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RESEARCH ARTICLE

Factibility of growing basil as an alternative crop for adaptation to climate change in Bosnia and Herzegovina

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ABSTRACT

Extremely high temperatures and droughts are expected in Bosnia and Herzegovina in the coming years due to climate change. These phenomena negatively affect most traditionally grown crops. However, optimal growth conditions can be provided for plants that originate from warmer climates. One of the alternative species that can be grown in high summer temperatures is basil (*Ocimum basilicum* L.) Therefore, the objective of this study was to determine the impact of different cultivars and growing locations on the contents of some bioactive components, yield, and the possibility of growing basil under the environmental conditions of Bosnia and Herzegovina. The treatment used in this study consisted of a combination of four different cultivars (Genovese, Minimum, Green, and Red Rubin) and two growing locations (Kakanj and Butmir). The results showed that in Bosnia and Herzegovina, favorable conditions exist for growing basil, and different cultivars and growing locations had significant effects on basil yield and quality. The highest fresh mass yield (447.28 g plant^{-1}), dry mass yield (98.84 g plant^{-1}), and oil content (1.49 mL 100 g^{-1}) were recorded in 'Green'. The highest total phenolic content (32.49 mg gallic acid equivalent g^{-1}) and antioxidant capacity (43.43 μM Fe^{2+} g^{-1}) were recorded in 'Minimum'. Furthermore, the fresh mass yield and dry mass yield were higher in Butmir (446.57 and 85.62 g plant^{-1}, respectively) compared to the growing location of Kakanj (174.08 and 85.62 g plant^{-1}, respectively).

Key words: Antioxidant activity, basil, climate change, cultivar, essential oil, growing location, *Ocimum basilicum*.

INTRODUCTION

Climate change is one of the biggest challenges threatening the world today and is defined as significant changes in average values of meteorological elements, such as temperature, precipitation, sunshine, humidity, wind, and cloudiness, that have been calculated over a long period (WMO, 1992). Since 1975, an increase in the average global temperature of 0.15-0.20 °C per decade has been recorded, which is expected to continue in the next period (Malhi et al., 2021). In addition to the increase in temperature, climate change also causes a decrease in summer rainfall amounts, severe drought, and an increase in the number of days with hail outbreaks (Dejanovic et al., 2019). Bosnia and Herzegovina has a similar climate, and in the future, a larger number of extreme climate events are expected (Cadro et al., 2018; Trbic et al., 2021). In Bosnia and Herzegovina, the future impacts of climate change include an increase in the frequency of extreme weather events, temperature rise, lack of precipitation, increase in flooding, changing agricultural landscapes, involving crop yield failure, and changes in habitat composition and species distribution, richness, and diversity (Vucijak et al., 2014). Such climate change negatively affects the growth, reproduction, and yield of traditional agricultural crops (Nejatzadeh-Barandozi, 2020). On the other hand, due to climate change and gradual global warming, optimal conditions are created for the growth and development of plants originating from warm climates. With the cultivation of such alternative species for agricultural adaptation to climate change, the ensuing negative impacts were alleviated in terms of the existing agricultural areas and the number of employees (Howden et al., 2007).

One of the alternative species that can grow in high summer temperatures is basil (*Ocimum basilicum* L.) Basil is native to tropical areas of India, but it is cultivated in many subtropical and tropical regions (Bucktowar et al., 2016). Bosnia and Herzegovina has a market for basil, but data on its cultivation, yield, and quality are scarce (Gavrić et al., 2018). Basil is resistant to high temperatures and can withstand temperatures of up to 38 °C without suffering any damage (Barickman et al., 2021). Basil is a spice and also a medicinal and aromatic plant that has a prominent place in the world economy nowadays due to the continuous and growing demand for its products (Ahl et al., 2015). As a spice, basil is used in a variety of dishes, including cured meat flavor, pastes, soups, liquors, sauces, marinated tomatoes, etc. (Fraszczak et al., 2015; Majkowska-Gadomska et al., 2017). Due to its chemical composition, basil is often used in traditional medicine for the treatment of various diseases (Venancio et al., 2011; Kasote et al., 2015; Bucktowar et al., 2016; Stanojkovic-Sebic et al., 2017). The quality and medicinal value of basil depend on bioactive phytochemical components such as phenols, flavonoids, alkaloids, and tanins (Zareen et al., 2014). Although the contents of these components in the plant are regulated by genetic processes, they are also strongly influenced by many abiotic factors, including growing location, weather conditions, UV radiation, altitude, salinity, etc., that cause changes in the growth of plants, as well as the quantity and quality of their bioactive phytochemical components (Gavrić et al., 2021). Due to its resistance to high summer temperatures and an expected future increase in temperature in Bosnia and Herzegovina caused by climate change, our hypothesis is that basil may be considered as an alternative to traditional crops, since in the future, with the continued global warming, favorable environmental conditions still exist in Bosnia and Herzegovina for growth and development of basil. Therefore, the objective of this study was to determine the impact of cultivar and growing location on the contents of some bioactive components and yield under the environmental conditions prevailing in Bosnia and Herzegovina.

MATERIALS AND METHODS

Field experiments and meteorological data

Two field experiments were conducted in Kakanj and Butmir during the 2019 growing season. The first field experiment was conducted at a private farm in Kakanj (44°07′30.1″ N, 18°07′42.3″ E; 400 m a.s.l.) The second field experiment was conducted at the Butmir experimental field of the Faculty of Agriculture and Food Science in Sarajevo (43°49′34.42″ N, 18°19′18.48″ E; 505 m a.s.l.)

Meteorological data collected from the Federal Hydrometeorological Institute, Sarajevo, Bosnia and Herzegovina (FHMZ, 2022) were used in this research. Data were obtained from two regional meteorological stations, Zenica (44°12′07″ N, 17°54′01″ E) and Sarajevo (43°52′04″ N, 18°25′22″ E). In the study, data were used for average monthly air temperature, monthly amount of precipitation, relative humidity and monthly insolation. Air temperature and relative humidity were analyzed as series of monthly means of observations taken at 07:00, 14:00 and 21:00 h local time, and daily averages. The monthly amount of precipitation was obtained by adding the daily amounts of precipitation. The monthly insolation was obtained by summing the daily insolation.

Plant material

Four cultivars of basil (*Ocimum basilicum* L.) (Genovese, Minimum, Green, and Red Rubin) were cultivated at the two locations, Kakanj and Butmir. Basil was sown on 16 April 2019. Seedlings were raised in polystyrene containers using a commercial substrate Klasmann Potgrond H (Deilmann GmbH, Geeste, Germany). Each tray contained 104 cells (pots), each with a capacity of 32 mL. Basil seedlings were transplanted in an open field at a planting density of 50 cm × 30 cm on 5 June 2019, 50 d after being sown.

Treatments and experimental design

The treatments of the experiment consisted of a combination of two factors, four different cultivars (Genovese, Minimum, Green, Red Rubin) and two different growing locations (Kakanj and Butmir). The experiment was conducted in a complete randomized block design with four replicates. The size of the plot was 5.0 m^2 (2.5 m long and 2.0 m wide).

Soil analysis and yield determination

Soil samples were collected at a depth of 0-20 cm before setting up the experiment at the two locations, Kakanj and Butmir. Each collected soil sample was a combination of five subsamples (one sample from each corner and one from the center of a 1 m^2 quadrat). The following soil properties were measured according to standard methods: soil pH (ISO 10390, 1994), organic matter content (ISO 14235, 1998), and contents of available K and available P (Egnér et al., 1960). According to soil analysis, the experimental plots had the following chemical characteristics: Location Kakanj pH 7.5, 5.50% organic matter, P_2O_5 = 20.1 mg 100 g^{-1}, K_2O = 31.4 mg 100 g^{-1}, soil classification was Eutric Cambisol; location Butmir pH 6.4, 2.32% organic matter, P_2O_5 = 6.04 mg 100 g^{-1}, K_2O = 18.3 mg 100 g^{-1}, soil was classified as alluvial type. The organic fertilizer (manure) was applied by tillage in a dose of 10 t ha^{-1}. Irrigation was not applied throughout the cropping period.

Harvesting (cutting) for yield determination was carried out at the flowering stage (BBCH 60-65). In the study, basil was harvested (cut) once. The fresh mass yield $plant^{-1}$ was determined during the harvest process. After cutting, basil samples were weighed and dried in a dark room at room temperature for 20 d. The dry mass $plant^{-1}$ was determined after drying.

Determination of total essential oils and phenolic content

The content of essential oils in basil was determined using the Clevenger-type apparatus (Clevenger, 1928). Briefly, 20 g powdered basil (dry mass) and 400 mL distilled water were added to 1 L flasks, and samples were distilled for 180 min. After distillation, the contents of essential oils were determined.

Plant extracts were prepared according to the cold extraction method (Gavrić et al., 2021). In brief, 0.5 g dried and powdered aerial parts were transferred to flasks and mixed with 50 mL 60% ethanol. After 24 h, extracts were filtered through the quantitative filter paper. Obtained extracts kept in sterile sampling tubes were stored at 4 °C.

The total phenolic content in extracts was determined by the modified Folin-Ciocalteu method (Gavrić et al., 2018). In brief, 0.5 mL each extract, blank or standard, was mixed with 0.25 mL Folin-Ciocalteu reagent, and the mixture was allowed to react for 3 min. Then, 0.75 mL 20% sodium carbonate solution was added, and the volume of the mixture was brought to a final volume of 5 mL with distilled water. The mixture was allowed to stand for 120 min at room temperature before measuring the absorbance at 765 nm using the spectrophotometer (Ultrospec 2100 Pro, Biochrom, Holliston, Massachusetts, USA). The total phenolic content was calculated from the calibration curve, and the results were expressed as mg gallic acid equivalent (GAE) per g sample.

Determination of antioxidant activity

The total antioxidant capacity of extracts from basil was measured using the ferric reducing antioxidant power (FRAP) method (Benzie and Strain, 1996). Briefly, 240 µL distilled water, 80 µL extract, and 2.080 µL FRAP reagent containing 0.3 M acetate buffer, 20 mM $FeCl_3 \times 6\ H_2O$, and 10 mM TPTZ in the ratio 10:1:1, were added to an Erlenmeyer flask. The absorbance at 595 nm was measured after a 5 min incubation at 37 °C. The total capacity of antioxidants was calculated from the standard calibration curve obtained by using different concentrations of the aqueous solution $FeSO_4 \times 7\ H_2O$.

Statistical methods. All experimental results were statistically analyzed with ANOVA at a significant level of 0.05. Statistical analyses were performed using the SPSS 22 software package (IBM, Armonk, New York, USA).

RESULTS

The climate data collected from regional meteorological stations are presented in Tables 1 and 2. Mean monthly temperatures at both study locations were different from those of the reference period (1961-1990). The average monthly temperature of the 2019 growing season (June-August) was 3.5 °C higher than that of the reference period (1961-1990) in Zenica (the growing location Kakanj) (Table 1). At the same study location, the amount of precipitation in 2019 was 58.7 mm higher compared to the reference period. The relative humidity ranged from 72% (July) to 75% (August) during the growing season of 2019.

The data presented in Table 2 show an above-average warm period during the growing season in Sarajevo (the growing location Butmir). The average monthly temperature during the growing season ranged from 21.0 (July) to 21.9 (August), and it was 3.2 °C higher than that of the reference period (1961-1990). In the growing season (June-August), the precipitation of 234.6 mm, approximately equal to that of the reference period, was recorded. Relative humidity in Sarajevo averaged 63% (June-August). The data presented in Tables 3 and 4 show that plant height was significantly dependent on basil cultivar and growing location. The maximum plant height (43.40 cm) recorded in 'Green' was approximately 7.86, 8.64, and 20.95 cm greater compared with 'Genovese', 'Minimum', and 'Red Rubin', respectively. The growing location also had a significant effect on plant height (Table 4). Basil grown in Butmir was 40% taller compared to that in Kakanj.

Table 1. Average monthly temperatures, the amount of precipitation, and humidity in Zenica (FHMZ, 2022).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					Average monthly air temperature (°C)							
1961-1990	-0.9	2.0	5.9	10.6	15.0	17.9	19.7	19.2	15.7	10.8	5.3	0.5
2019	-0.6	3.8	8.6	12.4	14.0	22.4	21.8	23.0	17.4	12.9	10.6	3.7
					Amount of precipitation (mm)							
1961-1990	51.0	48.0	54.0	62.0	74.0	83.0	62.0	69.0	65.0	67.0	74.0	67.0
2019	60.8	78.8	47.5	99.8	90.9	143.7	88.8	40.2	31.7	24.6	85.3	67.0
					Relative humidity (%)							
2019	83.0	75.0	70.0	70.0	77.0	74.0	72.0	75.0	75.0	74.0	76.0	80.0
					Insolation (h)							
2019	44.4	121.4	176.5	178.9	146.6	264.8	283.9	295.2	170.5	179.3	67.6	47.5

Table 2. Average monthly temperatures and the amount of precipitation in Sarajevo (FHMZ, 2022).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					Average monthly air temperature (°C)							
1961-1990	-0.9	1.5	5.1	9.4	14.1	16.9	18.9	18.5	15.1	10.4	5.3	0.3
2019	-1.5	2.5	7.7	11.4	12.3	21.1	21.0	21.9	16.5	12.9	10.6	3.6
					Amount of precipitation (mm)							
1961-1990	71.0	67.0	70.0	74.0	82.0	91.0	79.0	71.0	70.0	77.0	94.0	85.0
2019	79.3	56.7	51.8	98.2	102.3	97.1	67.8	69.7	44.1	38.0	80.3	64.8
					Relative humidity (%)							
2019	81.0	70.0	59.0	61.0	70.0	64.0	62.0	63.0	68.0	65.0	69.0	77.0
					Insolation (h)							
2019	50.5	120.3	184.7	155.6	133.2	262.3	269.8	268.6	183.3	233.2	88.1	64.1

The fresh and dry yield was significantly affected by cultivar and growing location. As shown in Table 3, the significantly highest yield (fresh and dry) was obtained in 'Green' (447.28 and 98.84 g, respectively), while the lowest yield (44.79 and 8.89 g plant^{-1}, respectively) was recorded in the 'Red Rubin'. 'Genovese' and 'Minimum' had significantly higher fresh yields (340.23 and 298.91 g, respectively) compared to 'Red Rubin' (44.79 g plant^{-1}) but significantly lower yields compared to 'Green' (447.28 g). The growing location had a significant impact on fresh and dry mass yield, with Butmir having a higher average yield (446.57 and 85.62 g plant^{-1}, respectively) than Kakanj (174.08 and 85.62 g plant^{-1}, respectively).

The essential oil content varied from 0.79 mL 100 g^{-1} for 'Genovese' to 1.49 mL 100 g^{-1} for 'Green' basil. Cultivars had a significant effect on essential oil contents, and 'Green' had a significantly higher essential oil content compared to other cultivars. The results of the study showed that the growing location did not significantly affect the essential oil content, i.e., the content was similar in both locations.

Total phenolic contents and the antioxidant capacity were significantly dependent on cultivars and growing location. Basil cultivars had a significant effect on the obtained contents of total phenolic and antioxidant capacity, with 'Minimum' (32.49 mg GAE g^{-1} and 43.43 µM Fe^{2+} g^{-1}, respectively) and 'Red Rubin' (31.61 mg GAE g^{-1} and 42.85 µM Fe^{2+} g^{-1}, respectively) having significantly higher total phenolic contents and antioxidant capacity than 'Green' (28.14 mg GAE g^{-1} and 38.22 µM Fe^{2+} g^{-1}, respectively). This experiment indicated that the growing location also influenced total phenolic contents and antioxidant capacity. Total phenolic content and antioxidant capacity of 32.00 mg GAE g^{-1} and 43.88 µM Fe^{2+} g^{-1}, respectively, were recorded in Kakanj, compared to those in Butmir (29.29 mg GAE g^{-1} and 39.25 µM Fe^{2+} g^{-1}, respectively).

Table 3. Effect of cultivars on plant height, fresh and dry mass yield, essential oil contents, total phenolic contents, and antioxidant capacity. Different letters indicate significant differences at the 0.05 level; ns: nonsignificant differences. GAE: Gallic acid equivalent.

Grown location	Cultivar	Plant height	Fresh mass yield	Dry mass yield	Essential oil	Total phenolics	Antioxidant capacity
		cm	——— g plant^{-1} ———		mL 100 g^{-1}	mg GAE g^{-1}	µM Fe^{2+} g^{-1}
Kakanj	Genovese	20.67b	184.67a	39.09a	0.70b	31.36ns	42.60b
	Minimum	19.77b	157.69ab	30.92ab	0.87b	31.98ns	43.92ab
	Red rubin	13.56c	44.89b	9.22b	0.76b	31.96ns	43.53ab
	Green	26.67a	257.33a	53.40a	1.63a	32.71ns	45.46a
Butmir	Genovese	53.56ab	526.90ab	85.59ab	0.88b	29.35a	40.91a
	Minimum	54.18ab	482.50ab	81.30ab	0.87b	32.99a	42.95a
	Red rubin	30.40b	44.70b	8.60b	0.85b	31.25a	42.18a
	Green	68.50a	732.20a	167.00a	1.39a	23.57b	30.98b
Average	Genovese	34.76b	340.23b	61.23b	0.79b	30.36ab	41.76a
	Minimum	35.54b	298.91b	52.82b	0.87b	32.49a	43.43a
	Red rubin	22.45c	44.79c	8.89c	0.81b	31.61a	42.85a
	Green	43.40a	447.28a	98.84a	1.49a	28.14b	38.22b

The results presented in Table 5 showed a positive correlation between some examined properties. A strong positive correlation was found between fresh mass yield and plant height (r = 0.841), dry mass yield and plant height (r = 0.807), dry mass yield and fresh mass yield (r = 0.971), and antioxidant capacity and total phenolic contents (r = 0.806). Data also showed a positive correlation between essential oil content and dry mass (r = 0.406). Correlation coefficients indicated that total phenolic contents had a strong negative correlation with plant height (r = -0.623), fresh mass yield (r = -0.481), and dry mass yield (r = -0.573). Antioxidant capacity was strongly negatively correlated with plant height (r = -0.738), fresh mass yield (r = -0.578), and dry mass yield (r = -0.682).

DISCUSSION

Meteorological data collected from regional meteorological stations (Zenica and Sarajevo) suggest that there was an increase in average monthly temperatures during the summer period. The above observations are in accordance with the predictions of Vucijak et al. (2014), who consider that in the future in Bosnia and Herzegovina, due to climate change, there will be an increase in the frequency of extreme weather events such as an increase in temperature, lack of precipitation, and an increase in floods. The assumption is that due to such climate changes, the yields of traditional agricultural crops will decrease (Cadro et al., 2018). On the other hand, due to the increase in temperature, optimal conditions are created for the growth and development of plants originating from warm climates. With the cultivation of such alternative crops, it is possible to mitigate climate change in an inexpensive way and reduce the negative impacts on the reduction of the existing agricultural area and the number of employees. However, in order to avoid unwanted consequences, alternative crops need to be thoroughly researched in new agroecological conditions before being introduced into wider production.

Basil is a species grown in many subtropical and tropical regions. It is characterized by many different cultivars, which differ significantly in morphological traits such as plant height and biomass (Svecova and Neugebauerová, 2010). A significant influence of cultivars on plant height and yield was recorded in our study. ‘Green’ exhibited the greatest plant height and highest yield, while the smallest height of the plant and lowest yield were obtained in ‘Red Rubin’ (Table 2). Our research confirmed the findings reported by Zlabur et al. (2021), who stated that morphological differences occurred between individual cultivars are caused by genetic characteristics. On the other hand, in our research, the growing location also had a significant impact on plant height and yield (Table 3). Plants grown in Butmir were 40% taller, and their yield was 2.5 times higher than those in Kakanj. Nurzynska-Wierdak et al. (2011), Al-Huqail et al. (2020), and Gavrić et al. (2021) state that air temperature and soil fertility are the most important factors affecting growth and yield of basil plants. Analysis of these traits in our study indicated that the air temperature had no effect on growth and yield of basil plants, whereas soil properties influenced these studied traits. Basil had a lower yield at a location with a higher average monthly temperature (Kakanj). Since optimum temperature for basil growth is within the range of 25 to 30 °C (Barickman et al., 2021) and no temperatures above the optimal values were recorded in this study (Tables 1 and 2), the effect of high temperature on yield was ignored. Since the temperature was not the main cause of differences in yield, they may have arisen under the influence of soil fertility. According to Alhasan et al. (2020), basil yield increases with the increased availability of nutrients in the soil. It should be pointed out that there were certain differences in the results of our research and other studies. In our study, a higher yield was found in the soil with lower fertility. These results suggest that in addition to the availability of nutrients in the soil, other soil factors also improved the growth and yield of basil. Among these possible factors, soil pH could have had a considerable impact on yield. This can be explained by the lower yield achieved in a soil with a pH 7.5 (Kakanj) compared to soil with a pH 6.4 (Butmir). This finding is also in line with the statement made by Nurzynska-Wierdak et al. (2011), who consider the optimum pH range of 5.5-6.5 for most horticultural plants.

Table 4. Effect of growing location on plant height, fresh and dry mass yield, essential oil contents, total phenolic contents, and antioxidant capacity. Different letters indicate significant differences at the 0.05 level; ns: nonsignificant differences. GAE: Gallic acid equivalent.

Grown location	Plant height	Fresh mass yield	Dry mass yield	Essential oil	Total phenolics	Antioxidant capacity
	cm	——— g plant^{-1} ———		mL 100 g^{-1}	mg GAE g^{-1}	µM Fe^{2+} g^{-1}
Kakanj	20.96b	174.08b	33.16b	1.01ns	32.00a	43.88a
Butmir	51.68a	446.57a	85.62a	1.03ns	29.29b	39.25b
Average	34.76	296.55	59.39	1.02	30.65	41.56

Table 5. Coefficients of the linear correlation between plant height, fresh and dry mass yield, essential oil contents, total phenolic contents, and antioxidant capacity. *, **Significant differences at the 0.05 and 0.01 levels, respectively.

	Plant height	Fresh mass yield	Dry mass yield	Essential oil	Total phenolics	Antioxidant capacity
Plant height	1					
Fresh mass yield	0.841**	1				
Dry mass yield	0.807**	0.971**	1			
Essential oil	0.324	0.287	0.406*	1		
Total phenolics	-0.623**	-0.481**	-0.573**	-0.221	1	
Antioxidant capacity	-0.738**	-0.578**	-0.682**	-0.196	0.855**	1

The resulting essential oil contents suggest two points. First, the essential oil content of ‘Green’ was higher than another cultivar at both locations. This is in accordance with the findings published by Rakic and Johnson (2008), Nurzynska-Wierdak et al. (2013), and Tsasi et al. (2017), who reported that the biosynthesis of essential oil was strongly influenced by genetic factors. Second, environmental factors such as the growing location did not affect essential oil contents. According to many authors, environmental factors such as air temperature (Wogiatzi et al., 2014; Muráriková et al., 2017) and precipitation (Omidbaigi et al., 2003) had significant impacts on the biosynthesis and accumulation of essential oils. Although, in our research, there were differences in temperature and precipitation at different growing locations, no effect was observed on the essential oil content. One of the possible reasons for the lack of their influence on this parameter is the slight difference in temperature and precipitation between locations.

Our results demonstrated that total phenolic contents and the antioxidant capacity of basil were affected by cultivar and growing location. ‘Green’ had a significantly higher content of total phenolics compared to other cultivars (‘Genovese’, ‘Minimum’, and ‘Red Rubin’) at both locations. While comparing locations, all basil cultivars in Kakanj were found to have significantly higher contents of total phenolics compared to those in Butmir. These results agree well with the findings of previous studies, in which the rate of production of the secondary metabolites, including total phenols in plants, was a result of the interaction between environmental and genetic factors (Ncube et al., 2012). For example, Bajomo et al. (2022) examined 22 basil cultivars and found their significant effect on the total phenol content and antioxidant capacity. On the other hand, Al-Huqail et al. (2020) found that stressful environmental conditions increased the concentration of total phenols. In general, total phenols play an important role in protecting the plants from sub-optimal temperatures (Kreft et al., 2013), drought (Lim et al., 2012), UV radiation (Martínez-Silvestre et al., 2022), pathogens (Kumar et al., 2014), and other unfavorable environmental conditions (Gavrić et al., 2020), and the increase in their concentration in plants occurs in response to environmental stressors (Stagnari et al., 2017). Therefore, it can be explained that one of the main factors that could affect the further synthesis of phenol in Kakanj is the environmental stress caused by sub-optimal soil pH. The optimum pH range for most horticultural plants is between 5.5 and 6.5 (Nurzynska-Wierdak et al., 2011), while in our research, the soil pH in Kakanj was 7.5.

Although our study has provided glimpses into the influence of cultivar and environmental conditions on the quality of basil plants, a sufficient set of data on the quality of essential oil was not obtained. Thus, future research should consider the potential impact of different basil cultivars and environmental factors on the composition of essential oils. However, our research showed that some benefits could be reaped in practice. Despite the current and expected future increases in global temperature due to climate change (Cadro et al., 2018), the conditions in this country are good for basil growth (temperatures are still not above the optimum range) (Gavrić et al., 2021). Basil can grow under the agro-ecological conditions of Bosnia and Herzegovina and thus be regarded as an alternative to species that are sensitive to high summer temperatures. Additionally, this study shed light on the optimal soil pH values for high-yielding basil plants, as soil quality is an important indicator of high crop yield, which is the most important criterion for evaluating the quality of basil plants.

CONCLUSIONS

The results of this research showed that due to climate change there was an increase in average monthly temperatures in the environmental conditions of Bosnia and Herzegovina. Such climate changes become unfavorable for most traditional agricultural crops, and favorable for new subtropical species. The results of this research showed that basil can grow under the environmental conditions of Bosnia and Herzegovina. The future increase in temperature due to climate change will not have negative impacts on the growth and yield of this species, thus making basil an alternative crop since it can replace the species sensitive to high temperatures and preserve the existing agricultural lands.

Author contributions

Formal analysis: S.M., L.Č. Investigation: T.G. Writing-original draft: T.G., S.M., L.Č. Writing-review & editing: S.M., L.Č. All co-authors reviewed the final version and approved the manuscript before submission.

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