UDC: 581.54:551.583(496.5)”2018/2023”
Review article

MANAGEMENT OF ABIOTIC STRESS IN PLANTS IN THE KORÇA REGION AS A RESULT OF CHANGING AGRO-CLIMATIC INDICATORS

Adrian MAHO, Gjergji MERO, Besnik SKËNDERASI
“Fan S.Noli” University, Faculty of Agriculture, Department of Agronomy, Korcë, Albania.
**Corresponding author, e-mail: maho.adrian@yahoo.com*

Abstract

Changing of agroclimatic indicators is one of the most problematic challenges of our time, affecting agroecosystems and biodiversity across the globe. Abiotic stress refers to the negative impact of non-living factors on living organisms in an ecosystem. Rhythms of change in agroclimatic indicators in recent years have been higher than expected. Abiotic stress brings changes in plant growth, development and metabolism, leading to reduced plant yields and changes in ecosystems. The study focused on the multi-year analysis of main climate indicators, such as temperature and precipitation. Collected data from hydrometeorological stations in the Korça region, Albania, were processed and compared with the corresponding indicators of data from the previous 30-year periods. Heat and drought are undoubtedly the two most important stresses that have a major impact on crop productivity. The average temperature and its extremes show an increasing trend from year to year. The annual amount of precipitation shows insignificant fluctuations, while the amount of precipitation that falls on fewer days but in larger daily amounts is a concern for plants. The structure of the diagram, where are integrated the temperature and average monthly precipitation, showed that there is an increase in the drought period. Changes in agroclimatic indicators present a challenge for producers in the field of agriculture, for the remodeling of agricultural areas and the determination of the most appropriate technologies for the cultivation of agricultural crops.

Key words: Ecosystem, climate change, Korça region, precipitation, abiotic stress, temperature, bioclimatic indicators.

1. Introduction

Climate change is one of the major concerns for all countries in the world. Its impact is reflected in many sectors, among which agriculture occupies an important place.

Climate change affects the sustainability of crop production. Plants form the basis of terrestrial ecosystems and food chains. Abiotic stress as a result of changes in agroclimatic indicators is one of the most worrying current factors for the productivity of agricultural crops and for sustainable development.

Changes in agroclimatic indicators continue to expose plants to a series of abiotic stresses, including:

1. Temperature stress (Heat and cold stress)

Increasing temperatures expose plants to heat and cold stress. Temperature directly affects the intensity with which various plant functions develop such as: germination, photosynthesis, transpiration, enzymatic activity, growth and development, accumulation of organic matter, passage of phenological phases and the plant cycle. Temperature affects microbial processes in the soil as well as the physico-chemical properties of the soil. Despite other suitable abiotic conditions such as light, moisture, nutrients, etc., plant growth stops when the temperature value drops below a minimum value or exceeds a maximum value, while it is carried out with different intensities between these two limits (Peçuli, and Kopali, 2007).

https://doi.org/10.62792/ut.jasrd.v3.i5-6.p3112

The average temperature is predicted to increase by 0.2°C per year. It will increase by 1.8°C to 4°C by the end of 2100, making temperature one of the most damaging stresses (Hasanuzzaman et al., 2013).

Climate change, temperature-related, is a global concern that has affected the physiological and biochemical activity of plants, reducing crop yields (Bandi et al., 2012).

2. Drought Stress (Water-related Stress)

Reduced precipitation and increased evapotranspiration lead to drought conditions. Drought stress causes plant wilting, leaf scorch, and reduced photosynthesis, reduces CO2 uptake, and limits photosynthesis (Baidya et al., 2022). Drought can also lead to reduced cell turgor, inhibiting cell expansion and growth.

Drought is one of the main factors affecting plant production. Plant growth and yield are affected by this stress (Atta et al., 2021). Drought stress is caused by a lack of precipitation, salt accumulation in the soil, increased temperature, and excessive light intensity. Drought stress has a significant impact on plant growth, water retention, and water efficiency (Atta et al., 2020; Fathi and Tari, 2016), and causes changes in physiological, biochemical, morphological, and molecular features.

Climate change affects the entire plant development cycle (Kopali and Doko, 2015). According to various studies performed by the IPCC in Southern Europe, where Albania is located, it is predicted that the occurrence of climate change will bring an increase in temperature and a decrease in precipitation (IPCC, 2007). The increase in temperature as part of climate change has significantly affected the productivity of crops cultivated in the spring, such as beans, potatoes, sugar beets, etc., as well as those planted in the fall, such as barley and wheat.

An important indicator of climate change that has been observed in this area is the decrease in the number of days with snow, as well as the delay in the bigininng of snowfall.

The Korca region is characterized by a faster increase than expected in temperature and drought. High temperatures and prolonged drought are the abiotic stresses with the greatest impact on agricultural crops (Maho et al., 2023). In these conditions, a scientific response to the scientific solution of this problem is a necessity for farmers. With these changing climatic conditions, climate-resistant crops and crop varieties have been recommended as a way for farmers to cope with or adapt to climate change. Integrated physiological and molecular approaches are important to combat multiple abiotic stresses.

The objective of the study was to assess the changes in climatic indicators for the Korça region in Albania, based on scientific parameters. Determining scientific solutions regarding of the management of abiotic stress in plants in the Korça region as a result of the change in agro-climatic indicators. Conducting these studies aims that climate change to turn from a problem into an opportunity for increasing the productivity of agricultural crops and sustainable agricultural development in harmony with the environment.

2. Material and Methods

Material

In this study are used climatic data, with reference to meteorological stations located in the plain area of Korça and Bilisht in Albania related to meteorological indicators (temperature, precipitation, relative humidity, wind speed and direction, solar radiation). Korça lies at an altitude of 850 m above sea level and is characterized by a Mediterranean mountainous and partly continental climate, with cold winters and hot and dry summers. The average annual temperature reaches up to 10.6 ºC. January is the coldest month, while August is the hottest. November is the wettest month with an average rainfall of 104 millimeters, while the average annual rainfall reaches 720 millimetres.

For this reason, in our study, have been collected and processed, data on agroclimatic indicators of a 120-year period (1901 - 2020). The data are grouped then into 30-year periods: 1901 – 1930, 1931 – 1960, 1961 – 1990 and 1991 – 2020.
In the study we reflect more detailed data for a shorter period of time 2018 – 2023 because in this period we have set up some experiments related to the impact of climate change as well as finding the most appropriate solutions to respond to these changes in some agricultural plants such as barley, corn, fodder peas, potatoes, small grain beans, sugar beet, etc.

Methods

The data's are obtained from different sources, such as:

- ✓ Hydro meteorological Institute - Academy of Sciences. Climate of Albania, Volumes I and II (data for the corresponding years 1931-1960 and 1961 - 1990)
- ✓ Institute of Geosciences (data for the corresponding years 1991-2021)
- ✓ Monthly climate bulletins, Institute of Geosciences publications (Climate Bulletin 2018-2023).
- ✓ The data's observed for the respective time periods are processed, and obtained different values of climate variables:
- ✓ Records on average, maximum and minimum monthly and annual temperatures;
- ✓ Records on monthly and annual rainfall;
- ✓ Daily and monthly records on average, maximum and absolute minimum temperatures;
- ✓ Monthly recorded values on the number of days with relative humidity equal or lower to 50 %;
- ✓ Monthly data of the number of days with relative humidity greater than or equal to 80% (≥ 80 %) for 14 hours;
- ✓ Number of days with snow
- ✓ Sum of active temperatures
- ✓ Frost-free period

From a general ecological standpoint, the classification of climate is done on the basis of climatic indicators. Generally, these indicators are focused on the thermal and precipitation regimes as the most important climate elements (Kopali et al,2012).
The determination of drought periods was calculated according to the Bagnlous & Gossen ombrothermic diagram method (Bagnlous and Gossen, 1957). The temperature and precipitation trends and their tendencies are analysed by using regression equations and correlation coefficients.
The sum of active temperatures is calculated:

$\sum AT = \sum T > 10^0C$
where :
$\sum AT$ - Sum of active temperatures;
$\sum T > 10^0C$ - sum of average daily temperatures $>10^0C$

3. Results and Discussion

Results

From the data processed, the climatic features of the Korça plain and Bilisht were determined, based on the four analysed variables:

1. Temperature (ºC) minimum, maximum, average;
2. Average precipitation mm;

3. Number of days with snow
4. Drought period
5. Sum of active temperatures
6. Frost-free period

The obtained results for the period 2018-2023 were processed and compared with data on agroclimatic ratios of a 120-year period (1901 - 2020).

The data on average atmospheric temperatures 2018-2023, 1931-1960, 1961-1990, 1991-2020 in the Korça region are presented in Table 1.

Table 1. Average atmosphere temperature (°C) in the Korça region [Processed by the Meteorological Bulletins published by the Institute of Geosciences, Energy, Water and Environment, related to the average temperature for the years 2018 – 2023 in the Korça region.]

Average atmospheric temperatures (°C)										
Month	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	Average 2018-2023	Average 1991-2020	Average 1961-1990	Average 1931-1960
January	2.8	-2.2	1.8	2.2	1.9	3.5	1.7	-0.8	0.5	0
February	3	3.2	4.6	4.2	4.3	3.5	3.8	0.6	1.8	1.6
March	7.1	7.5	7	4.7	4.4	7.6	6.4	4.2	4.9	4.8
April	12.5	10.6	9.8	9.4	10	9.2	10.2	8.8	9.7	9.4
May	17.1	13.2	15	15.8	16.7	13.6	15.2	13.4	14	14.5
June	18.5	20.5	18.3	19.4	20.9	18.8	19.4	18	17.8	17.5
July	21.4	21.5	22.1	21.4	22.3	24.4	22.2	20.9	20.5	19.5
August	20.5	22.8	21.2	21.5	21.5	21.8	21.6	21.3	20.8	19.1
September	18.1	18.7	18.4	18.3	17.6	19.2	18.4	16.1	17.3	16.2
October	14.3	15	12.5	13.7	13.1	15.2	14	11.4	11.5	11.3
November	8.2	9.8	7.2	8.4	9.1	9.7	8.7	6.1	7.2	6.3
December	2.2	4.4	5.6	3.9	6.3	5.9	4.7	1.2	2.8	1.9
Average	12.1	12	11.9	11.9	12.3	12.7	12.2	10.1	10.7	10.2

The data on average precipitation 2018-2023, 1931-1960, 1961-1990, 1991-2020 in the Korça region are presented in Table 2.

Table 2. Average precipitation for the corresponding years in the Korça region. [Meteorological Bulletins published by the Institute of Geosciences, Energy, Water and Environment, related to monthly and annual amount of rainfall for the years 2018 – 2023, in the Korça region.]

Precipitation (mm)										
Month	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	Average 2018-2023	Average 1991-2020	Average 1961-1990	Average 1931-1960
January	52	145	15	172	25	105	85.8	73	47	70
February	47	12	45	87	76	20	47.8	76	54	68
March	123	12	115	52	48	62	68.7	77	46	53
April	12	55	54	53	78	66	53	75	48	54
May	128	82	41	18	16	110	65.8	67	62	58
June	145	65	41	85	80	142	93	34	45	42
July	25	74	38	32	40	7	36	26	32	21

August	160	21	112	22	42	25	63.6	21	23	25
September	8	17	32	35	44	41	29.5	49	38	44
October	12	25	56	67	52	36	41.3	67	76	85
November	156	184	12	52	68	165	106.2	87	105	112
December	42	74	71	65	45	38	55.8	96	75	89
Average	910	766	632	740	614	817	746.5	748	651	721

Discussion

From the data presented an increase in the average air temperatures was observed. For the corresponding period 2018 – 2023 compared to the years 1961-1990 the average minimum atmosphere temperatures was increased by 0.85 °C, average maximum temperature was increased by 2.15 °C, while the average temperature show ed an increase by 1.5 °C.
The Mediterranean region (which includes Albania) has been identified as one of the regions that will be affected by significant climate change (Alessandri et al., 2014, Diffenbaugh and Giorgi, 2012). Cultivars selection is one of the best ways to cope with the negative effects of climate change and environmental stresses (Souri and Hatamian, 2019, Zivdar et al., 2016). It is predicted that with climate change there will be a significant increase in maximum and minimum temperatures in all seasons (Cardoso et al., 2019). The best way to deal with crop responses to a warmer climate is to assess the response of cropping systems. Plant phenology is one of the fundamental characteristics and serves as an indicator of production. It changes as crops adapt to changing environmental conditions (Duchêne and Schneider, 2005., Lipiec et al., 2013., Sadras and Monz, 2006; Wolfe et al., 2005).
From the data presented, an increase in the average air temperatures was observed. For the corresponding period 2018 – 2023 compared to the years 1961-1990, the average minimum atmosphere temperatures was increased by 0.85 °C, the average maximum temperature was increased by 2.15 °C, while the average temperature showed an increase by 1.5 °C.
The highest increase in temperatures has occurred in the periods February - March and June - August. Based on the data's analysed, it can be argued that the significant increase of temperatures has directly affected the performance of plant cultivation. The increase in temperature has been determined by other studies but the growth rates are higher. Temperature is one of the most important ecological elements. It determines the intensity of various plant functions such as germination, photosynthesis, respiration, accumulation of organic matter.
By integrating the data records on temperatures and precipitation through Bagnoulus-Gaussen ombrothermic diagrams, were determined the drought periods in Korça region. These authors define drought periods as periods when monthly precipitation is less than twice the average monthly temperature.

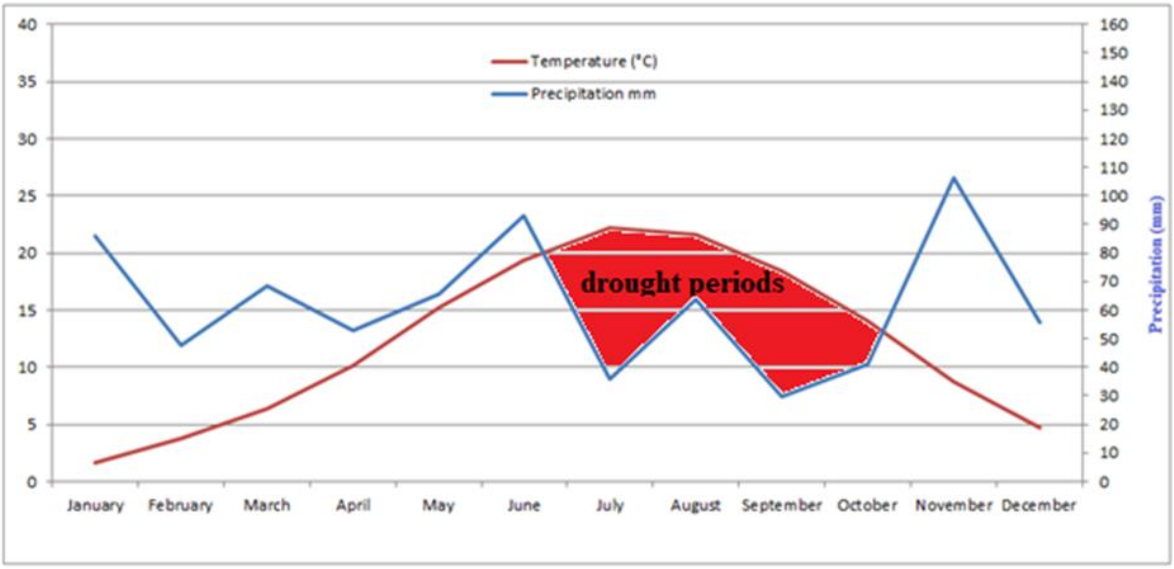

Figure 1. Ombrothermic diagram of Bagnoulus & Gaussen for drought periods in Korça region for (2018 – 2023)

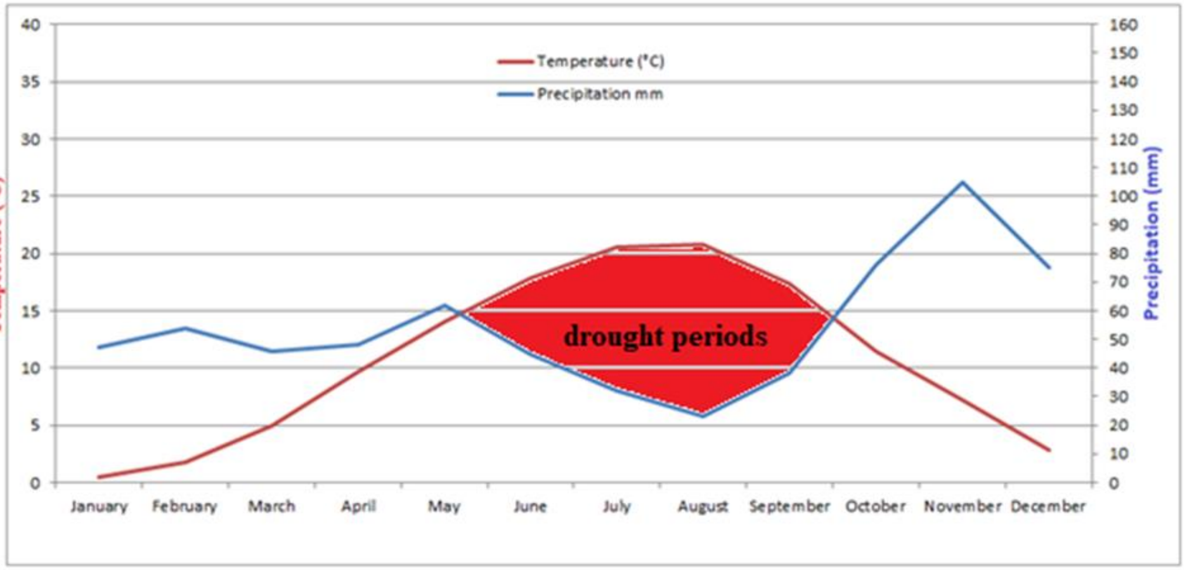

Figure 2. Ombrothermic diagram of Bagnoulus & Gaussen for drought periods in Korça region for (1961 – 1990)

Based on the data's shown in Figures 1 and 2 presented above, it can be concluded that climate changes has significantly influenced drought periods. From the graphic analysis, on the agro-climatic context, it is observed that drought for the period 1961 - 1990 in the region of Korça, starts from the first 10 days of June and continues until the second 20th of September. On the other side, for the period 2018 – 2023, drought starts from the first 10 days of June and continues until the second 20th of October. Based on that, it is easily identified that there is a one month extension of the drought period. There are also significant changes in monthly precipitation for this periods. That data's observed indicate a trend of increased temperatures throughout the year, while it is difficult to conclude the same for the amount of precipitation. From the study of these diagrams, we come to the conclusion that climatic factors affect the development of plants not separately but integrated.

The fairest assessment of climate change is the use of scientific methods for collecting and processing climate data for a specific area. To draw valid conclusions, the comparison of processed data should include long periods of time. The use of this practice is necessary to avoid "accidental" changes in a short period of time.

Based on these studies, the plants most stressed by the increase in temperature in the Korça region are small bean and potato.
The optimal temperatures for flowering and pod formation are 18-25 ºC. This is the period when beans are quite sensitive to this factor. When temperatures are around 29-32 ºC accompanied by a lack of soil moisture, they cause massive flower drop, preventing the pollination of the beans. The greatest sensitivity of the bean plant is due to significant temperature changes (Maho and Mero, 2018).
Potato is very sensitive to high temperatures above 25-30°C. The continuous and long-term action of high temperatures above 30°C at the time of tuber formation, especially at night, brings about the so-called ecological degeneration. As a result, there is a decrease in the quantity and quality of production and the production capacity of tubers for the following year (Maho et al, 2019).
Cultivar selection is one of the best ways to adapt to negative climate changes. The best examples in this regard are the alpha cultivar in barley, Voskopoja peas, etc. (Maho et al, 2018). These two cultivars have created the possibility of planting since autumn (barley and fodder peas are traditionally planted in the spring), affecting a 2-3-fold increase in production.
Another equally important way is to change the technology of agricultural crops cultivating. The change in planting dates has been quite effective as it affects the modification of the phenological periods of plants by moving them to periods more suitable for the plants.
For beans, potatoes, sugar beets, planted 10 days earlier than the traditional planting dates has resulted in quite positive results (Maho and Skënderasi, 2020).
For wheat and barley, the optimal planting date has been extended by 10 days. The optimal planting date today is recommended from October 1 to November 10.
The increase in temperatures has had a positive impact on corn productivity. Before the 1990s, the use of corn hybrids up to class 500 (with a 116-120-day germination - full ripening cycle) was recommended. In recent years, the 600 class of corn hybrids (with a 121-130 day germination - full ripening cycle) has also been used.

4. Conclusions

From the data presented an increase in the average air temperatures was observed. For the corresponding period 2018 – 2023 compared to the years 1961-1990 the average minimum atmosphere temperatures was increased by 0.85 °C, average maximum temperature was increased by 2.15 °C, while the average temperature show ed an increase by 1.5 °C.
The highest increase in temperatures occurred in the periods from February to March and from June to August.
In the agro-climatic context, for the period 2018 – 2023, drought has started from the first 10 days of June and continuing until 20th of October. Based on that, it is concluded that there is a one month extension of the drought period. For the same period, significant changes in the monthly precipitation have occurred. It is observed a trend of increased temperatures throughout the year, while it is difficult to conclude the same for the amount of precipitation. In the last decade, the average number of days with snow in Korça plain has been reduced by about 10 days. The average start date of snow has been postponed for about a month.
The selection of cultivars is one of the best ways of adapting to negative climate changes. Among the best examples in this direction is the alpha cultivar in barley, Voskopoja pea, etc. These two cultivars have created the possibility of planting in the autumn (barley and fodder peas are traditionally planted in the spring), influencing in increase the 2-3 times of production.
Another an important way is to change the cultivation technology of agricultural crops. The change in planting dates has been quite effective as it affects the modification of the phenological periods of plants by moving them to more suitable periods for the plants.

For the bean, potato, sugar beet, planted 10 days earlier than the traditional planting dates, it turned out to be quite positive.

For wheat and barley, the optimal sowing period has been extended by 10 days. The optimal planting period today is recommended from October 1 to November 10.

The increase in temperatures has had a positive impact on maize productivity. In recent years, is being used the 600 class of corn hybrids (with a cycle of 121-130 days of germination - full ripening)

Acknowledgements

The authors gratefully acknowledge the support of "Fan S.Noli" University, Faculty of Agriculture, Department of Agronomy, Korce, Albania, for assisting the experiment.

References

[1] Alessandri, A., De Felice, M., Mariotti, A., Zeng, N., Mariotti, A., Pan, Y., Cherchi, A., Lee, J., Wang, B., Ha, K., Ruti, P. and Artale, V., 2014. Robust assessment of the expansion and retreat of Mediterranean climate in the 21st century. *Scientific Reports*, 4, DOI: 10.1038/srep07211.

[2] Atta, K., Chettri, P., Pal, AK., 2020. Physiological and biochemical changes under salinity and drought stress in Ricebean [Vigna umbellata (Thunb.) Ohwi and Ohashi] seedlings. *International Journal of Environment and Climate Change.* 2020;10(8):58-64. DOI: 10.9734/ijecc/2020/v10i830218

[3] Atta, K., Chettri, P., Pal, AK., 2021. Effects of salinity, drought and heavy metal stress during seed germination stage in ricebean [Vigna umbellata (Thunb.) Ohwi and Ohashi]. *Plant Physiology Reports.* 2021;26(1):109-115

[4] Bagnlous, F and Gossen, H. 1957: Les climats bilogiques et leur classification. *Ann.De Geogr*. 1957:2.

[5] Baidya, A., Ali, AM. and Atta, K., 2022. Climate Change and Abiotic Stresses in Plants. Advances in Plant Defense Mechanisms. *Book. DOI: 10.5772/intechopen.105575*

[6] Bandi, V., Shanker, AK., Shanker, C. and Mandapaka M., 2012. Crop Stress and Its Management: Perspectives and Strategies. Berlin, Germany: *Book. Publisher: Springer Dordrecht* ISBN: 9400722192 Springer; 2012. pp. 261-316.

[7] Cardoso, R., Soares, P., Lima, D. and Miranda, P., 2019. Mean and extreme temperatures in a warming climate: EURO CORDEX and WRF regional climate high-resolution projections for Portugal. *Climate Dynamics*, 52, 129-157.

[8] Diffenbaugh, N.S. and Giorgi, F., 2012. Climate change hotspots in the CMIP5 global climate model ensemble. *Climatic Change*, 114, 813-822.

[9] Duchêne, E. and Schneider, C., 2005. Grapevine and climatic changes: a glance at the situation in Alsace. *Agronomy for Sustainable Development*, 25(1), 93-99.

[10] Fathi, A. and Tari, DB., 2016. Effect of drought stress and its mechanism in plants. *International Journal of Life Science*. 2016;10:1

[11] Hasanuzzaman, M., Nahar, K., M, MA., Chowdhury, RR. and Fujita M., 2013. Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. *International Journal of Molecular Sciences.* 2013;14: pp 9643-9684

[12] Hydrometeorological Institute, 1990. Climate of Albania. Tirana: Hidmet Book Publishers.

[13] Institute of GeoSciences, Energy, Water and Environment Monthly. *Climate Bulletin 2018-2023.*

[14] Intergovernmental Panel on Climate Change (IPCC), 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. New York: Cambridge University Press.

[15] Kopali, A., Peculi, V., Teqja, Z., and Rota, E., 2012. A study on agroclimatic characterization of Albanian Territory. *AGRIS* Nr. 3/Vol. 11, p.173-177.

[16] Kopali, A. and Doko, A., 2015. Studies on agroclimatic characterization of the area of Korça. *Proceeding of Second International Conference of Agriculture Food and Environment*, Korçë, Albania, September 25, 2015, pp. 321-329.

[17] Lipiec, J., Doussan, C., Nosalewicz, A. and Kondracka, K., 2013. Effect of drought and heat stresses on plant growth and yield: a review. *International Agrophysics*, 27(4), 463-477.

[18] Maho, A. and Mero, Gj., 2018. The evaluation of the bean autochthonous germoplasma in Korça region. *Annals Valahia" University of Targoviste – Agriculture*. Volume 12: Issue 1 Date: 01 Apr 2018, Pages: 44–50. DOI : 10.2478/agr-2018-0008.

[19] Maho, A., Mero, Gj., and Maho, F., 2018. Changes in the agro-technique cultivation of barley as an adaptation to climate change. *Ecological Questions* 33(2022)4, Volume 33: Issue 4 (2022) Date: 12 August 2022 Pages: 1–22 http://dx.doi.org/10.12775/EQ.2022.038.

[20] Maho, A., Mero, Gj., and Maho, F., 2023. Changes in Agro-climatic Indicators in the Korça Region. *Current Applied Science and Technology* Vol. 23 No. 4 pp 1-10.

[21] Maho, A., Skënderasi, B., 2020. The change of planting timing to sugar beet cultivars as an adaptation to climate change. *Journal of the austrian society of agricultural economics*. Volume 16, Issue 05, May, 2020. Pages 111-123. JASAE-15-07-2020-32

[22] Maho, A., Skënderasi, B., and Cara, M.,2019. Changes in potato cultivation technology in Korça region as adaptation to climate change. *Italian Journal of Agronomy* 2019; volume 14:1374 84-93.

[23] Peçuli, V. and Kopali, A., 2007. Agroecology. Agricultural University of Tirana. Tirana: *Toena Book Publishers.*

[24] Sadras, V. and Monz, J.P., 2006. Modelled wheat phenology captures rising temperature trends: Shortened time to flowering and maturity in Australia and Argentina. *Field Crops Research*, 99(2), 136-146.

[25] Souri, M.K. and Hatamian, M., 2019. Aminochelates in plant nutrition; a review. *Journal of Plant Nutrition*, 42(1), 67-78.

[26] Wolfe, D., Schwartz, M., Lakso, A., Otsuki, Y., Pool, R. and Shaulis, N., 2005. Climate change and shifts in spring phenology of three horticultural woody perennials in northeastern USA. *International Journal Biometeorology*, 49(5), 303-309.

[27] Zivdar, S., Arzani, K., Souri, M.K., Moallemi, N. and Seyyednejad, S.M., 2016. Physiological and biochemical response of olive (Olea europaea L.) cultivars to foliar potassium application. *Journal of Agricultural Science and Technology*, 18(12), 1897-1908.