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Effect of heat waves in processing tomato yields

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Introduction

Heat waves are prolonged periods of high temperature and excess heat that have significant impacts on natural and human ecosystems (Perkins, 2015). These exceptional events have increased in frequency, duration, and intensity in recent years (Lorenzo et al., 2021). Critical weather events can affect crop yields (Lesk et al., 2016), thus affecting food supply and commodity prices (Heinicke et al., 2022). Heat damage to tomato plants and, more importantly, to industrially grown varieties (WPTC, 2023) is heterogeneous and numerous. Sato et al. (2000) concluded that the most sensitive period to a moderate increase in temperature is between 8 and 13 days before anthesis, and that these two weeks are critical for development, with stress affecting pollen development, fruit growth, respiration, cell wall structure and, ultimately, production (Alsamir et al., 2021).

Objective: To evaluate the evolution of heat waves in the main industrial tomato growing areas of Extremadura, "Vegas bajas and Vegas Altas del Guadiana". To identify the years in which heat waves have occurred, to identify the phenological moments of the plots and to evaluate the effect of temperature and the phenological moment of the crop on production.

Material and Methods

For this work, an evaluation was made of the temperatures obtained at different agro-meteorological stations (orange symbols) distributed in the two main processing tomato growing areas: "Vegas bajas del Guadina" green and "Vegas altas del Guadiana" purple (Figure 1). In figure 1, the plots for processing tomatoes in 2023 are shown in red.

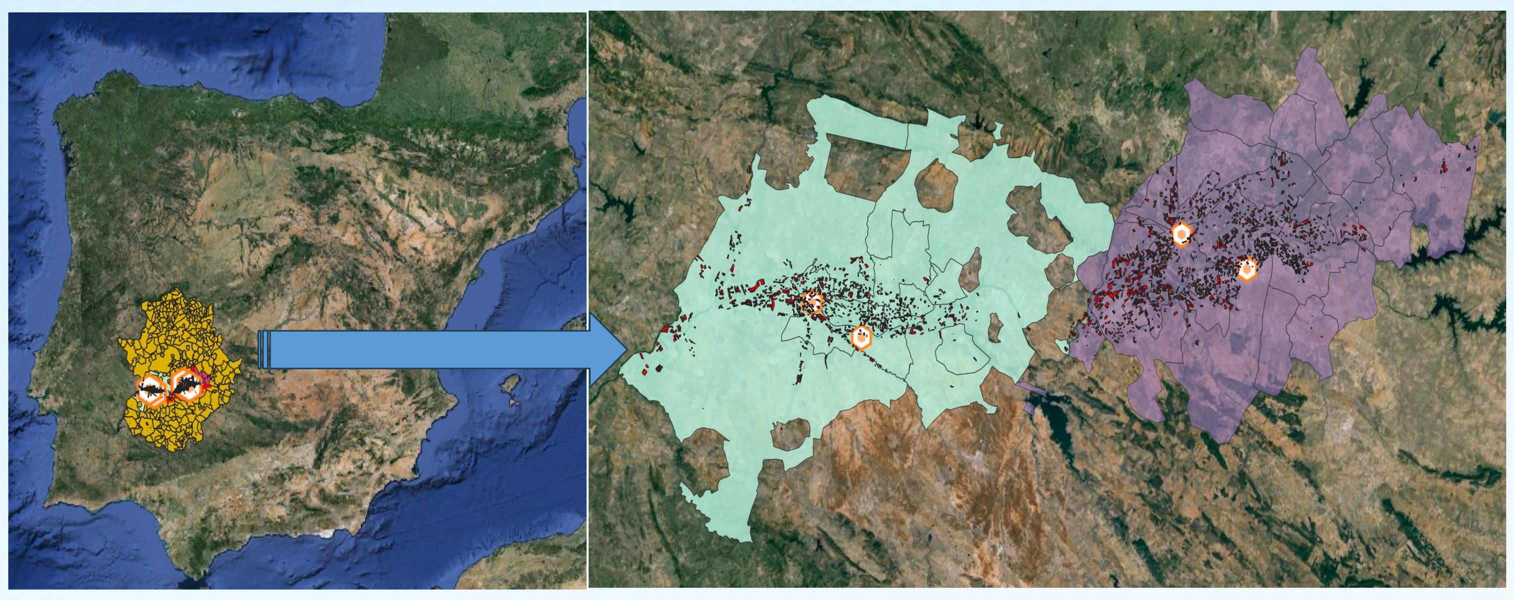
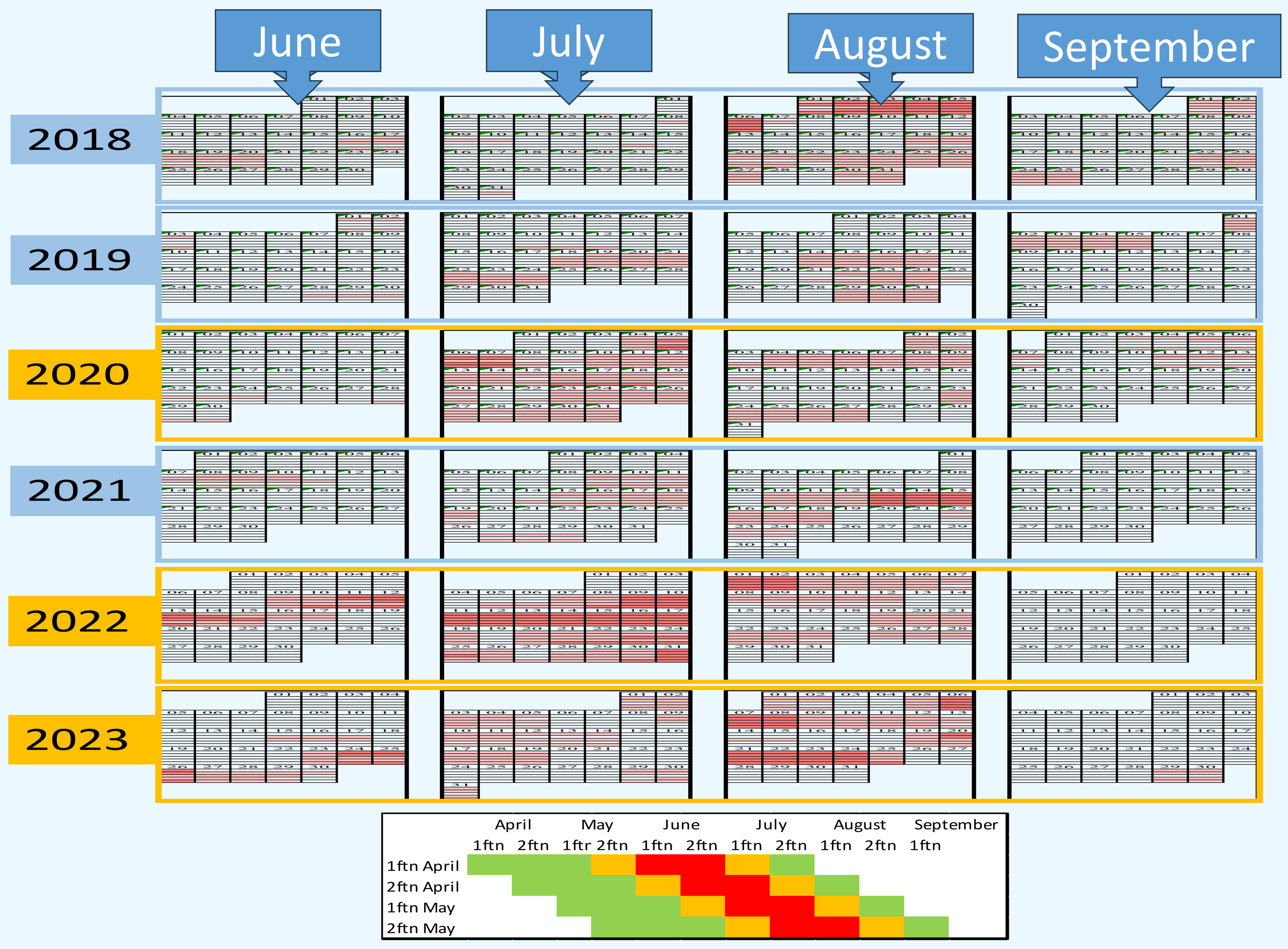


Figure 1. Agro-meteorological stations located in the main processing tomato production zones in Extremadura.

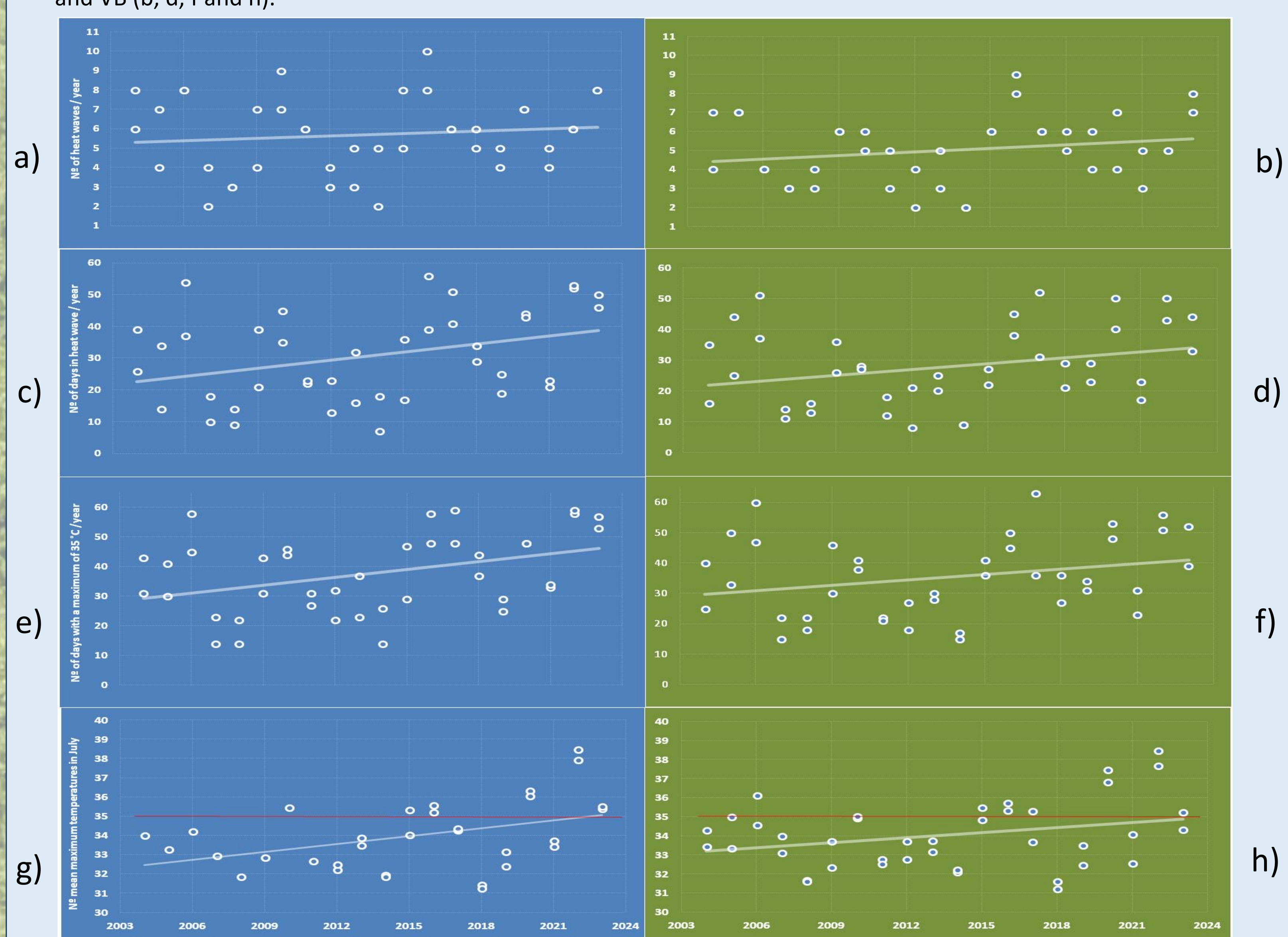
Results

Figure 2. Days with temperature over 35 °C from agrometeorological weather station in different years during main production month in processing tomato in VA and VB.



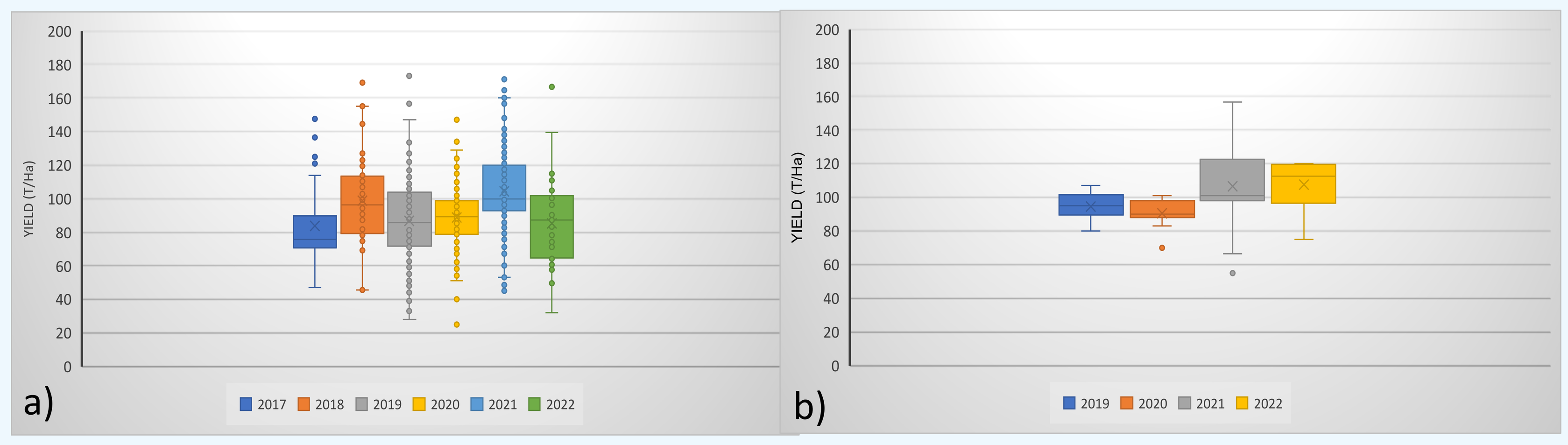
Heat waves occur mainly in the months of July and August in the "Vegas Low (VB) and Vegas High (VA)". The analysis of the last six years shows that the years with the highest number of days with temperatures above 35 °C in most of the stations studied were 2020, 2022 and 2023; years considered in which heat waves could have had an impact on the average production. It is observed that in 2020 and 2022, the first weeks of July, which is the main flowering period in plantings in 2sdftn April and 1erftn May (planting average), as can be seen in the graph in red and orange, were periods with the highest recorded high temperatures.

Figure 3. Evaluation of the number of heat waves (a, b), number of days in heat waves (c, d), number of days over 35 °C (e, f) , and mean of maximum temperature in July (g, h) in agrometeorological weather station of VA (a, c, e and g) and VB (b, d, f and h).



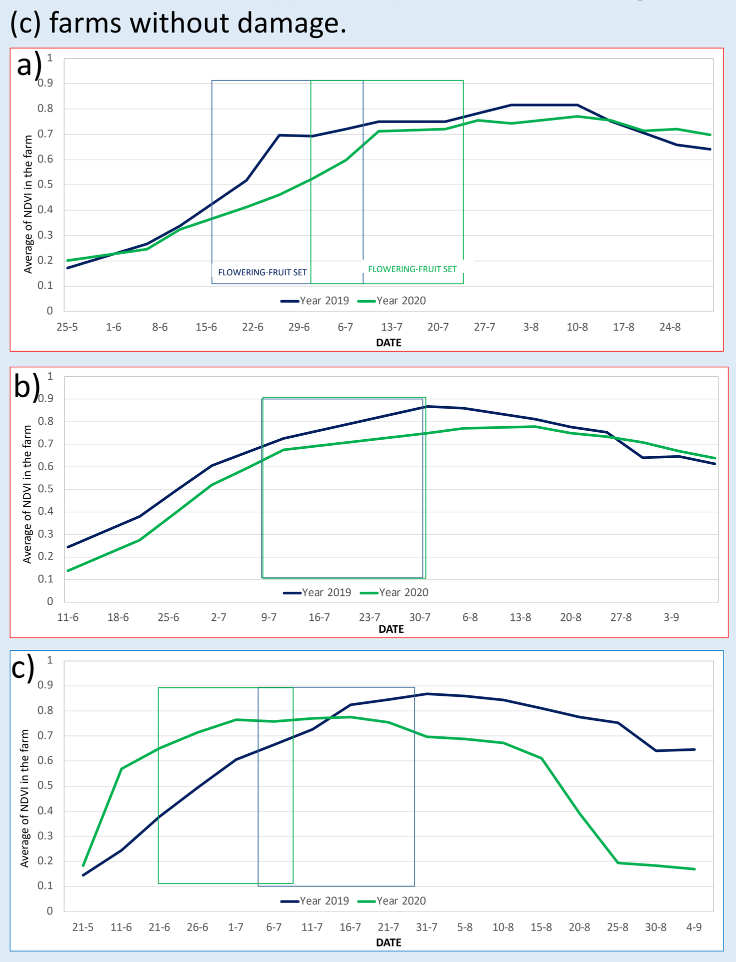
Analysing the temperature data of the last 20 years recorded at two reference stations in VA and VB, a slight increase in the number of heat waves is observed, although this increase is more pronounced in VB. However, when analysing the number of days when the crop was in a heat wave situation and above 35 °C, the number of days has increased significantly over the last 20 years, with the number of days doubling in both areas, although more significantly in VA. The average maximum temperature in July in recent years has been above 35 °C in both areas, which can affect the transplants, as this is the time of maximum flowering and fruit set.

Figure 4. Distribution of Yield in different years (2017-2022) in different farms in VB and VA.



The yield of 823 plots in VB and 103 plots in VA was evaluated in over several years (Figure 4). In VB there is a significant variability of production between years, maintaining an average of between 80-90 t ha^{-1} commercial production (Figure 4a). 2017 and 2020 are the years with the lowest variability. In the case of 2020, it was the year with the lowest production values, with plots with production data below 50 t ha^{-1}, coinciding with a year in which heat waves were recorded. In the case of 2019 and 2021, low yields were also recorded, although there were also plots with high yields. In the case of the plots analysed in VA, 2021 and 2022 were the most productive years; however, 2021 was the year with the greatest variability in yields, with plots with high and low yields (Figure 4b). The yield data of the studied plots show a slightly higher yield in VA compared to VB.

Figure 5. Evolution of the NDVI in three different farms for 2019 and 2020. (a) and (b) farms with damage and (c) farms without damage.



The phenological stage at which the crop is found is important when it comes to the effect that the heat wave can have on production. Of the selected plots, two were selected where there was a 40-50 % reduction in yield this year compared to 2019, and another where there was no reduction in production compared to the previous year. Figure 5 shows the evolution NDVI (from Sentinel 2) for the two years (2019 and 2020) in the three selected plots, two of them (Figure 5a and 5b) where yield declines were recorded and another plot (Figure 5c) where no yield declines were recorded. In each of the plots the flowering periods of the crop have been identified, considering these periods from the moment when the maximum NDVI was reached, taking into account 10 days before and 10 days after this point. The data obtained from the analysis of the critical moment coincided with the period of abnormally high maximum and minimum temperatures, which occurred in 2020 during the period from 6 to 31 July, causing plots where the crop was at that time in the critical period for the crop, such as flowering and fruit set, to experience a decrease in production, while crops that were outside this period did not register a significant decrease due to this fact.

Conclusions

Over the last 5 years, the number of days of heat stress due to heat wave has increased in the processing tomato crop.

In Extremadura, the increase in temperature had a negative effect on yields in the tomato-growing areas of Guadiana's Vegas Bajas and Vegas Altas.

Crop phenology is a differentiating factor during periods of high temperatures, with flowering and fruit set being critical. NDVI, as an indicator of crop development, can identify the critical time for damage assessment and applied mitigation strategies.

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