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Changes in the agro-technique cultivation of barley as an adaptation to climate change

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Abstract. Agricultural crops productivity depends on the optimum degree of genetic factors, climate, soil and the level of agro-technology. These factors are changing constantly. The study is focused in a multi-year analysis of the climatic indicators in the region of Korça, by analysing the impact of these changes on the performance of morphological, physiological and production indicators of barley cultivars. The experimental part of the study identified the most suitable barley cultivars and planting period in response to climate changes. The observed data for the time period 2018–2021, and their comparison with a 30-year range period 1961–1990, indicated an increase by 1.8°C of the average atmosphere temperature. During the years of the study, the annual average amount of precipitation has shown not significant changes, but is observed less rainy days with high intensity. The application of the integrated Bagnoulus & Gaussen method indicated that the drought period has increased. From the study it is concluded that climatic factors affect the development of plants not separately but integrated. The period with the greatest influence of ecological factors on the production of different genotypes of barley occurs in the months May – June, a period where the plant is in the ripening stage. The main factor identified, in terms of adaptation to climate change, is the planting of barley in October compared to March, applied in previous practices. Different barley genotypes manifest different degrees of response to climate changes.

Key words: planting period, barley; climate changes; cultivar; temperature.

1. Introduction

Climate changes affect the sustainability of crop production. The degree to which agricultural plants adapt to the climatic environment and the level of technology, determines significantly the level of production. On the other hand, agricultural plants have diverse requirements in terms of climate and extend their development cycle into different periods of the year, where climatic conditions not always are suitable. Climatic features of different areas are studied and expressed through climatic classifications, but when it comes to agricultural plants the climatic environment should be characterized through agro-climatic classification of areas, since within the same area different plants react in different ways.

Korça plain is one of the most productive agricultural areas in Albania. The cultivation of Barley in this area is closely related not only with animal feed but also with the supply of the first beer factory established in Albania. Since 1928, "Korça Beer" has continuously used barley as raw material.

The yield of agricultural crops in agro-ecosystems varies from year to year. However, despite that fact, the cultivation techniques remain the same (in experiments settled up for this purpose). From this point of view, it can be determined that this variability derives from the direct or indirect influence of climatic factors that do not depend on the human being (Peçuli & Kopali, 2007). The Fluctuations of annual climatic elements directly affect the intensity of growth and production of agricultural plants.

Regardless of the degree of adaptation of agricultural plants to the climate and the level of technology used, the annual fluctuations of climatic elements determine the level of production achieved. On the other hand, agricultural plants have differentiated climatic requirements and extend their cycle of development at different times of the year, but not always, climatic conditions are appropriate (Kopali & Doko, 2015).

According to studies conducted (IPCC, 2007), Southern Europe, part of which is also Albania, is getting dryer and hotter with less precipitation. Agriculture and rural areas will be more affected by climate change and especially from the lack of rainfalls. In southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity.

The temperature increase as a result of climate changes has significantly affected the productivity of crops that are cultivated in spring, such as: beans, potatoes, sugar beets, etc. In the same time, climate changes also affects the cultivation of crops that are planted in the fall, such as barley and wheat.

An important indicator of climate change that has been observed in this area is the decline of snowy days, as well as the day of the onset of snow. According to the data published by the Hydro meteorological Institute in 1990 (these data reflect a summary of 30 years referring to the time periods 1931–1960 and 1961–1990), the average number of days with snow in the plain of Korça was 34.8, while the average start date of snow was December 11th. The data's of the year 1990, from the Hydro meteorological Institute and the Institute of Geosciences, Energy, Water & Environment (2016-2021) have shown significant changes in these indicators. In the last decade, the average number of snowy days in the Korça plain is 24.6, while the average start date of snow is January 3rd. Snow has an important role because it serves as a cover that reduces the impact of negative temperatures on barley during December. A period when the plants are in the fraternization phase.

The magnitude of reduction of mean snow height depends mainly on location, whereas for the contraction of the snow season elevation is the key factor. It could be shown that the temperature–precipitation combination as expressed in the snow dynamics explain changes in ground temperatures more than the individual changes in either parameter. (Bender et al., 2020)

The most important negative effect of occurrence of warm winters is reduction of the duration and thickness of snow cover (Tomczyk et al., 2021).

Altitude-dependent trends are found in autumn and early winter where the trends are stronger at low altitudes (<800 m asl), and in spring where slightly stronger trends are found at altitudes close to the snow line.

Depending on the duration of the fully insulating snow cover, snow cover can increase annual ground temperature by 2–7°C (Bartlett et al., 2004). Differences in the onset and melt-out day of snow cover can change mean annual ground temperature by up to 6°C (Goodric, 1982). Studies have shown (Ling & Zhang, 2003) that the onset date of snow cover in autumn is more critical than the melt-out day and additionally, an increase in snow depth by one meter can increase temperature by 2.7°C. The Mediterranean region, (Albania is part of it) has been identified as prominent climate change hot spot (Diffenbaugh & Giorgi, 2012; Alessandri et al., 2014).

Furthermore, other studies ascertain a significant increase of both maximum and minimum temperatures in all seasons and climate change scenarios (Cardoso et al., 2019).

In order to respond to climate changes it is important to identify the best genetic resources for the region. One of the most essential features of barley stand in its ability to adapt to ecological conditions due to the wide plasticity of species and the large number of ecotypes and cultivars. Barley is less resistant in low temperatures compared to other winter-crops (rye and wheat). It can withstand up to -12°C, depending on the biological type. Its stability increases when the temperatures drops slowly, especially when this crop is covered with snow. Newly grown barley shoots can withstand up to -4°C, while other specific cultivars up to -9°C, but may suffer some partial leaf damage. The spring forms pass the stage of vernalisation at temperatures scales 5-8°C, while in autumn 0-2°C. Somewhat worryingly, in southern European countries both wheat and barley yields have stagnated, a situation partly attributable to the emerging impacts of climate change (Brisson et al., 2010). All predictions indicate that these impacts will only be exacerbated in the future.

New genomic approaches may with other advances in targeting genes allow for more specific, localized responses to climate change that support resilience, while maintaining and enhancing productivity and quality, and facilitate the better deployment of existing varieties in modified and new climate spaces (Dawson et al., 2015).

From the widest perspective, almost all crops share the needs for improved tolerance to stress factors and for a reduction in the gap between potential and realized yields, and such research on barley is therefore generally informative (Newton et al., 2011).

In barley, the inheritance is quite consolidated with 2n = 14 chromosomes and with a self-fertilization almost complete. The species *Hordeum sativum* crosses within it and has high hereditary qualities. The increase in biological productive capacity is done without multiplying the number of chromosomes. Polyploid species with 2n = 28 chromosomes have also been observed, but these species have lower yields than the diploid form 2n = 14. The genetic improvement is mainly based on the pedigree method and on artificial mutations.

The planting time is very important, because it has a significant effect on the increase of production. Due to the non-compliance with the planting period, i.e. late planting (especially in cold areas, planting in late March-April) the yield has already fallen and the production has been completely compromised (in years without moisture).

The tetrastic barley (very serpentine) is mostly planted in autumn, but it can be done even in spring. In recent years, based on the experiments conducted in Korça region, it has resulted that even in the cold areas the polystyrene barley may produce high yield when planted in autumn. In this context, with reference to this area, today practices require more planting during the fall, combined with convenient cultivars.

The distic barley is planted in early spring, in the cold mountainous and pre-mountainous area at temperatures of 5–7°C up to the limit 2–3°C. Nowadays, as a winter biological type of cultivar, this type has been widely found in autumn plantings, not only in warm regions but even in cold ones. Autumn plantings have yielded twice as much output compared to the ones planted in spring. This is due to:

Increased winter hardiness which has increased up to – 16°C;

Transition from spring biological type to intermediate or winter type;

In order to better respond to climate changes, a significant factor is considered the experiment that is related to the best planting time.

Although fall-sown barley in regions with winter precipitation patterns can have significant yield advantages compared with spring-sown barley, there is a heightened risk of low temperature-induced crop injury. This risk is problematic at two stages of development: at the vegetative stage and at flowering (Muñoz-Amatriaín et al., 2020).

In general, the rate of sowing advance was accelerating in time and, also from representative concentration pathways 4.5 to 8.5, reaching 23 days for spring barley (Marcinkowski & Piniewski, 2018).

Crop phenology assumed to be one of the most important features involved in the final yield assessment and the adaptation of crops to the changing environmental conditions. The assessment of cropping systems response to a warmer climate plays a crucial role in the evaluation of future agricultural production potential, and the investigation of crop phenology response is a key stage for a better formulation of adaptation policies (Duchene & Schneider, 2005; Lipiec et al., 2013; Sadras & Monzon, 2006; Wolfe et al., 2005).

Extreme minimum temperatures and their continuity have an important role on the performance of physiological processes, not only for barley but also for all other plant species. These factors, are the main source of plant damage, which in particular years can damage it up to 40%. This is mainly related to the changing state of water within the cell.

Protoplasts, as material components of the cell, are surrounded by a layer of lipids. The "grounding" of the lipid layers that derive from the low temperature, due to the increase of oxidations, favours the cooling of the protoplast. In the intercellular spaces, the water is deprived of this protection and freezes after a relatively low cooling.

Depending on the location and intensity of the ice formation, different types of stresses can arise. At the time of ascents, in order to determine the main types of stresses, the continuous evaluation of the state of water (liquid or solid) in plant tissues is used.

In cases of ice formation in the intercellular spaces, to the extent that allows the normal physiological development of the plant, the amount of water decreases, thus increasing the stability of the plant. In terms of cold resistance, a significant role has the time of keeping the plant in a frozen state. Barley plants that have been exposed to temperatures up to -7°C during the last 10–15 days, are damaged more compared to those that have been exposed to -12°C, for a period of 2–3 days. The damage is greater in those cases when the temperature approaches the lethal level of plants. Due to the effect of low temperatures, three types of freezing have been observed: two types of leaves and that of the root.

The first type of freezing is observed in stable leaves, where the time of their formation coincides with the period with low temperatures.

The second type of freezing is observed in the leaves with lower stability, those that are formed at an age that correspond to higher temperatures.

The third type of freezing is found in the hydrated roots of the barley plant. This is referred as immediate freezing in transmission systems.

Through microscopic images are observed damages around xylem vessels.

Recent data concede that in winter resistant plants with normal hydration, the upper part of the fragmentation node and the leaves are more resistant to lower temperatures compared to the lower part or the root node.

Evidence based practice has recognized cases of root damage during winter and their revitalization has occurred because of the development of the new root system from the fraternity node in the spring period. In cases of fraternity node damages up to the level of impossibility of extracting the permanent root system, the barley plants are completely damaged.

The objective of our study was the of climate change assessment and the best ways of cultivating barley as adaptation to these changes.

The applied experiment with planting of the basic barley cultivars in October (during previous periods, traditional crops were planted in March), in order to test the impact of climate change.

2. Material and methods

In this study are used climatic data, with reference to meteorological stations located in the plain area of Korça and Bilisht 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°C. January is the coldest month, while August is the hottest. November is the wettest month with an average rainfall of 104 millimetres, while the average annual rainfall reaches 720 millimetres.

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 1991–2001)
- Monthly climate bulletins, Institute of Geosciences publications (data for the corresponding years 2018–2021)

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;

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 (Peçuli & Kopali, 2007).

The determination of drought periods was calculated according to the Bagnlous & Gossen ombrothermic diagram method (Bagnlous & Gossen, 1957). The temperature and precipitation trends and their tendencies are analysed by using regression equations and correlation coefficients.

Emberger pluviometric indicator.

Applied formula:

$$Q = (M + m) \times (M - m) / 100 R, \text{ where}$$

R – annual precipitation in mm; M – average of maximum temperatures of the hottest month;

m – average of the minimum temperatures of the coldest month;

Rivas – Martines Indicator (Rivas-Martínez et al., 2011):

Temperature amplitude Ic = Tmax – Tmin;

Thermal index TI = (T + m + M) x 10, where:

Tmax average of maximum temperatures of the hottest month of the year;

Tmin – average of minimum temperatures of the coldest month of the year;

M – Average temperatures of the hottest month;

m – average temperatures of the coldest month;

T – average the sum of annual temperatures.

The impact of agro-climatic indicators on barley is based on the database of the experimental data attained during the period 2018–2021 in the Bilisht area of Korça Region. The study was conducted according the Randomized Block scheme, with 4 repetitions and variant size of 20 m² (Xhuveli & Salillari, 1984).

The study is applied into 4 main cultivars of barley: Alfa, Napoli (distich) and Reni, Enti No. 2 (polystic), which are all planted in Korça region.

Each genotype was studied before planting for their physiological parameters, such as: germination power and energy, absolute weight. Based on these indicators, the unified seed quantity for 400 plants/m² was calculated.

The agro technical services were the same for each variant, calculating an optimal amount of macro-fertilizers. During the three years of research, planting was carried out within the first 10 days of October.

During the vegetation period, phenological phases were held and were performed field descriptions and biometric analyses for each genotype.

From the IVth repetition, an average sample of 1 kg was taken out and was performed laboratory analysis for the content of protein, carbohydrates, etc.

Statistical processing was performed in accordance with the literature and were analysed the coefficients of correlation, regression, etc.

In order to carry out the analysis for determining the time and action type of climatic factors on barley, the climatic data were grouped according to the stages of plant development. Then the assessment of the relationship between the yield of this crop for different stages and for the whole plant cycle was performed.

Plant development and productivity is related to climatic factors. In addition, different species, ecotypes or hybrids manifest different requirements in terms of climatic factors.

The data's on the bioclimatic study of barley are divided into production, phenological and climatic data.

In order to analyse the impact of climatic factors on barley productivity, analytical methods were used. In order to determine this connection, this method uses the linear function: $y = a + bx$.

The following system was used to define the parameters of the function:

$$na + b\sum x = y_i$$
$$a\sum x + b\sum x2 = \sum xy_i ,$$

where:
n – number of years taken into analysis;
yi – actual yield by years.

The production of barley as for all other plants is influenced by genetic factors, climatic factors and agro-techniques used. Since in the set up experiment the genetic factors and the agro-technique used are the same, the influence of climatic factors was analysed, in particular temperature and precipitation, on biological indicators and the production of barley cultivars. Determine the size, type and direction of the bonds was used the method of mathematical analysis. The correlation analysis method was based on the determination of the correlation coefficient. It was defined by the following formula:

$$r = \frac{\sum XiYi - nXmeanYmean}{\sqrt{(\sum Xi^2 - nXmean^2)(\sum Yi^2 - nYmean^2)}},$$

where:
r – correlation coefficient;
Xi – The observed values of the feature that we study;
Yi – Observed values of the second feature (in the case of productivity studied).

3. Results

From the data processed, the climatic features of the Korça plain and Bilisht were determined, based on the four analysed variables: average rainfall (mm); average annual temperature (°C); average number of days with relative humidity ≥ 80% annually, and average number of days with relative humidity ≤ 50% per 14 hours. The obtained results were processed and compared with the data's of study conducted in 2013 (Kopali et al., 2013).

On the table below are presented the records for climate indicators for the time period 2018–2021.

Table 1. Atmosphere temperatures during 2018–2021

Month	Minimum average atmosphere temperature °C				Maximum average atmosphere temperature °C			
	2018	2019	2020	2021	2018	2019	2020	2021
January	-1	-6.5	-3.4	-2.3	6.6	2.1	7	6.7
February	0	-2	-1	-1.7	6	8.4	10.2	10.1
March	2.2	1.8	1.9	0.3	12	15.2	12.1	9.1
April	4	4.8	3.6	3.7	21	16.4	16	15.1
May	11.6	8.2	8	9.1	22.6	18.2	22	21.5
June	12.6	13.9	12.6	12.8	24.4	27.1	24	26
July	15.3	14.9	15.1	15.2	27.5	28.1	29.1	28.1
August	14.8	15.6	15.4	15.4	26.2	30	27	27.5
September	11.4	12.2	11.8	11.5	24.8	25.2	25	24.9
October	9.9	8.6	6	8.1	18.7	21.4	19	19.8
November	4.1	5.8	1	3.5	12.3	13.8	13.4	13.3
December	-2	0.2	0.8	-0.2	6.4	8.2	9.4	8.1
Average	6.9	6.5	6	6.3	17.4	17.8	17.8	17.5

The indicators presented in Table 1 reflect the data processed by the Meteorological Bulletins, published by the Institute of Geosciences, Energy, Water and Environment, related to the minimum and maximum temperatures for the years 2018–2021 in the region of Korça. By comparing these data with the multi-year ones, we can reach scientific conclusions regarding the indicators of climate change. In the meantime, these data serve to identify whether we have a limiting climatic factor related to the development of barley plant.

Table 2. Average atmosphere temperature °C in the region of Korça.

Month	Average atmosphere temperature °C			
	2018	2019	2020	2021
January	2.8	-2.2	1.8	2.2
February	3	3.2	4.6	4.2
March	7.1	7.5	7	4.7
April	12.5	10.6	9.8	9.4
May	17.1	13.2	15	15.8
June	18.5	20.5	18.3	19.4
July	21.4	21.5	22.1	21.4
August	20.5	22.8	21.2	21.5
September	18.1	18.7	18.4	18.3
October	14.3	15	12.5	13.7
November	8.2	9.8	7.2	8.4
December	2.2	4.4	5.6	3.9
Average	12.1	12	11.9	11.9

The indicators presented in Table 2 reflect the data processed by the Meteorological Bulletins published by the Institute of Geosciences, Energy, Water and Environment, related to the average temperature for the years 2018 – 2021 in the region of Korça. By comparing these data with the perennial ones, we can reach scientific conclusions regarding the indicators of climate change.

Table 3. Average precipitation for the corresponding years in the region of Korça

Month	Precipitation mm						
	2018	2019	2020	2021	Average 2018-21	Average 1961–90	Average 1931–1960
January	52	145	15	172	96	47	70
February	47	12	45	87	48	54	68
March	123	12	115	52	76	46	53
April	12	55	54	53	43	48	54
May	128	82	41	18	67	62	58
June	145	65	41	85	84	45	42
July	25	74	38	32	42	32	21
August	160	21	112	22	79	23	25
September	8	17	32	35	23	38	44
October	12	25	56	67	38	76	85
November	156	184	12	52	101	105	112
December	42	74	71	65	63	75	89
Total	910	766	632	740	760	651	721

The indicators presented in Table 3 reflect the data processed by the Meteorological Bulletins published by the Institute of Geosciences, Energy, Water and Environment, related to monthly and annual amount of rainfall for the years 2018–2021, in the region of Korça. By comparing these data with the perennial ones, we can reach scientific conclusions regarding indicators of climate change.

From the records presented on table 3, it is observed that compared to multi-years data, the highest amount of precipitation (910 mm) recorded in 2018, and minimum (632 mm) recorded on 2020, are closer to the probability of coincidence with 75%.

After processing the data's on the average, maximum and minimum of monthly and annual temperatures, the differences between them were analyzed, as reflected on Table 4.

Table 4. Records of monthly and annual temperatures for the corresponding years (minimum, maximum, average)

Months	Minimum average atmosphere temperature °C		Maximum average atmosphere temperature °C		Average atmosphere temperature °C		
	Average 2018– 2021	Average 1961–1990	Average 2018–2021	Average 1960–1990	Average 2018–2021	Average 1931–1960	Average 1961–1990
January	-3.3	-3.8	5.6	3.8	1.1	0.5	0
February	-1.2	-2.2	8.7	5.4	3.8	1.8	1.6
March	1.6	- 0.2	12.1	9.8	6.6	4.9	4.8
April	4	4.4	17.1	14.4	10.6	9.7	9.4
May	9.2	8.1	21	19.7	15.3	14	14.5
June	13	11.4	25.4	23.6	19.2	17.8	17.5
July	15.1	12.8	28.2	26.2	21.6	20.5	19.5
August	15.3	12.6	27.7	25.6	21.5	20.8	19.1
Septem-ber	11.8	9.8	25	22.6	18.4	17.3	16.2
October	8.2	5.5	19.7	17.1	13.9	11.5	11.3
Novem-ber	3.6	1.9	13.2	10.7	8.4	7.2	6.3
December	-0.3	-2	8	5.8	4	2.8	1.9
Average	6.5	4.9	17.5	15.4	12	10.7	10.2

4. Discussion

From the data presented it is observed an increase in the average air temperatures (minimum, maximum and average). For the corresponding period 2018–2021, the average minimum atmosphere temperatures has increased by 1.6°C, average maximum temperature is increased by 2.1°C, while the average temperature has occurred an increase by 1.8°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 (Kopali & Doko, 2015) but the growth rates are higher. In the last 150 years, the planet's surface temperature has risen by an included value between 0.6°C and 0.8°C (IPCC, 2007). The current study reflects higher increases in temperature. The study data are in line with the made forecasts (IPCC, 2007), Southern Europe, of which Albania is part, is becoming drier and hotter and with less rainfall.

Temperature is one of the most important ecological elements. It affects all stages of barley plant development. It determines the intensity of various plant functions such as germination, photosynthesis, respiration, accumulation of organic matter. Exactly the increase of the average air temperature (minimum, maximum and average) has given

Table 5. Productivity of barley cultivars according to experimental data (kv/ha)

Cultivars	2019	2020	2021	Average
Alfa	54	40	50	48
Napoli	58	49	55	54
Reni	42	32	40	38
Entity Number 2	44	39	43	42
Mesatarja	49.5	40	47	45.5

the possibility that some of the barley ecotypes are cultivated in autumn. We emphasize that the barley crop is sensitive to biological minimums which present stimulating changes for cultivation since autumn.

By integrating the data records on temperatures and precipitation through Bagnoulus & Gaussen ombrothermic diagrams, were determined the drought periods in Korça region.

Based on the data's shown on the figures 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 2018–2021, 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 problematic

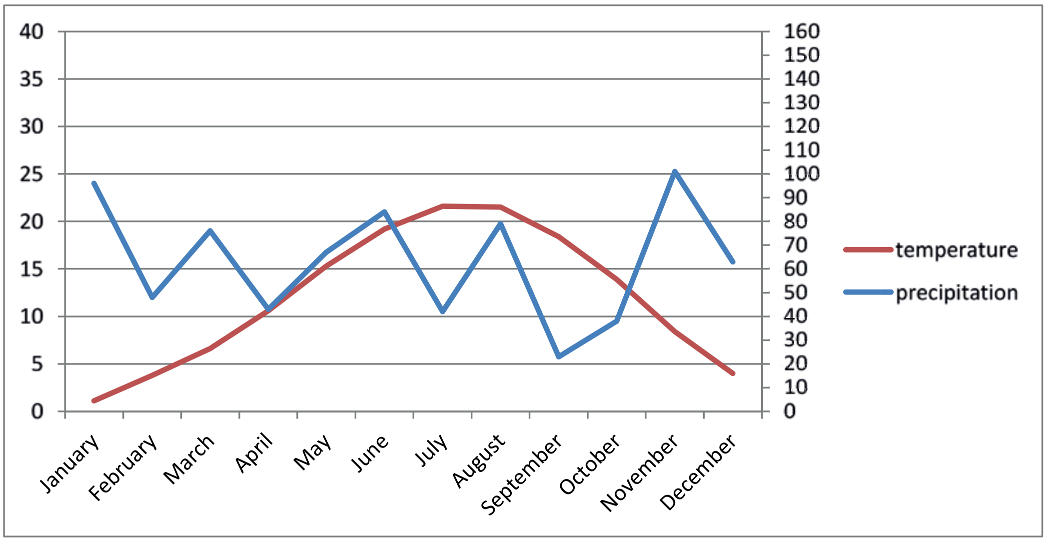

Figure 1. Ombrothermic diagram of Bagnoulus & Gaussen for drought periods in Korça region (2018–2021)

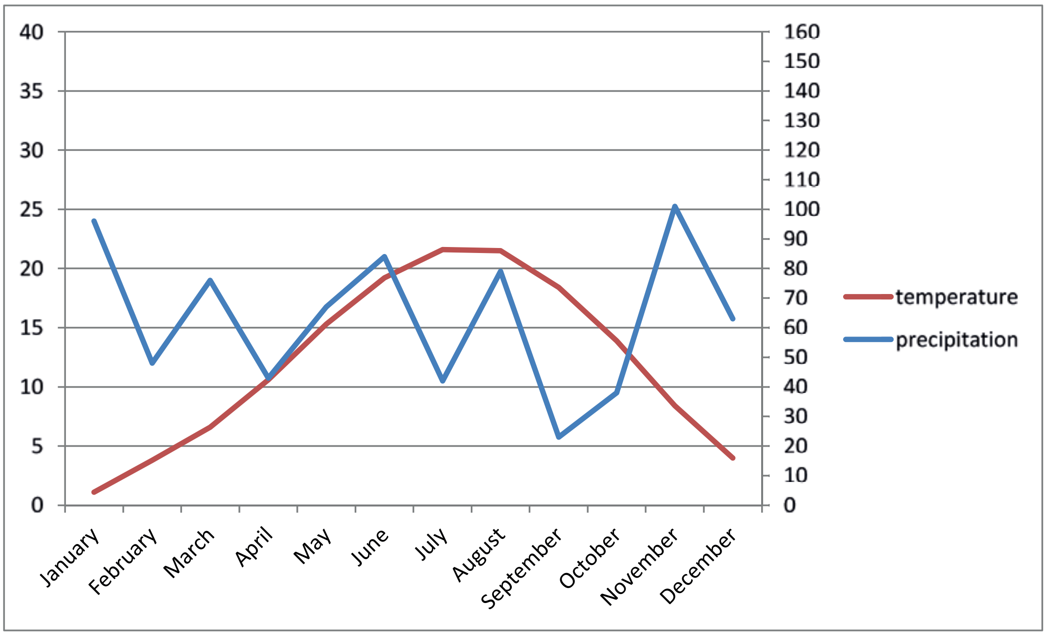

Figure 2. Ombrothermic diagram of Bagnoulus & Gaussen for drought periods in Korça region for (1961–1990)

period for the development of barley occurs in June, during which the barley plant is in the ripening – wax milk stage. There is a strong correlation between the time of onset of drought reflected through the ombrometric diagram and the productivity of the barley plant.

On Table 5 is illustrated the productivity of barley cultivars and their respective yields. As presented, all cultivar variants perform very positively since their cultivation period in autumn. The influence of climatic factors to different cultivars is determined based on the application of correlation analysis and determination of linear productivity function. On this basis is determined the order of cultivars in relation to the influence of environmental factors.

Correlation analysis for determining the linear productivity function:

Table 6. Summary of linear function of climatic factors that affect production

Cultivars	Linear function	Ranking by greatest influence
Alfa	y = 34 + 7x	1
Napoli	y = 45 + 4.5x	3
Reni	y = 28 + 5x	2
Entity Number 2	y = 37 + 2.5x	4
Average (Barley)	y = 34 + 5.7x	

From the analysis of the summary table of the linear function of the influence of climatic factors on production we conclude that different barley genotypes present changes in the intensity of the influence of these factors. The highest productivity sensitivity is represented by Alpha cultivar and the lowest by cultivar Entity Number 2.

During the experimental period we realized measured a series of biometric indicators to analyse their correlation with the productivity of different genotypes. Different stages of the plant were identified such as germination, fraternization, uplift, heading, flowering and maturation. From the collected data result changes both in terms of their beginning but also their duration. From this we conclude that it is the climatic factors that have a significant impact on the development of barley plants.

A parameter that strongly affect bio-physiological nature of productivity is the vegetative period on the day of ripening.

In addition, the effect of average temperature and precipitation on the number of days of baking/ripening and production are analyzed.

Based on the data processed it is concluded that there is a negative correlation between the increased atmosphere temperatures and the reported period of ripening. On the other hand, the quantity of precipitation presents even a stronger positive correlation.

These data show that all barley genotypes placed in the experimental test have the highest productivity have appeared in 2019, during which in the heading-ripening period we have the largest amount of precipitation, 137 mm, and the average air temperature with moderate which according to fluctuates from 17.6–18°C. The lowest productivity of all genotypes was realized in 2020, during which in the heading-ripening period we have the smallest amount of precipitation, 87 mm, and the highest average air temperature which varies from 18.1–18.6°C. The different temperatures during this stage of development for different genotypes are related to the different time of entry into this stage by them.

So, climatic factors in an integrated way determine the length of the heading-ripening phase which presents a strong correlation with production.

The correlation between the amount of precipitation (Xi) mm and the number of heading-ripening days (Yi) is presented in the following Table 8:

Table 7. Relationship between temperature and precipitation with production

Cultivars	Average atmosphere temperatures °C			Precipitation mm			Days to ripening			Production kv/ha		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Alfa	17.8	18.4	17.5	137	68	87	44	38	42	54	40	50
Napoli	17.9	18.2	17.7	137	68	87	48	41	45	58	49	55
Reni	17.6	18.1	17.6	137	68	87	40	35	37	42	32	40
Entity Number 2	18	18.6	17.8	137	68	87	42	37	40	44	39	43

Table 8. Correlation between the amount of precipitation mm (Xi) and the number of heading-ripening days (Yi).

Years	Precipitation mm Xi	Number of heading-ripening days Yi	Xi2	Yi2	XiYi
2019	137	43.5	18769	1892.25	5959.5
2020	68	38	4624	1444	2584
2021	87	41	7569	1681	3567
n = 3	Xmean= 97.3	Ymean = 40.8	$\sum Xi^2 = 30962$	$\sum Yi^2 = 5017.25$	∑ XiYi = 12110.5

The correlation between the amount of precipitation mm (Xi) and the number of heading-ripening days (Yi) is determined by the correlation coefficient which is found through the formula: **r = + 0.82**

This coefficient indicates that there is a strong correlation between the amount of precipitation mm (Xi) and the number of heading-ripening days (Yi).

Correlation between the number of baking days (Xi) and production (Yi) **r = + 0.92**

This coefficient indicates that there is a strong correlation between the number of heading-ripening days (Xi) and production (Yi).

Correlation of the amount of precipitation mm (Xi) in the period of heading-ripening and production (Yi) **r = + 0.88**

This coefficient shows that there is a strong correlation between the amount of precipitation mm (Xi) in the heading-ripening period and the production (Yi).

5. Conclusions

From the analysed data's in terms of climate and their comparison with 30-year range periods, respectively 1931-1960 and 1961-1990, it resulted that during the period 2018–2021: the average minimum atmosphere temperature has increased by 1.6°C; the maximum atmosphere temperature has increased by 2.1°C; the average atmosphere temperature has raised by 1.8°C. The largest increase in temperatures occurred in the periods from February to March and from June to August. This significant increase in temperatures has directly affected the performance of barley plant cultivation.

In the agro-climatic context, for the period 2018–2021, drought has started from the first 10 days of June and continuing until the second 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.

Referring to the years of study and comparing them with the multi-year period, it is noticed that the maximum amount of 910 mm is in 2018, while the minimum amount of 632 mm in 2020.

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. Snow plays the role of a cover, by reducing the impact of negative temperatures on the barley plant on December, when the plants are in the fraternization phase. Planting of barley in autumn has produced high yields compared to spring plantings. This requires experimentation in order to determine the most suitable cultivars.

All studied cultivars have performed very positively during cultivation period in autumn. The effect of climatic factors to different cultivars is determined based on the correlation analysis and determination of linear productivity function. The climatic conditions had a greatest impact on productivity of Alpha cultivar, followed by Reni, Napoli and Entity Number 2.

A parameter that strongly affect bio-physiological nature of productivity is the vegetative period on the day of ripening.

This coefficient indicates that there is a strong correlation between the amount of precipitation mm (Xi) and the number of heading-ripening days (Yi). **r = + 0.82**

This coefficient indicates that there is a strong correlation between the number of heading-ripening days (Xi) and production (Yi). **r = + 0.92**

This coefficient shows that there is a strong correlation between the amount of precipitation mm (Xi) in the heading-ripening period and the production (Yi). **r = + 0.88**

There is a negative correlation in terms of the increased temperature in the pre-baking period, while precipitation had a stronger positive correlation.

Like other crops (rye and wheat), even barley is less resistant to low temperatures. It lasts up to

-12°C depending on the biological type. Its stability increases when the temperatures drop slowly, especially when the plant is covered with snow. Newly grown shoots last up to -4°C, while specific cultivars up to -9°C, with partial leaf damages.

On spring forms, the vernalisation phase elapses at 5-8°C, while autumn forms on 0-2°C.

Barley has a better resistance on high temperatures at the time of grain binding, compared to oat and wheat. Humidity reaches the highest critical point before quenching. Distich barley requires more humidity, while polystyrene and those planted in autumn are more tolerant of drought. If there is rain at the time of ripening of the wax, the grain undergoes biochemical changes, which reduces the germination power and yield, while in distich barley it affects the beer malt.

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