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Temperature and Precipitation Regime Impact on Spring Barley (Hordeum Vulgare) Growth in Priekuļi Case

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***Abstract*. In Latvia, the effects of drought and extreme temperatures on spring barley have so far been little studied due to the availability of data and the fact that meteorological conditions are only one of the multi-influencing factors that affect the agricultural sector.**

Barley usually flowers before or at the same time as ear emergence. During the flowering period high ambient temperatures are critical for yield formation. If the air temperature during flowering is above 22°C the flowers of spring barley become sterile. From 2004 - 2022, a significant and positive correlation (R = 0,57) was observed between the average maximum daily temperature from sowing to ear emergence and the number of empty flowers in the main spike. A significant negative correlation (R = 0,55) was observed between plant height and the sum of precipitation from sowing to ear emergence and spike length and the sum of precipitation from ear emergence to maturity (R = −0,54), drought also negatively affects tillering rate and number of productive stems per plant.

The combination of all the above-mentioned conditions significantly impacts the yield of barley. The following and relevant findings are very important for the agricultural sector, especially in the context of climate change.

Keywords: drought, extreme temperature, spring barley, yield.

I. INTRODUCTION

Ambient temperature and precipitation regimes have a significant impact on the agricultural sector. More frequent extreme weather events are one of the most visible manifestations of climate change and may cause severe crop yield losses [1].

Drought and very high ambient temperatures are among the most significant climate-related stressors affecting the crop industry. They can significantly reduce crop yield and quality or cause complete crop failure [2]. High temperatures hinder the absorption of sunlight, thus the photosynthesis and the circulation of nutrients in plants deteriorate, growth may be interrupted, and premature aging of plants may begin [3]. Water stress causes many changes in the morphology and anatomy of plants [4]. In addition, heat and drought stress can indirectly promote the spread of pests and diseases - weakened plants are more susceptible to the effects of harmful organisms, and drought and increased air temperature limit the possibilities of using plant protection products. The frequency of hot temperature extreme events and the impact of heat and drought is predicted to increase in the future [5].

In the studies carried out so far in Latvia, the influence of temperature and precipitation regimes on the growth and yield of cereals is mostly not evaluated separately, in most studies it is mentioned as one of the influencing factors, along with agrotechnical measures, characteristics of variety, and soil conditions.

The study aimed to evaluate the impact of temperature and precipitation regimes on spring barley (*Hordeum vulgare*) growth in the Priekuļi case.

II. MATERIALS AND METHODS

Data of the main growth and yield indicators were used for the period from 2004 to 2022 when the variety

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‘Ansis’ was grown in barley plant breeding as a standard variety in the Institute of Agricultural Resources and Economics Priekuļi research center. Barley was grown in an organic farming system. It means that the results are not influenced by using fertilizers and plant protection products. Yield and growth parameters were counted for 10 plants and the average value was calculated. Barley development stages are marked according to the BBCH scale where BBCH00 – dry seed, BBCH49 – first awns visible, BBCH51 – beginning of heading, and BBCH89 – fully ripe [6]. In this study, BBCH00 is used to indicate sowing time. The study uses data from Priekuļi (57°18'56.1" N, 025°20'16.8" E, 122 m a.s.l.) meteorological observation station (obtained by the Latvian Environment, Geology, and Meteorology Centre). Daily mean temperature (DMT), daily mean maximum temperature (DMMT and the sum of precipitation were calculated for two periods – BBCH00 – BBCH49 and BBCH51 – BBCH89. Also, the number of summer days (days with daily maximum temperature >25ºC [7]) was calculated. Data was processed and visualized in the R environment particularly using the *tidyverse* set of packages [8].

III. Results And Discussion

Although barley is considered one of abiotic stress most tolerant cereals [9] it is sensitive to drought throughout whole its development period, especially during the four development phases – at germination, at the beginning of flowering, at the anthesis, and at the beginning of a milky stage of grain. The intensity of the effects of drought depends on how long the plants are exposed to moisture deficit [10], [11].

To better show the precipitation effect on spring barley growth and yield, three years with very different weather conditions were compared. 2019 is chosen as a year with weather conditions representing the long-term average for the period from April to July and average growth and yield parameters. In 2017 none of the periods with precipitation less than 1 mm exceed 6 consecutive days but in 2018 from sowing till heading there were only 9 days with rainfall and two drought periods – 13 and 11 consecutive days when the sum of precipitation was less than 1 mm. In 2017 during the spring barley growth period, there were 11 days with heavy (≥ 10 mm) and very heavy (≥ 20 mm) precipitation but in 2018 only 3 days with heavy and very heavy rainfall. These differences were reflected in both growth and yield indicators. In 2017 the yield was 27.2 centners higher than in 2018. Significant differences in weather conditions were reflected in tillering rate, plant height, thousand-grain weight, and yield (TABLE 1). The number of grains per spike in barley species may also be affected by moisture deficit [12]. However, this study does not show a strong correlation between precipitation and number of grains per spike.

TABLE 1 GROWTH AND YIELD IN THREE DIFFERENT YEARS

Parameter	Year		
	2017 (wet)	***2018 (dry)***	***2019 (typical)***
Tillering rate, productive stems per plant	3.00	2.20	2.80
Plant height, cm	79.60	55.40	66.10
Spike length, cm	6.04	7.20	6.44
Thousand-grain weight, g	50.30	41.70	46.25
Yield, centners per hectare	58.90	31.70	45.92

Unlike other cereal species, barley flowers before anthesis. It means that the temperature right before anthesis is critical for fertility. Usually, it is in the second or third decade of June. The relatively large number of sterile flowers in the main spike in 2016 and 2021 (Fig. 1) can be explained by extreme heat when the daily maximum temperature exceeded 25°C for several days in a row immediately before or simultaneously with the beginning of the heading (BBCH51). Whereas in the years when the daily maximum temperature at the approximate time of flowering did not exceed 25°C like it was in 2004 and 2015 average number of sterile flowers in the main spike was 0.30. Considering the morphology and development characteristics of barley it is not possible to detect the exact time of flowering stage.

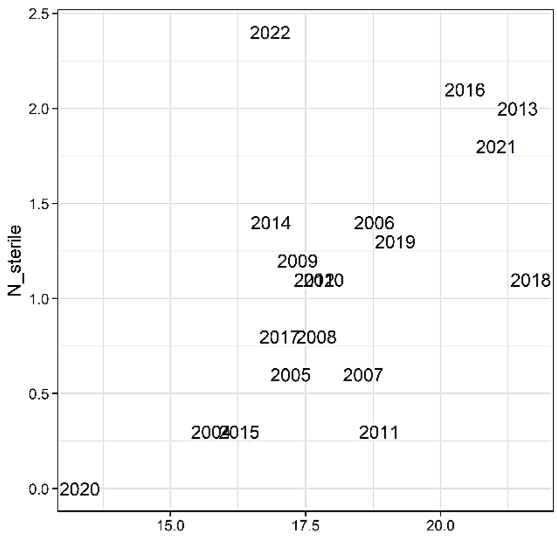

Fig. 1. Number of sterile flowers in the main spike depending on daily mean maximum temperature BBCH00 – BBCH49.

Some of the yield parameters are both affected by moisture and temperature. For instance, negative relation was observed between precipitation and mean air temperature at late development stages (from BBCH51 to BBCH89) and 1000 grain weight (TGW) (Fig. 2). Very dry weather during the grain ripening phase, especially at its beginning, accelerates grain maturation, inhibits nutrient uptake and normal grain maturation, resulting in low 1000-grain mass [13]. Higher TGW was obtained in years with moderate temperatures and relatively high levels of precipitation.

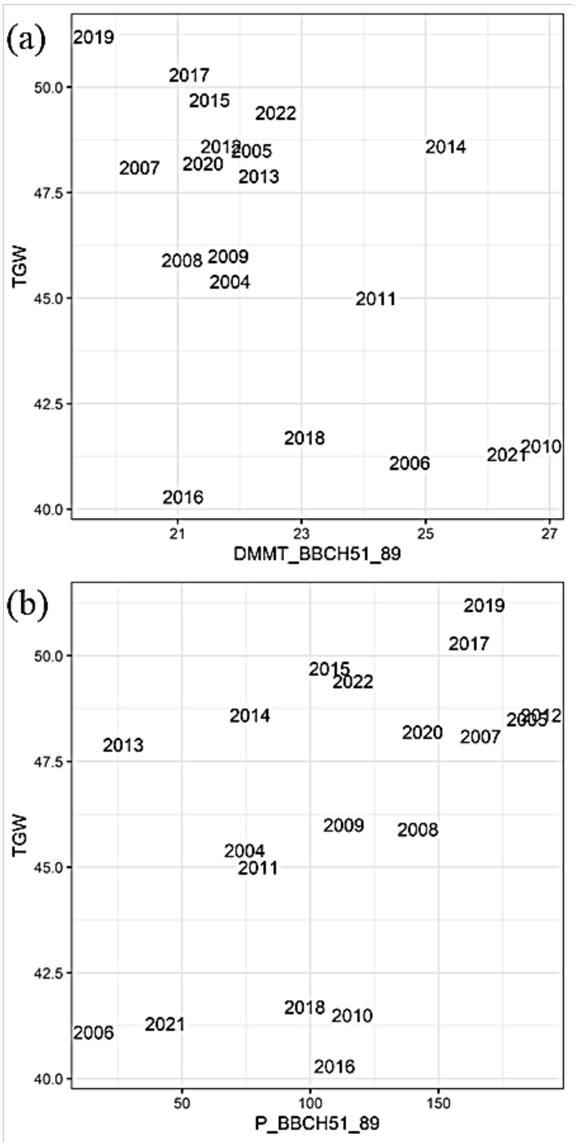

Fig. 2. Thousand-grain weight (grams) depending on daily mean maximum temperature BBCH51-89 (a) and the sum of rainfall BBCH51-89 (b).

The study shows a negative relation between yield and daily mean maximum temperature both in the early and late development stages (Fig. 3).

In a study carried out in Scotland, results highlighted that rainfall is more important than the temperature for spring barley yield [14]. Our study does not show such a relation. This difference is explained by the fact that in Latvia air temperature more often reaches an optimum above which there would be a negative effect on yield and growth of barley.

Weather conditions, including extreme weather events like drought periods, heavy rainfall, and heat waves, may also affect the length of the barley growing season. The growing period for spring barley runs on average from the first decade of May to the first decade of August (Fig. 4). The timing is mostly affected by weather conditions between April and July.

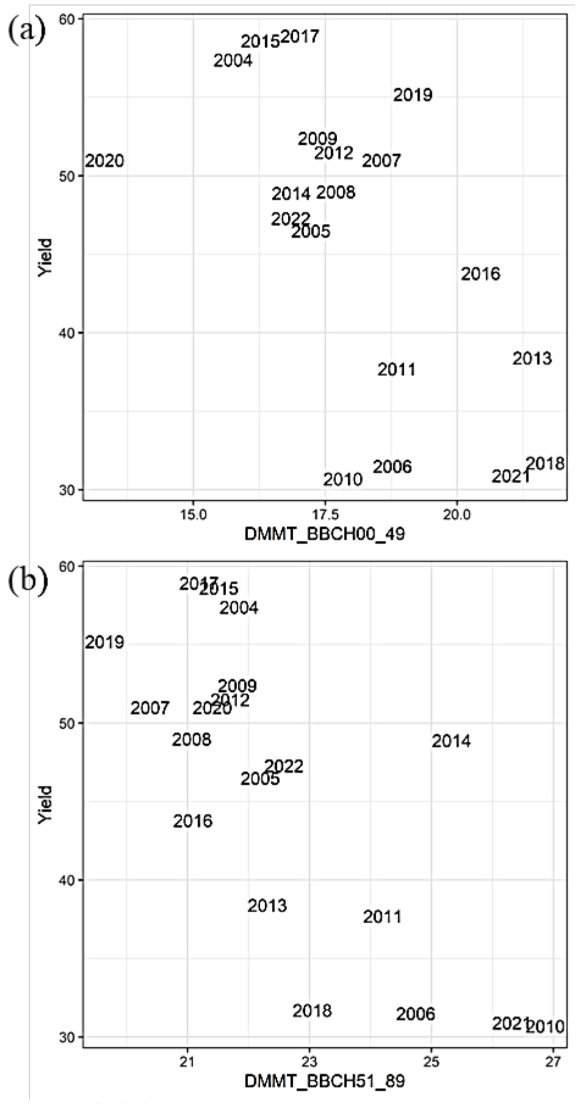

Fig. 3. Yield daily mean maximum temperature BBCH00-49 (a) and BBCH51-89 (b).

In warm and dry springs barley is sown earlier, but in cool and wet springs sowing occurs later. These observations are in line with the general trend in northern Europe, where crop development depends more on changes in air temperature than on precipitation, as is the case in southern Europe [15]. In Priekuļi a negative correlation ($R = -0{,}81$) between the daily mean maximum temperature from sowing to ear emergence and the length of the period from the beginning of heading to the end of the ripening stage has been observed. As shown in Fig. 5 high ambient temperatures in early development stages accelerate grain formation and maturation.

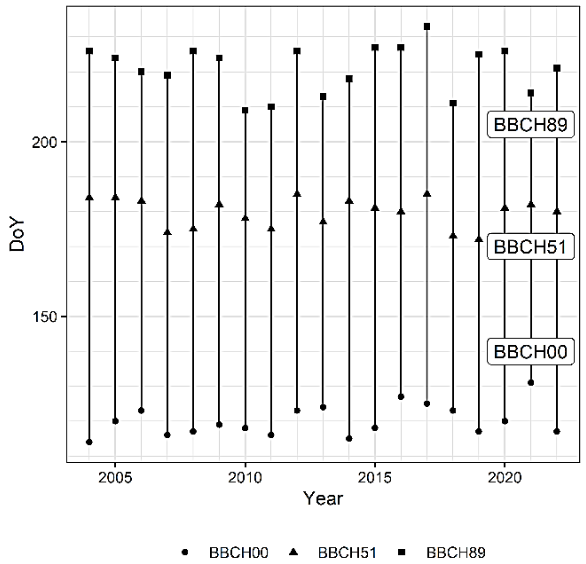

Fig. 4. Time of onset of development phases, days from the beginning of the year.

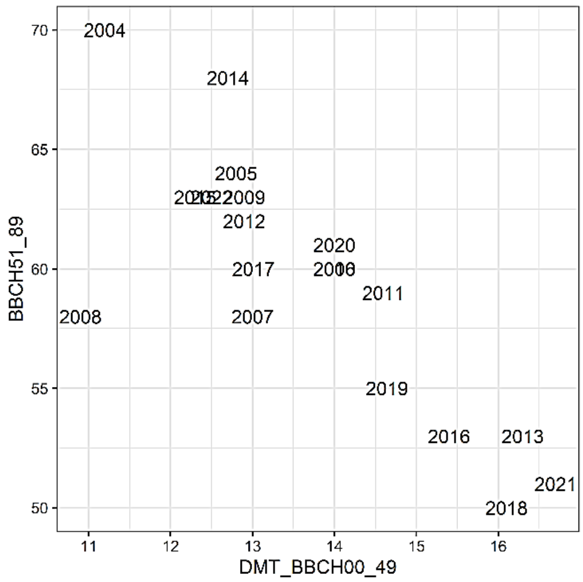

Fig. 5. Daily mean maximum temperature BBCH00-49 and duration in days from growth stages BBCH51 to BBCH89.

The optimum temperature during spring barley growth is 15 – 22°C [16]. A significant negative correlation (R = –0.76) was observed between the number of days from sowing to full ripening and the number of summer days. In years when the daily maximum temperature during the barley growth period frequently exceeded 25°C, the growing period was shorter than in years with just a few summer days (Fig. 6).

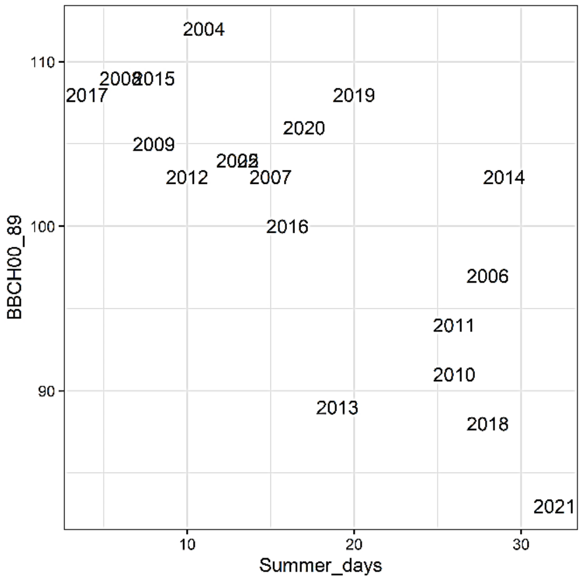

Fig. 6. Relation between the duration of days from BBCH00 to BBCH89 and the number of summer days.

In 2021 32 summer days (from BBCH00 to BBCH89) were observed, but in 2017 there were 4 summer days during the period of 108 days. The largest number of tropical nights when the daily maximum temperature was above 20°C was also observed in 2021. in the other years examined in the study, it does not exceed 3 tropical nights from sowing to the full ripening stage.

IV. Conclusions

The results confirm that temperature and precipitation significantly affect barley in both early and late development stages. In years with frequent and long drought periods (more than 10 consecutive days) and many days with daily maximum temperature above 25°C throughout the period from sowing till full ripening, yields were significantly lower than in years when rainfall was more frequent, and temperatures mostly did not exceed species optimum. Our data also show that weather conditions at the beginning of barley development play a major role in subsequent development and yield formation.

Since barley, like other cereal species, is very sensitive to climate change, it is important to better understand its response to different temperature and precipitation regimes. This can be a good basis for developing adaptation strategies.

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