivars were Maximus Kozmo, Dekalp 5741 and PIONEER 0937 in examined farms.

There was an investigation into three distinct maize fields, each of which used a drip irrigation system with a single trickle lateral layout for two rows of plants which is common practice in region (Figure 2). In that case, by considering the plant row space of 45 cm, lateral space was 140 cm (2x45 cm). In study fields, groundwater was used as an irrigation water supply. Table 1 lists some of the features of drip irrigation systems and water sources.

Figure 2. Drip lateral design for grain-maize crop.

The applied water by farmer's practices was calculated by following steps;

The average flow rate was calculated by averaging three discharges of emitters being at 40% of the lateral length (de Andrade et al. 2021).

$$q_{avr} = (q1+q2+q3)/n \qquad (1)$$

Where; q_{avr}-mean flow rate (L/h); q1, q2, q3= flow rates of first, second and third emitters at 40% lateral length (L/h), and n= number emitters

The emitter watering rate was calculated as follows;

$$Ep= (q_{avr} / (Es \times Ls)) \qquad (2)$$

Where; Ep- Emitter watering rate (mm/h), Es-Emitter space (m), and Ls-Lateral space (m)

Table 1

Properties of drip irrigation systems for using maize irrigation

Farm No	Depths of Wells (m)	Capacity of Wells (m^3/h)	Diameters (mm)			Lateral Space (cm)	Emitter Space (cm)
			Main Line	Manifold	Lateral		
1	130	108	125	90	22	140	30
2	130	108	125	90	22	140	30
3	120	101	125	90	22	140	30

By sum of irrigation duration for examined farms total irrigation time (Ta) for growing season was determined. By multiplying the Ep with Ta values seasonal applied water (I) was calculated as;

$$I=Ep \times Ta \quad (3)$$

Where; I- Irrigation water (mm).

The watering performance of drip irrigation system was determined by considering Irrigation Water Use Efficiency, IWUE, as calculated by;

$$IWUE=Y/I \quad (4)$$

where; IWUE- Irrigation Water Use Efficiency (kg/m^3); Y-Grain Yield (kg/ha); I-Applied Water (m^3).

RESULTS AND DISCUSSIONS

Applied Water and Irrigation Water Use Efficiency (IWUE)

There was insufficient rainfall in May-June 2022 so around 40 mm irrigation water was applied with sprinkler system by farmer's during the germination cycle of the maize crop in studied farms.

In accordance of the field tests, average flow rates in examined farms of 1, 2, and 3 were determined as 1.560 L/h, 1.152 L/h, and 1.132 L/h, respectively.

The E_p values for those three drip irrigation systems using for irrigation of maize crop were computed as 2.752 mm/h, 2.742 mm/h, and 2.695 mm/h, respectively in accordance of mean emitter discharges, dripper and lateral spaces.

In study location 7-day irrigation interval has been applied by farmers in general. Irrigation times for fields of 1, 2, and 3 for each irrigation process were found as 14-19 h, 15-20 h, and 15-24 h, respectively depending on crop growth cycles. Total seasonal irrigation water application times for field of 1, 2, and 3 were 155 h, 152 h, and 164 h, respectively. By multiplying average flow rates (Ep) with seasonal irrigation durations (Ta) seasonal applied water (I) was obtained (Table 2).

Table 2 shows that the average I values for farms of 1, 2, and 3 were 427 mm, 417 mm, and 442 mm, respectively. Among the farms we looked at, there wasn't much variation in the amount of irrigation water used. This indicates that farmers have used a trickle irrigation technique to provide roughly the same amount of water to grain-corn plants. Irrigation water amounts for grain corn have been studied in several countries, with results ranging from 375 to 555 mm in

Taiwan under surface irrigation (Greaves & Wang, 2017) and 486.8 mm in Ethiopia (Tefera & Mitku, 2017). The results of the present study agree with those of Greaves & Wang (2017) and are consistent with those of adjacent Tefera & Mitku (2017).

In the current investigation grain yields ranged from 14200 to 16750 kg per hectare. Grain yields were reported to be as high as 18375 kg/ha in Italy when irrigated with sprinklers (Camporese et al. 2021) and as 2993 kg/ha in Pakistan (Tariq & Usman, 2009) and as 3777 kg/ha in Ethiopia when irrigated with drip system (Tefera & Mitku, 2017). Comparing the present study's findings to those of Camporese et al. (2021) and Kuscu et al. (2013) reveals that they are quite close, while also ranking higher than those of Tariq & Usman (2009) and Tefera & Mitku (2017). Climate and corn cultivar differences among research ecosystems may explain the observed variances in grain yield.

The average IWUE was 3.93 kg/m^3 for the 1-farm scenario, 3.77 kg/m^3 for the 2-farm scenario, and 3.21 kg/m^3 for the 3-farm scenario. In most cases, there were not notable differences across the farms that were studied. The results of this research are higher than the findings of Kuşçu et al. (2013). The reason for this may be the corn type and environmental differences.

Table 2

The applied water, addition of water by rainfall, and IWUE

Farm No	Rainfall During Vegetation Cycle (mm)	Applied Water by Farmers with Drip System (mm)	Total (mm)	Grain Yield (kg/ha)	IWUE (kg/m^3)
1	62.2	426.56	488.76	16750	**3**.93
2	62.2	416.78	478.98	15700	3.77
3	62.2	441.98	504.18	14200	3.21

Analysis of water movement in soil profile

The wetting boundary cross section between the two laterals in a single drip lateral design for two rows of plants was determined to be insufficient (Fig 3). In fig. 3, the vertical wetting front and the maximum wetness width (just below the 17-20 cm soil depth) were both around 50 cm. These numbers line up with Acar et al. (2009). In previous studies conducted in study region, significant yield losses were reported for potato (Yavuz et al. 2016) and sunflower (Yavuz & Yavuz, 2023) under one lateral design for two plant rows. Therefore, we recommend 70 cm lateral space (one lateral for each plant row) to achieve almost adequate wetted soil volume in rooting environments consequently maximal crop production.

Figure 3. Water movement in soil profile under single drip lateral design for two plant rows

CONCLUSIONS

Farmers using one drip lateral per two rows of plants applied an average of 430 mm irrigation water for grain maize by drip irrigation system. The low amount of water used to the crop may be related to the use of a drip irrigation system with efficient water management. The inadequate watering zone throughout the cropped fields was caused by the use of a single lateral line for two rows of crops. Therefore, it was suggested a single crop row use a 70-centimeter-wide lateral design to ensure almost adequately moistened soil profile consequently maximal grain production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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QUANTITATIVE ANALYSIS OF SOME CLASSES OF BIOACTIVE ANTIOXIDANT COMPOUNDS IN FENNEL (*FOENICULUM VULGARE* MILL.) LEAVES

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Keywords: *fennel, carotenoids, phenolic compounds, ascorbic acid, essential oils*

ABSTRACT

Fennel leaves from local production were studied for their content in some classes of compounds with antioxidant potential. Chlorophylls (a and b), carotenoids (total, β-carotene, lycopene, lutein, zeaxanthin and cryptoxanthin), phenolic compounds (total, flavonoids, anthocyanins), ascorbic acid, essential oils.

The chlorophyll content was 1,459 mg/kg DW, of which over 86% chlorophyll a. Total carotenoid concentration was 1,609 mg/kg DW, including 1,002 mg/kg β-carotene, 109 mg/kg lycopene, 32 mg/kg lutein and low amounts of other compounds. 13,292 mg/kg was the total phenolic content, of which 686 mg/kg flavonoids, including 146 mg/kg anthocyanins. Leaves contained 2,658 mg/kg ascorbic acid and 20,553 mg/kg essential oil.

While comparable with other Apiaceae in most types of compounds, fennel had a lower flavonoid inventory, but a higher amount of lycopene.

INTRODUCTION

Fennel (*Foeniculum vulgare* Mill., Apiaceae family) is a herbaceous aromatic plant, native of the Mediterranean region. It has a tall (up to 2.5 m) stem, with a bulb-like base, long (40 cm), pinnately dissected leaves, yellow flowers grouped in compound umbels. Fruits are indehiscent schizocarps.

It is widely cultivated as an aromatic and medicinal plant and, in the last years it is gaining popularity in Romania also. Leaves are strongly aromatic. Stem base (in Florence fennel) is used in cuisine as a vegetable. Fruits are also aromatic and rich in essential oil, used in cosmetic and pharmaceutic products.

Among its medicinal uses, it is known to be antioxidant, antimicrobial, anti-inflammatory, analgesic, hepatoprotective, diuretic and antispasmodic (Herb Society of America 2005; Aprotosoaie et al. 2010).

Plants are known to contain several classes of bioactive compounds with antioxidant potential.

Chlorophylls (of which chlorophylls a and b are found in land plants) are the main pigments used in photosynthesis. They also have anti-inflammatory activity for consumers, enhance wound healing and inhibit calcium oxalate dihydrate accumulation (kidney stones), while limiting dietary uptake of some known carcinogens. Chlorophylls are among the main antioxidant compounds, preventing oxidative stress-associated diseases (Inanç 2011).

Carotenoids (including carotenes, lutein, lycopene, zeaxanthin) are accessory photosynthetic pigments. Some of them (especially carotene) are precursors of retinol and key to melanin synthesis, thus important for eye and skin functioning. They are also antioxidant and antiproliferative and researches show that lycopene is among the most important dietary anticarcinogens (Eldahshan & Singab 2013).

Phenolic compounds are a variate group of bioactive compounds, functioning as plant pigments, but also as antimicrobials and antifungals. Flavonoids (among them being anthocyanins – plant pigments and strong antioxidants), phenolic acids and tannins belong to this group (Kivrak & Kivrak 2014). For consumers, phenolic compounds are a key class of antioxidant, reducing and radical scavenging agents (Zymonė et al. 2018).

Ascorbic acid (vitamin C) is a key antioxidant, countering lipid oxidation at cell level in all organisms (Riscahyani et al. 2019)

Essential oils are complex mixtures of organic compounds, of which over 90% are volatile. Their composition includes terpenes (mostly mono- and sesquiterpenes), hydrocarbons and derivatives, flavonoids, aldehydes, alcohols, esters, etc., with a volatile fraction over 90%. They give plant products their specific aroma, while also having antimicrobial and antioxidant properties (Orphanides et al. 2011).

The objective of this paper was to determine the amount of several compounds and compound classes belonging to these categories in fennel leaves.

MATERIAL AND METHODS

Fennel leaves were collected from the experimental farm of the "Ovidius" University of Constanța.

Chlorophylls and carotenoids were determined by 80% acetone extraction and spectrophotometric absorption reading (S106 WPA spectrophotometer) at 470, 647, 663 nm (Popoviciu et al. 2020). Concentrations were calculated according to Lichtenthaler & Buschmann 2001.

Among individual carotenoid compounds, β-carotene, lycopene, lutein (and lutein esters), zeaxanthin and cryptoxanthin were determined by extraction in acetone:hexane:petroleum ether, petroleum ether, ethanol, acetone and using the spectrophotometric methods of Braniša et al. 2014, Sujith et al. 2010, Butnariu et al. 2014, Biehler et al. 2010, respectively.

The total concentration of phenolic compounds was determined by extracting plant tissue in methanol and reaction with Folin-Ciocâlteu reagent (10%) and sodium bicarbonate (7.5%) for 30 minutes. Absorbance was read at 765 nm against gallic acid calibration curve (Popoviciu et al. 2020). Flavonoids were determined by precipitation with hydrochloric acid and formaldehyde, followed by quantification of non-flavonoid phenolic content by Folin-Ciocâlteu reaction (de Lima et al. 2011). Anthocyanins were determined by 70% ethanol extraction and spectrophotometry at 520 and 700 nm (Braniša et al. 2014).

For total ascorbic and dehydroascorbic acid, ethanol extraction, reaction with ammonium molybdate and sulfuric acid, followed by spectrophotometric reading at 494 nm were employed (Riscahyani et al. 2019)

Essential oils were determined by petroleum ether extraction and gravimetry (Orphanides et al. 2011).

Dry biomass (23.25% on average) was determined through oven drying and used to express the concentrations of bioactive compounds in mg/kg DW.

RESULTS AND DISCUSSIONS

The concentrations of various classes of compounds with bioactive potential are shown in Figures 1-4.

Total chlorophyll content was 1,459 mg/kg, of which chlorophyll a was dominant (over 86%).

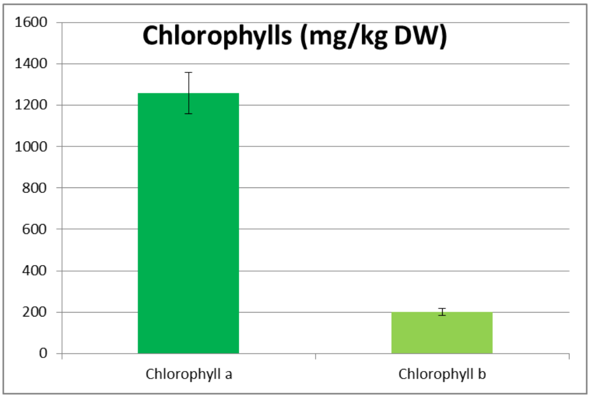

Figure 1. Concentrations of chlorophylls a and b in fennel leaves (mg/kg DW)

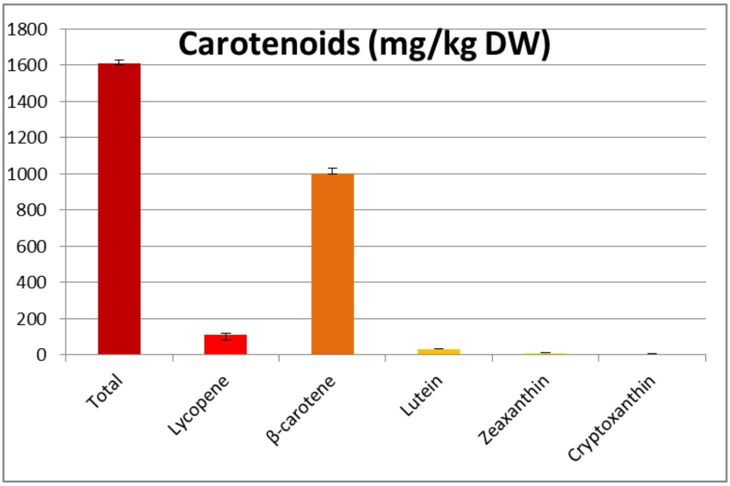

Figure 2. Concentrations of total and some individual carotenoids in fennel leaves (mg/kg DW).

Carotenoids were 1,609 mg/kg. Of this amount, β-carotene constituted over 62% (1,002 mg/kg). Lycopene amounted for 109 mg/kg (6.80% of the total amount). Lutein and xanthins were found only in small amounts. Apiaceae leaves are known to be a rich source of carotenoids, of which β-carotene is usually dominant. Researches on anise, chervil, caraway and dill found amounts of 126-179 mg/kg FW of this compound, lower than the 233 mg/kg FW equivalent found in fennel. However, all these species also contain significant amounts of lutein (9-18 mg/kg FW compared to 7.42) rather than lycopene (Giordano et al. 2022). On the other hand, it should be noted that carotenoid content is a highly variable character, that can show major differences among cultivars of the same species, as shown in coriander (from 15 to 103 mg/kg β-carotene; Priyadarshi & Naidu 2019).

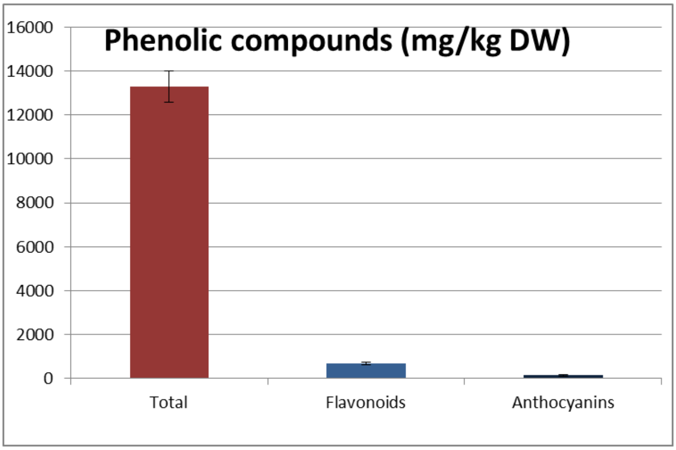

Figure 3. Concentrations of total phenolic compounds, flavonoids and anthocyanins in fennel leaves (mg/kg DW)

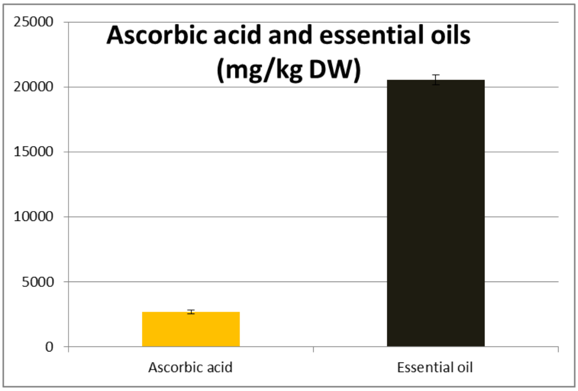

Figure 4. Concentrations of total ascorbic and dehydroascorbic acid and essential oils in fennel leaves (mg/kg DW)

Average total phenolic content was 13,292 mg/kg. Of these, the flavonoid fraction constituted only 5.16% (686 mg/kg). Of flavonoids, 21% (146 mg/kg) were anthocyanin pigments. For comparison, other phenolic contents found in Apiaceae leaves range from 2,300 (cumin) to 21,630 (parsley) mg/kg DW. However, in most cases flavonoids constitute 50% or higher (Deroiuch et al. 2020; Pricop et al. 2020; Thiviya et al. 2021).

2,658 mg/kg was the total amount of ascorbic and dehydroascorbic acid, while the average concentration of volatile oils was 20,553 mg/kg. The amount of ascorbic acid (618 mg/kg FW), while high, is lower than those found in other Apiaceae, like chervil and dill (Giordano et al. 2022).

CONCLUSIONS

Fennel leaves had a high chlorophyll content (1,459 mg/kg DW), mostly chlorophyll a.

With 1,609 mg/kg DW, the carotenoid concentration was also high, dominated by β-carotene constituted over 62% (1,002 mg/kg). While lutein content was lower than in other related species, fennel leaves contained a high amount of lycopene (109 mg/kg DW).

At 13,292 mg/kg DW, the total phenolic inventory is comparable to that found in other Apiaceae. While rich in total phenols, fennel leaves had a low amount of flavonoids (686 mg/kg), of which 21% were anthocyanins.

Average ascorbic acid content was 2,658 mg/kg, comparable, but lower than in other Apiaceae species.

Fennel leaves were rich in essential oils, with an average concentration of 20,553 mg/kg DW.

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