ANALYSIS OF THE DYNAMICS OF CLIMATE FACTORS AND THEIR IMPACT ON THE MONOIC HEMP CULTURE

Cătălina COJOCARIU[1], Georgeta POP[1]

[1]University of Life Sciences „King Mihai I" from Timisoara,
119, Calea Aradului, 300645, Timisoara, Romania
Corresponding author: getapop_tm@yahoo.com

Abstract. *In the last decades, the main meteorological parameters, namely the air temperature and the amounts of atmospheric precipitation, have registered significant variations, both from one year to another, and within the same year, from one season to another. In addition to the variable climatic conditions, specific to the Timiş Plain, in the case of the hemp culture, the ecological conditions specific to this culture must also be taken into account. Based on these considerations, the aim of the paper is to carry out a detailed analysis of climatic factors and their impact on the main stages of growth and development of hemp, under the conditions of Timisoara. The analysis of temperatures and atmospheric precipitation was done over a period of six years, respectively 2017 – 2022. Average monthly thermal values and the sum of precipitation amounts were extracted for each year considered. For the period 2017 – 2022, four bioclimatic indices were calculated, based on which the main meteorological parameters with an impact on the hemp culture were characterized. In order to monitor the dynamics of the hemp culture (Mara 21 Variety) during the vegetative cycle, the BBCH scale (proposed by Mishchenko et al., 2017) and the average daily temperatures were used, based on which the sum of the temperature degrees was calculated, for each stage phenological and during the entire vegetation period. In the Mara 21 hemp variety, a vegetative and a generative stage were determined in the 150-day vegetation interval. The sum of the temperature degrees from sowing to harvesting the seeds was 3372.3^{0}C. The research results support the idea of variability of climatic conditions, especially of the amounts of atmospheric precipitation in the analyzed territory, which is also reflected on the hemp culture.*

Keywords: *monoic hemp, air temperature, atmospheric precipitation, vegetative phenophases.*

INTRODUCTION

Hemp is a crop of enormous social and economic value as it can be used to produce food, textiles, clothing, biodegradable plastics, paper, paint, biofuel as well as animal feed (SCHLUTTENHOFER, YUAN, 2017, DRESDEN, D., 2020, CERINO ET AL., 2021, ZHAO ET AL, 2021). Due to its value and impact on the environment, the hemp culture fits into the bioeconomy concept that characterizes the European Green Deal hypotheses (ZIMNIEWSKA, 2022).

On the territory of Romania, hemp culture is lost in the mists of time, having been cultivated for over 2000 years for fibers and there are no data that it was cultivated for drugs. In the medieval period, the whole family lived from hemp. From hemp they made their clothes, table linen, bed linen and everything in a house made of fabric (TABĂRĂ, 2005).

Hemp for fibers and especially Cannabis sativa L., which includes the varieties grown in Romania and, in general, in Europe, have a low content of narcotic and hallucinogenic substances (0.2%, according to the law). This hemp is created and used specifically for fiber production.

Regarding narcotic substances during the growing season, two processes take place in the hemp plant: the transformation of CBDA (cannabidiolic acid) into THC (tetrahydrocannabinol) and the transformation of THC into CNB (cannabinol), which is a pharmacologically inactive compound (GRINSPOON ET AL., 1993, BRETT, WALDRON, 1996, BRENNEISEN 2007, VANDOLAH ET AL., 2019, ROCK, PARKER, 2021). The first process is

strongly dependent on light and high temperature. The second process takes place within the transformations of the plant during the maturation period.

The influence of air temperature and day length on the phenophases of hemp vegetation and the thermal limits between which plants can grow and develop have been followed for a long time (AMADUCCIA, 2008, NIKOLAOU, EVANGELINOS, 2010, MUELLER ET AL., 2012).

Hemp needs a warm and humid environment (ADESINA ET AL. 2020) but it can adapt to a wide range of temperatures and rainfall levels (DHONDT 2020, ŻUK-GOŁASZEWSKA, GOŁASZEWSKI 2020.

Under the conditions in Romania, the seeds germinate at 2 - 3°C, but uniform germination is achieved at temperatures above 8°C; under optimal conditions hemp germinates after 7 - 9 days. After emergence, hemp grows rapidly until flowering, when it stops growing. Budding and flowering take place normally at a temperature of 18 - 20°C, and flowering and seed maturity take place well at a temperature of 20 - 24°C (MIHOC-BĂLUȚĂ, 2013, PANDA ET AL., 2017).

For the same period of the year and in the same place, temperatures can vary greatly from one year to another. This explains why a vegetation phase can appear earlier in one year than in another, the rapidity of plant growth and development largely depending on the temperature.

Based on these considerations, the aim of the paper is to carry out a detailed analysis of climatic factors and their impact on the main stages of growth and development of hemp, under the conditions of Timisoara.

MATERIALS AND METHODS

The study area

The experimental site is located in the east of the administrative-territorial unit of Timişoara and the urban area of the Municipality of Timişoara, in the premises of the Young Naturalists' Station, affiliated to the University of Life Sciences „King Mihai I" from Timisoara (Figure 1).

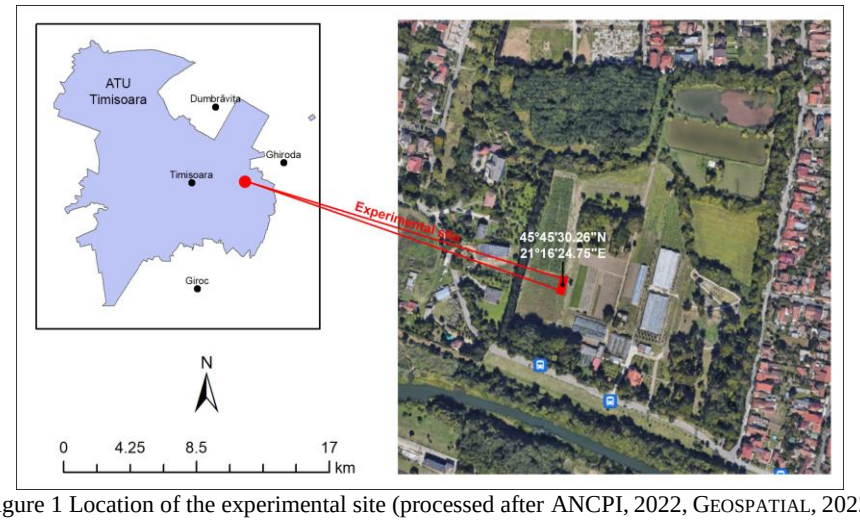


Figure 1 Location of the experimental site (processed after ANCPI, 2022, GEOSPATIAL, 2022)

From a physical-geographic point of view, the experimental site is defined by the specific conditions of the low plain of Banat, with almost flat relief, with altitudes below 100 m and low slopes, which is also reflected in the "behavior" of the other environmental factors (POSEA, 2005; RUSU, 2007).

Analysis of climate factors with impact on hemp culture

For the analysis of the climatic conditions in the experimental site, the following parameters were taken into account (CLIMATE DATABASES, 2022):

- average annual and multiannual temperatures, in the period 2017 – 2022;
- average monthly temperatures (Figure 2) and multiannual monthly averages, in the period 2017 – 2022;
- average daily temperatures, for the period 01.04.2022 – 30.09.2022;
- amounts of annual and monthly precipitation in the period 2017 – 2022;
- average monthly (Figure 2), annual and multiannual precipitation amounts, in the period 2017 – 2022.

According to the data presented graphically in figure 2, average monthly temperatures and amounts of precipitation vary from one season to another, but also from one year to another, which is also reflected in the vegetation dynamics.

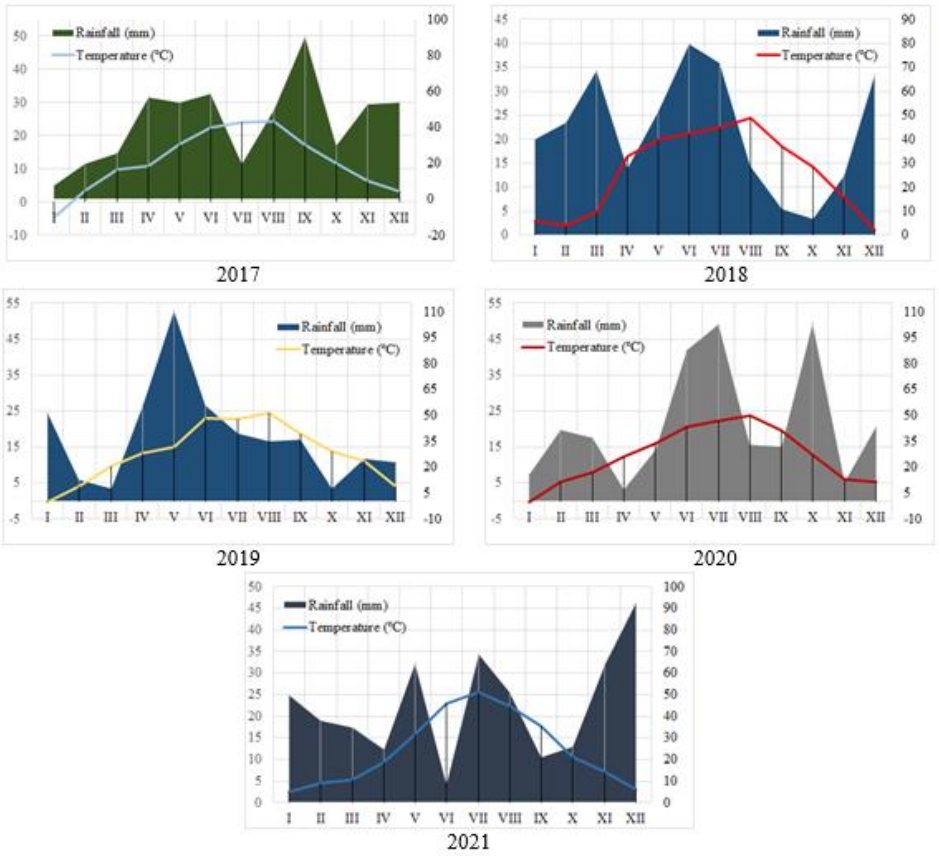


Figure 2 Climate diagrams for the period 2017 – 2021, at the Timişoara weather station (processed after CLIMATE DATABASES, 2022)

Bioclimatic indices (ecometric climatic indices) used in the characterization of the experimental site

The indices presented in table 1 were used for the climatic characterization of the experimental site, but also to highlight the influence of some climatic parameters on the hemp culture.

Table 1

Bioclimatic indices used in the characterization of the experimental site

Indice bioclimatic		Formula		Semnificație
CSOi	The Compensated Summer Ombrothermic index	$CSOi = \frac{(P_5 + P_6 + P_7 + P_8)}{(T_5 + T_6 + T_7 + T_8)}$ (RIVAS-MARTÍNEZ ET AL., 1999, SALAMON-ALBERT ET AL., 2016, qouted by VLĂDUȚ ET AL, 2017)	(1)	P_5.....P_8 – the sum of precipitation from May to August T_5.....T_8 – the sum of the temperatures from May to August
T_M	Mayr tetratherm	$T_M = \frac{t_V + t_{VI} + t_{VII} + t_{VIII}}{4}$ (SATMARI, 2010; VLĂDUȚ ET AL, 2017)	(2)	t_V....t_{VIII} – average monthly temperature between May and August
P_{veg}	The sum of precipitation in the months when the mean temperature is higher than 10ºC (VLĂDUȚ ET AL, 2017)		(3)	P – the amount of precipitation during the vegetation period
R	The rain factor of Lang	$R = \frac{P}{T}$ (SATMARI, 2010)	(4)	P – average annual precipitation amounts; T – average annual temperatures

Analysis of the hemp culture by vegetation phenophases

In order to monitor the dynamics of the hemp culture (Mara 21 Variety) during the vegetative cycle, the BBCH scale was used (proposed by MISHCHENKO ET AL., 2017) and the average daily temperatures, based on which the sum of the temperature degrees was calculated, for each phenological stage and for the entire vegetation period.

During the development of the hemp culture, biometric measurements were made on seven consecutive dates (11.04, 18.04, 4.05, 18.06, 16.07, 11.08, 08.09). At those dates, the corresponding BBCH codes were identified based on the main stages and the specifications proposed by MISHCHENKO ET AL., 2017, as follows: 00 Dry seeds (sown 11.04); BBCH 09 Emergence: cotyledons pierce the soil surface (18.04); BBCH 15.35 – 15 - 5 pairs of true, compound leaves and 35 - stem 50% of final length (4.05), BBCH 18, 25 -18- 8 pairs of true, compound leaves and 25 more lateral shoots at the base of the leaf (18.06); BBCH 67,71- 67- Flowering finish: 70% of flowers open, many male flowers fallen and 71 - 10% of fruits have reached final size and color (16.07); BBCH 76.83 – 76-76 60% of the fruits have reached the final size and color and 83 - 30% of the ripe fruits (11.08); BBCH 87 - 70% of ripe fruit (08.09).

RESULTS AND DISCUSSIONS

Analysis of the climate factors with impact on hemp culture

In the case of plants, in general, the air temperature has a particularly important role in the processes of photosynthesis, respiration, germination, vernalization, transpiration, the accumulation of dry matter, the appearance of phenophases and implicitly on production (ENACHE, 2009).

The influence of precipitation on vegetation depends on a series of factors, such as: the absorption capacity of the soil and its characteristics, the nature of the vegetation, the

amounts of water lost through evapotranspiration, but also the precipitation regime in the areas and periods referred to (ENACHE, 2009).

Four bioclimatic indices were used for the characterization from the climatic point of view, but also to capture the influence of the meteorological parameters on the experimental site, respectively the analyzed monoic hemp culture. The indices are described in the following.

The Compensated Summer Ombrothermic index (CSOi) is used to assess aridity or, conversely, to highlight aspects related to the humidity that plants can benefit from in a given region, given that the calculation formula is a ratio between precipitation and average temperatures in the hottest months of of the year (Relation 1).

For the period 2017 – 2022 analyzed in the case of the experimental site, the CSOi values are presented in figure 3.

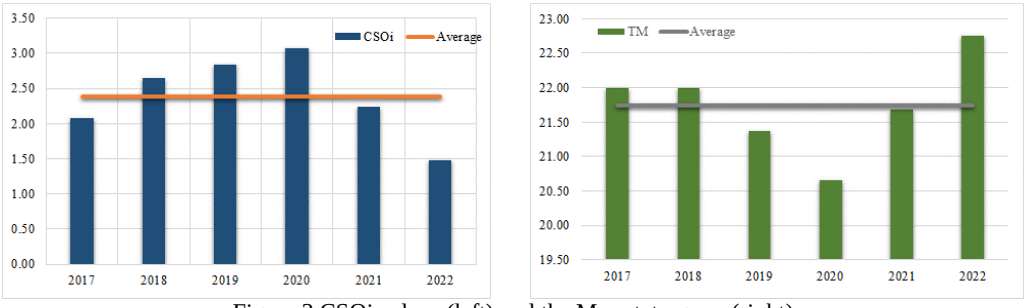


Figure 3 CSOi values (left) and the Mayr tetragram (right)

According to the CSOi values, framed based on the vlasifications made by Rivas-Martıinez et al. (2011), the experimental site is located in temperate continental climate conditions, and the location in the low plain area determines a dry character, especially in the summer. The greater deviation from the average value is observed in the case of 2022, against the background of reduced amounts of precipitation.

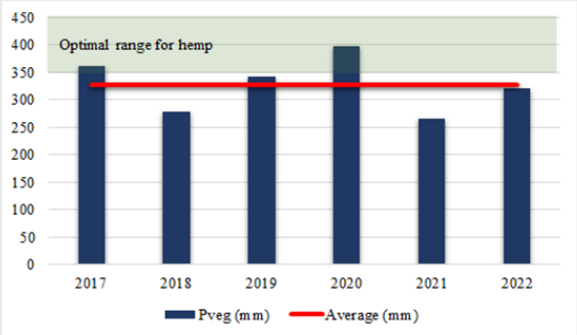
Mayr tetratherm (T_M) expresses the optimal thermal regime for vegetation in the period with maximum biological activity, being conceived as the arithmetic mean of the four warmest consecutive months, according to Relation (2). For the analyzed period, namely 2017 – 2022, the values of the Mayr tetraterm are presented in figure 3.

In the case of the experimental site, the Mayr tetratherm values are lower in 2020 and 2021, due to lower temperatures in May (the beginning of the interval).

For the analyzed area, the Mayr tetratherm (Figure 3), indicates optimal conditions for the development of steppe vegetation (VLĂDUȚ ET AL, 2017).

Regarding **the sum of precipitation in the months when the mean temperature is higher than 10ºC** (P_{veg}), in the case of the experimental site, the period April - October was taken into account, in which this condition is met for all the analyzed years. This interval completely overlaps the vegetation period (seven consecutive months per year) and is of major importance in the growth and development of hemp plants.

The analysis of Figure 4 shows differences in the amounts of precipitation. The lowest P_{veg} values were recorded in 2021, and the highest in 2020. In this context, the variability of precipitation amounts is observed. And through this index, the dry nature of the study area is emphasized, especially during the summer.



Yera	Annual amount	Pveg % of total	% of Pveg in VI-VIII
2017	522	69.15	35.73
2018	527	52.94	64.87
2019	462.8	73.91	38.29
2020	548.6	72.47	56.33
2021	546	48.71	48.49
2022	480.1	66.86	31.15

Figure 4 P_{veg} for the experimental site during the period 2017 - 2022

The rain factor of Lang (R), conceived as a ratio between the average annual values of temperatures and precipitation (Relation 4), it places the analyzed territory in the semi-arid and steppe climates (SATMARI, 2010). This index also emphasizes the variability of climatic parameters, from one year to another (figure 5).

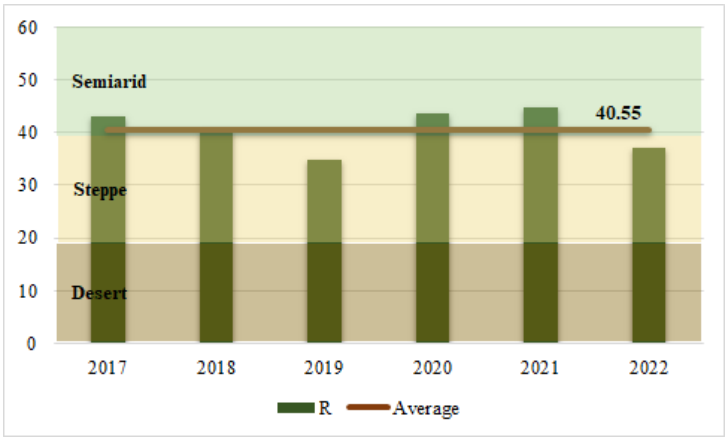


Figure 5 Values of R for the experimental site, during the period 2017 - 2022

Analysis of the hemp culture by phenophases of growth and vegetation

In the experimental year 2022, two stages of growth and development were identified for the Mara 21 hemp variety: a vegetative and a generative stage (Figure 6) carried out over an interval of 150 days. The vegetative stage of the analyzed variety ends on 18.06.2022 BBCH 18, 25 and the generative stage begins.

From figure 6 it can be seen that, in the vegetative stage which lasts 68 days, the average temperatures start to rise until they reach 23^0C, and in the generative phase in the months of July and August, the average temperatures are around 25^0C, with days when the temperatures they also exceeded 30^0C.

The research is in accordance with the specialized bibliography which mentions that hemp plants grow well at temperatures above 15^0C until budding, above 18^0C from budding to the end of flowering and 20 - 24^0C during the period of seed formation and ripening (TABĂRĂ, 2005, MIHOC-BĂLUȚĂ, 2013).

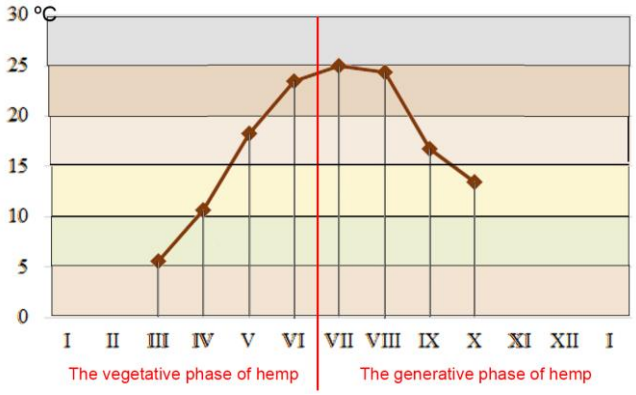


Figure 6 Histophenogram during the hemp vegetation period - 2022 – Timisoara weather station

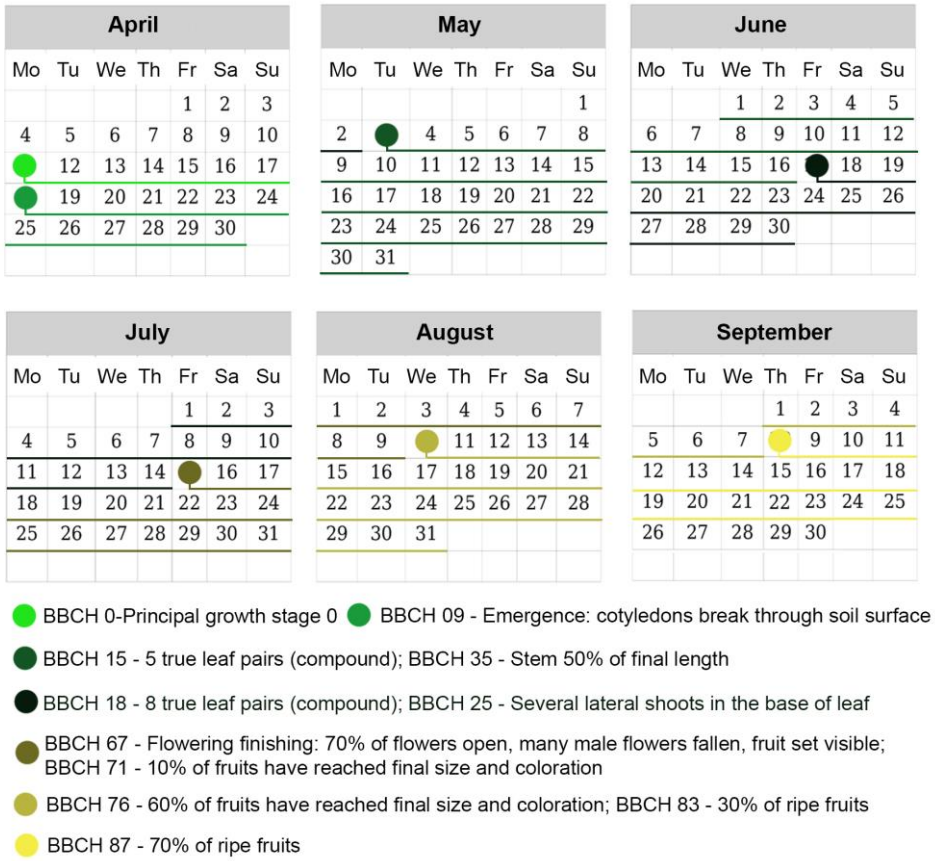


Figure 7 Phenology in the Mara 21 variety in time intervals

The manifestation of the main characters in the Mara 21 variety of hemp is presented in figure 6. Thus, from sowing to sunrise (BBCH 09), hemp needed an interval of 7 days with temperatures between 7 - 14^{0}C. It took 16 days to reach BBCH phenophase 15.35; 45 days to phenophase BBCH 18.25; 27 days to phenophase BBCH 67.71; of 26 days to reach the BBCH 76,83 phenophase and another 29 days to reach the BBCH 87 phenophase (Figure 7).

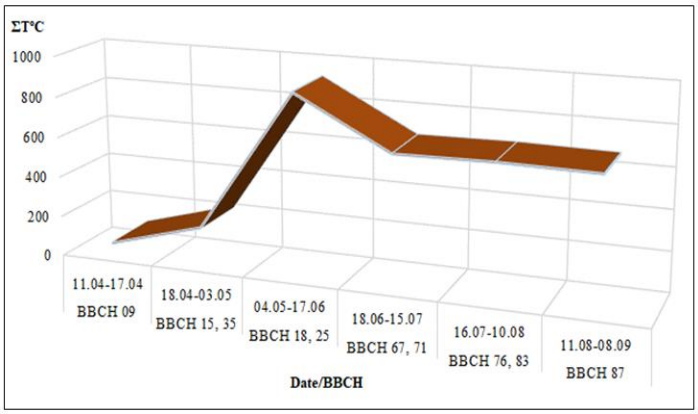


Figure 8 Distribution of the sum of temperature degrees (^{0}C) by phenophases, in hemp

The sum of the temperature degrees, recorded for the Mara 21 hemp variety from sowing to harvesting the seeds, was 3372.3^{0}C, the year 2022 being excessively hot.

In the analyzed time interval (150 days) the sum of the temperature degrees was 3154.92^{0}C, distributed as follows: 71.2^{0}C until the BBCH 09 phenophase; 203^{0}C until the hemp reached the phenophase BBCH 15.35; 904.8^{0}C until the hemp reached the phenophase BBCH 18.25; 656.7^{0}C and 27 days until the phenophase BBCH 67.71; 663.2^{0}C until the hemp reaches the phenophase BBCH 76,83 and 655.9^{0}C to reach the phenophase BBCH 87 (Fig. 8).

CONCLUSIONS

The bioclimatic indices used for the analysis of the main climatic parameters, namely air temperature and atmospheric precipitation, "localize" the experimental site in the temperate continental climate, with shades of dryness. However, the climatic conditions do not restrict the cultivation of hemp in the analyzed area.

In the Mara 21 hemp variety, two stages of growth and development were identified during the vegetation period: a vegetative and a generative stage. During the vegetative stage, which lasts 68 days, the average temperatures start to rise up to the threshold of 23^{0}C, and in the generative phase, the average temperatures are around 25^{0}C, with few exceptions.

From sowing to the BBCH 87 phenophase, under the conditions of 2022, it took 150 days.

The sum of the temperature degrees, recorded in the Mara 21 hemp variety from sowing to harvesting the seeds, was 3372.3^{0}C.

Experimental field research based on bioclimatic indices in correlation with phenology, provides a detailed but also an overall picture of the processes and phenomena involved in the effective planning of the hemp culture.

BIBLIOGRAPHY

ADESINA, I., BHOWMIK, A., SHARMA, H., SHAHBAZI, A., 2020 - A review on the current state of knowledge of growing conditions, agronomic soil health practices and utilities of hemp in the United States. Agriculture 10:129. https://doi.org/10.3390/agriculture10040129

AGENŢIA NAŢIONALĂ DE CADASTRU ŞI PUBLICITATE IMOBILIARĂ (ANCPI), 2022 – baza de date geospaţiale -https://geoportal.ancpi.ro/portal/home/

AMADUCCIA, S., COLAUZZI, M., BELLOCCHI, G., VENTURIC, G., 2008 - Modelling post-emergent hemp phenology (*Cannabis sativa* L.): Theory and evaluation, European Journal of Agronomy,Volume 28, Issue 2, 90-102

CLIMATE DATABASES, 2022 - https://rp5.ru/Weather_in_Timisoara

BRENNEISEN, R., 2007 - Chemistry and analysis of phytocannabinoids and other Cannabis constituents. In: ElSohly MA (editor). Marijuana and the Cannabinoids. Totowa, NJ, USA: Humana Press, pp. 17-49. doi: 10.1007/978-1-59259-947-9_2

BRETT, C.T., WALDRON, K.W., 1996 - Physiology and Biochemistry of Plant Cell Walls. The Netherlands: Springer Netherlands (Topics in Plant Physiology)

CERINO P, BUONERBA C, CANNAZZA G, D'AURIA J, OTTONI E, FULGIONE A, DI STASIO A, PIERRI B, GALLO A., 2021 - A review of hemp as food and nutritional supplement. Cannabis and cannabinoid research; 6(1):19-27)

DHONDT, FBEP., 2020 - The future of hemp fibres under changing climate conditions. Bachelors Thesis, Amsterdam University of Applied Sciences

DRESDEN, D., 2020 - What's the difference between indica and sativa? https://www.medicalnewstoday.com/articles/indica-vs-sativa, on February 6, 2020, accesed on 15.05.2022

ENACHE, L., 2009 – Agrometeorologie, Universitatea de Stiinţe Agronomice şi Medicina Veterinara Bucuresti

GEOSPATIAL, 2022 - ROMÂNIA: seturi de date vectoriale generale, http://geo-spatial.org/vechi/download/romania-seturi-vectoriale

GRINSPOON, L., GRINSPOON, L., BAKALAR, J.B., 1993 - The history of Cannabis In: Marihuana, the Forbidden 21 Medicine. New Haven, CT, USA: Yale University Press, pp. 1-23

MIHOC-BĂLUŢĂ, MARCELA, 2013 - Doctoral thesis - "Impact of ecological, biological and technological factors on the quality of hemp seeds for oil", Timişoara

MISHCHENKO, S., MOKHER, J., LAIKO, I., BURBULIS, N., KYRYCHENKO, H., DUDUKOVA, S., 2017 - Phenological growth stages of hemp (*Cannabis sativa* L.):codification and description according to the BBCH scale, ŽEMĖS ŪKIO MOKSLAI. T. 24. Nr. 2:31–36

MUELLER, N.D., GERBER, J.S., JOHNSTON, M., RAY, D.K., RAMANKUTTY, N., FOLEY, J.A., 2012 - Closing yield gaps through nutrient and water management. Nature, 490, 254–257

NIKOLAOU, I., EVANGELINOS, K., 2010 - A SWOT analysis of environmental management practices in Greek Mining and Mineral Industry. Resour. Policy, 35, 226–234

PANDA, A. O., TABĂRĂ, V., HORABLAGA, N. M., POP, G., 2017 - Research on the production capacity of some dioecious varieties under the conditions of the Agricultural Research and Development Station Lovrin in the years 2014-2016, Research Journal of Agricultural Science, 49 (2)

POSEA, G., 2005 - Geomorfologia României, Ed. Fundaţiei „România de Mâine”, Bucureşti

RIVAS-MARTÍNEZ, S., SÁNCHEZ-MATA, D., COSTA, M., 1999 - North American boreal and western temperate forest vegetation. Itinera Geobot. Springer. Navarra. 12: 5-316

RIVAS-MARTI´NEZ, S., SAENZ, S.R., PENAS, A., 2011 - Worldwide bioclimatic classification system. Global Geobotany, 1, 1–634

ROCK, E.M., PARKER, L.A., 2021 - Constituents of *Cannabis sativa*. Adv Exp Med Biol. 1264:1-13. doi: 10.1007/978-3-030-57369-0_1. PMID: 33332000

RUSU, R., 2007 - Organizarea spaţiului geografic în Banat, Ed. Mirton, Timişoara

SALAMON-ALBERT, E., LŐRINCZ, P., PAULER, G., BARTHA, D., HORVÁTH, F., 2016 - Drought Stress Distribution Responses of Continental Beech Forests at their Xeric Edge in Central Europe. Forests. Springer. London. 7(298): 2-16

SATMARI, A., 2010 - Lucrări practice de biogeografie. Edit. Eurobit. Timişoara, 85 pp. Available on: www.academia.edu/9909429/05_indici_ecometrici

SCHLUTTENHOFER, C., YUAN, L, 2017 - Challenges towards Revitalizing Hemp: A Multifaceted Crop. Trends Plant Sci. 22, 917–929

TABĂRĂ, V., 2005 - Fitotehnie, Vol. I – Oil and textile technical plants, Ed. Brumar, Timisoara.

VANDOLAH, H.J., BAUER, B.A., MAUCK, K.F., 2019 - Clinicians' Guide to Cannabidiol and Hemp Oils. Mayo Clin. Proc., 94, 1840–1851

VLĂDUȚ, A., NIKOLOVA, N., LICURICI, M., 2017 - Influence of climatic conditions on the territorial distribution of the main vegetation zones within Oltenia region, Romania. Oltenia. Studii și comunicări. Științele Naturii. 33. 154-164

ZHAO, H., XIONG, H., CHEN, J., 2021 - Regional Comparison and Strategy Recommendations of Industrial Hemp in China Based on a SWOT Analysis. Sustainability, 13, 6419. https://doi.org/10.3390/su13116419

ZIMNIEWSKA, M., 2022 - Hemp Fibre Properties and Processing Target Textile: A Review. Materials (Basel).15(5):1901. doi: 10.3390/ma15051901. PMID: 35269132; PMCID: PMC8911747

ŻUK-GOŁASZEWSKA, K., GOŁASZEWSKI, J., 2020 - Hemp production. In: Crini G, Lichtfouse E (eds) Sustainable agriculture reviews 42: hemp production and applications. Springer International Publishing, Cham, pp 1–36. https://doi.org/10.1007/978-3-030-41384-2_1