OBSERVED CHANGES IN THE OCCURRENCE OF EXTREME EVENTS IN THE MAIN VEGETABLE-GROWING REGIONS IN THE CZECH REPUBLIC

VERA POTOPOVÁ[1], PAVEL ZAHRADNÍČEK[2,3], ALEŠ FARDA[2,3], PETR ŠTĚPÁNEK[2,3], LUBOŠ TÜRKOTT[1], JOSEF SOUKUP[1]

[1]*Department of Agroecology and Biometeorology, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, Kamýcká 129, 165 21 Prague, Czech Republic*
[2]*Global Change Research Centre AS CR, v. v. i. Bělidla 986/4a, 603 00 Brno, Czech Republic*
[3]*Czech Hydrometeorological Institute, Brno Regional Office, Kroftova 43, 616 67 Brno, Czech Republic*

Assessments of risks, impacts and vulnerabilities, through regional and decadal-scale analysis and prediction are more relevant for local and regional growers. Extremes such as heavy precipitation, extended dry spells and heat waves/heat stress have a strong impact on vegetable crops. Enhancing prediction capabilities of such phenomena as well as improving the usability of such climate knowledge to users would strongly benefit horticultural growers. This study deals with the frequencies of heat and dryness stress in the main vegetable-growing regions at the territory of the Czech Republic. The impact indicators are calculated from daily precipitation, maximum and minimum temperatures for the period 1961-2014. A total of 135 grid-points were chosen for calculation of the number of dry days, dry spells, the maximal length of the dry spell, the number of heat waves and heat stress. The research area covered the 23 main vegetable growing districts. It was found that dry periods were the most frequent event in all planting areas. The heat stress occurred more frequently in the reproductive period of Fruit vegetable than in the vegetative period. While the highest occurrences of dry days and heavy rains correspond with planting period of Fruit vegetables.

Keywords: dry spells, dry days, extended dry spells, heat-stress, heavy rainfall

INTRODUCTION

Extremes such as the heavy precipitation, the extended dry spells and the heat waves and/or heat stress have a strong impact on vegetable crops. Climate services aim at providing more reliable climate information for the near future relevant for local and regional users (EUPORIAS, 2013). Enhancing prediction capabilities of such phenomena as well as improving the usability of such climate knowledge to users would strongly benefit society. A globale scale, the recently findings of Donat et al. (2013) include widespread significant changes in temperature extremes consistent with warming, especially for those indices derived from daily minimum temperature over the whole 110 years of record but with stronger trends in more recent decades. Seasonal results showed significant warming in all seasons but more so in the colder months. Precipitation indices also showed widespread and significant trends, however, results indicated more areas with significant increasing trends in extreme precipitation amounts, intensity, and frequency than areas with decreasing trends.

Harvested vegetables can be potentially exposed to numerous abiotic stresses during production, handling, storage and distribution. Some of these stresses can be minor in nature, resulting in no quality loss or, in some cases, in quality improvement during distribution (Toivonen and Hodges, 2011). However, when the abiotic stress is moderate or severe, quality losses almost always are incurred at market. As a consequence it is important to understand the nature and sources for abiotic stresses that affect vegetables. Dryness and water stress during the production phase of vegetables may affect their physiology and morphology in such a manner as to influence susceptibility to weight loss in storage. Water stress also diminishes plant vigor and alters carbon-to-nitrogen ratios. Attack by fungal pathogens of stem and root is favored by weakened plant conditions (Peet et al., 1998).

The main objectives of this study were given in the following: (i) to calculate major dryness and heat stress indices by analysing the gridded daily precipitation, maximum and minimum temperatures data sets during the last 54 years in the main vegetable production regions in the Czech Republic (CR); and (ii) to analyse the spatial and temporal frequencies of heat and dryness stress during the growing season of Fruit, Brassicas, Root and Bulb vegetables.

MATERIALS AND METHODS

The study was based on gridded daily series of precipitation, maximum and minimum air temperatures for the period 1961-2014. The mainly vegetable growing regions comprise 135 grid-points at a 10-km horizontal resolution, and their distribution per districts at the territory of the CR is shown in Fig. 1. The statistical analysis of impact indices was conducted using the averaged daily series of precipitation, maximum and minimum air temperatures for 23 districs. Four main vegetable-growing regions were defined to classify districts: **Root vegetable region** (prevailing such as *Apium graveolens* L.; *Daucus carota* L.*)*, **Brassicas vegetable region** (*Brassica oleracea* L. convar. *acephala* var. *gongylodes)*, **Bulb vegetable region** (*Allium cepa* L.) and **Fruit region** (*Solanum lycopersicum* L.; *Cucumis sativus* L.).

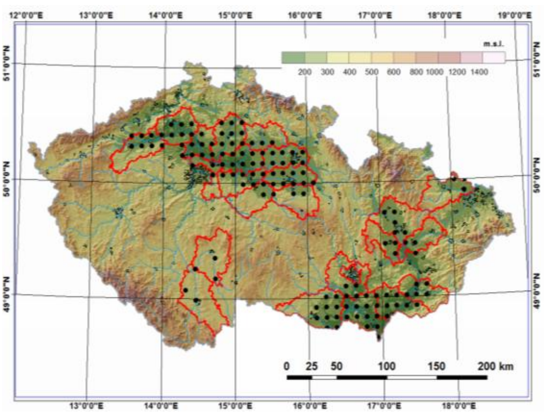


Fig. 1 Distribution of the grid-points in the main vegetable producing areas in the Czech Republic

A range of indices was selected based on known climate impacts on vegetable crops in the CR. They were calculated according to the following definitions: (i) Dry spells are defined as periods of at least 5 consecutive days with daily precipitation below 1 mm; (ii) Extended dry spells are defined as 95th percentile of the length of all identified dry spells; (iii) Heat waves were defined as periods of more than three consecutive days exceeding the 99th percentile of the daily maximum temperature; (iv) Heat stress is day with Tmax ≥32 °C (maximum daytime temperature) and Tmin ≥21 °C (minimum nighttime temperature); and (v) Heavy precipitation is defined as the 95th percentile of daily precipitation (only days with precipitation > 1 mm.day^{-1} are considered).

Different indices were used to reflect different dimensions of heat and dryness stress, which have different impacts on vegetable growth and yield. The impact indices were calculated in the main vegetable producing areas (Fig. 1). From 1961 to 2014, we calculated for each district the monthly, seasonal, annual and the main growing season (April-September) of the number of dry days, dry spells, the length of extended dry spells, the number of heat waves, the number of days with heat stress and heavy precipitation.

RESULTS

The impacts of extreme temperature events can be difficult to separate from those of dryness. Drought and heat stress often occur simultaneously (e.g. 1992, 1994 and 2003), but they can have different effects on various physiological, growth, developmental, and yield forming processes. The effects of drought and heat stress on crops depend on the occurrence of the event in relation to the crop phenological stage. For fruit vegetables, frequency of extreme events affecting leaf growth, generative organs from planting to harvest has been estimated (Fig. 2a). Dryness had showed the highest frequency from planting to ripening of fruit, including dry days between 65 % and 70 %. The number of dry spells is less than 8 % of this total. In the analysis of regional extreme-dry-spell frequency, more attention needs to be paid to the maximum dry spell in each district during the entire period. The percentage of extended dry spells was about 14 %. Heavy rain is the top second studied extremes that occur frequent at 4-8 %, followed by the heat-stress (3 %) and heat waves (2 %).

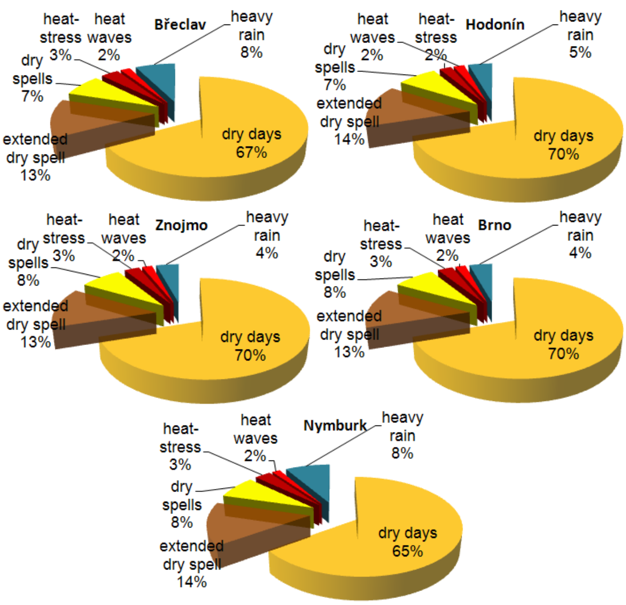


Fig. 2a Frequency of extreme events from planting to harvest period in the main Fruit producing areas for the period 1961-2014 in the Czech Republic

Some 68 % drought occurred from planting to harvest of Brassicas and Root vegetables (Fig. 2b), while 42 % of dry events occurred in the onset of vegetative period. Water deficits in the case of root vegetables, such as carrot, where pre-harvest water stress (watering to 25-75 % of soil water field capacity) can weaken the cells, resulting in higher membrane leakage and consequently greater weight loss in storage (Shibairo et al., 1998).

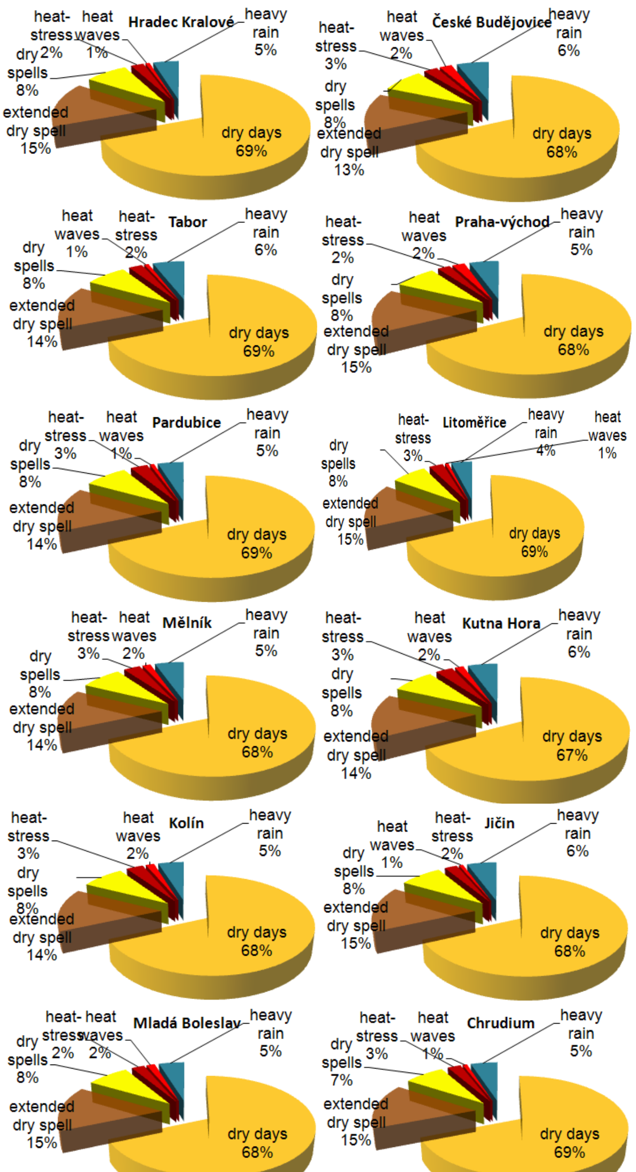
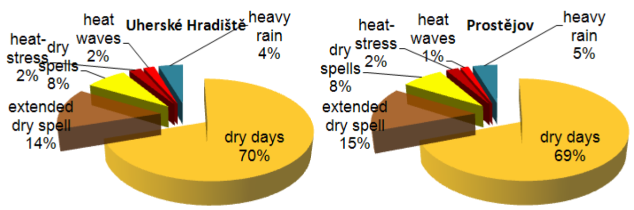


Fig. 2b Frequency of extreme events from planting to harvest in the main Brassicas and Root producing areas for the period 1961-2014 in the Czech Republic

As for Bulb producing areas, about 69-70 % of drought occurred from sowing to harvest period, while heavy rain only 4-5 % (Fig. 2c).



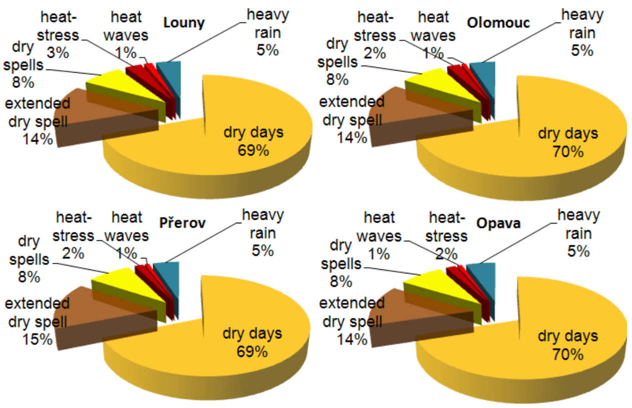
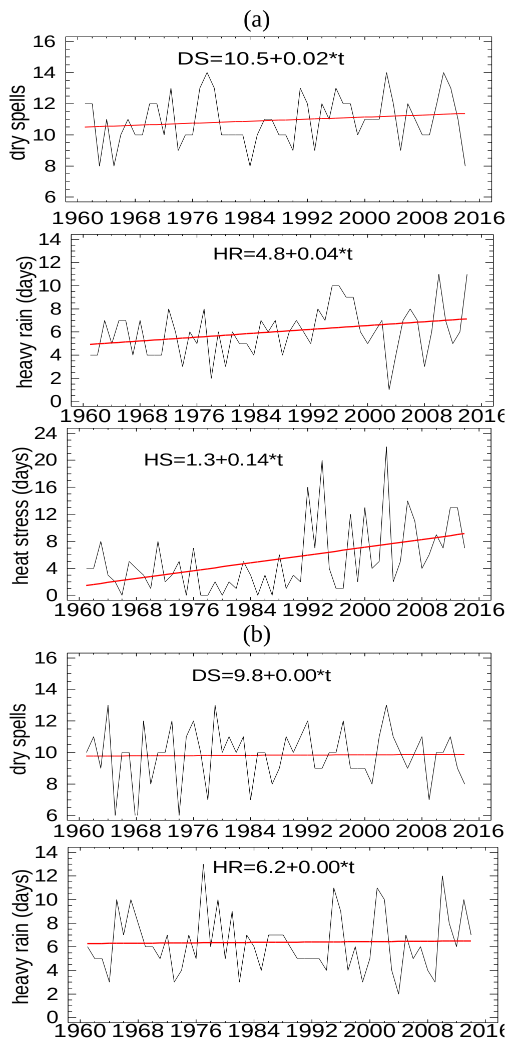


Fig. 2c Frequency of extreme climate from sowing to harvest period in the main Bulb producing areas for the period 1961-2014 in the Czech Republic

Trends of the number of dry spells, the number of days with heavy rain, and the number of days with heat sress for Fruit areas in South Moravia and middle Elbe River valley are shown in Fig. 3. All these indices show a clear prominence of positive trend estimates. Differences among the two Fruit regions in trends of heat and dryness stress between planting and ripening during the last 54 years were observed. Significant increasing trends of all heat and dryness stress indices were observed in South Moravia, but not observed in the middle Elbe river valley. For example, the number of days when precipitation exceeds the 95 % precipitation quantile has increased in South Moravia, and this increase is statistically significant.



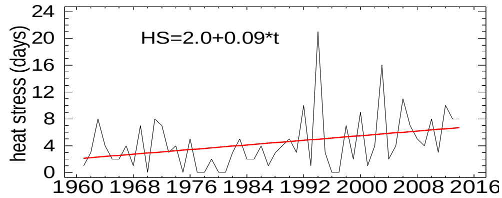


Fig. 3. Trends of the number of dry spells, the number of days with heavy rain, the number of days with heat sress for Fruit areas in South Moravia (a) and middle Elbe River valley (b) for the period 1961-2014

Figure 4 summarised distributions of dry days and heavy rain during the year, and assessment of the risk of water deficits during plant growth period. In both regions the highest occurrences of dry days and heavy rains correspond with planting period of Fruit vegetables.

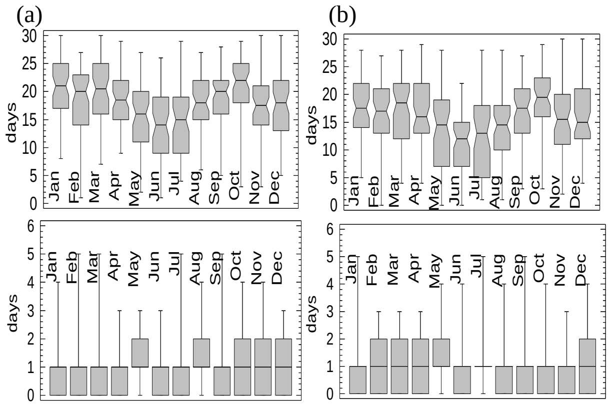


Fig. 4 The annual distributions of the number of dry days (top) and the number of days with heavy rain (bottom) for Fruit areas in South Moravia (a) and middle Elbe River valley (b) for the period 1961-2014.

CONCLUSION

The frequencies of dryness and heat stress during the growing season of vegetables from 1961 to 2014 were analysed. The results showed that: (i) Huge differences existed between the frequencies of different precipitation and temperature impact indicators; (ii) It was found that dry periods were the most frequent event in all planting areas; and (iii) The heat stress occurred more frequently in the reproductive period of Fruit vegetable than in the vegetative period.

Acknowledgement

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