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

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This study deals with projected changes in the occurrence of extreme events in the main vegetable-growing regions at the territory of the Czech Republic using two regional climate models (ALADIN-Climate/CZ and RegCM) under the A1B SRES scenario at a high horizontal resolution of 10 km. In order to estimate potential future changes in the dryness and heat stress over the growing vegetable areas, we calculated the number of dry days, dry spells, the length of extended dry spells, the number of heat waves and the number of days with heat stress during the growing season of Root, Fruit, Brassicas and Bulb vegetables for current climate and two future climate horizons. Projected changes of several impact indices for 2021-2050 and 2071-2100 with respect to 1971-2000 have been estimated. Results illustrate considerable differences among RCMs in simulation of the number of days with heat stress. However, at the end of the 21st century both RCMs detected that the length of dry spells and heat-stress from anthesis to maturity and fruit development/maturation will be relatively increased above the present level in traditional Fruit vegetable localities. Substantial lengthening of the dry spells is visible during the period 2071-2100. A combination between changes in length of extended dry spells and the number of dry spells has been investigated. According to the ALADIN-Climate/CZ simulation, more but shorter dry spells are projected in the Bulb and Brassicas regions. While for Fruit planting areas with a large increase in the length of extended dry spells, but the number of dry spells is decreasing.

Keywords: vegetables, high-impact phenomena, heat stress, dryness stress

INTRODUCTION

The projected increase in global temperature will affect, negatively or positively, future vegetable production depending on the geographical location. Global temperatures are rising asymmetrically with the daily minimum temperature rising faster than the daily maximum temperature (Easterling et al., 1997). Whilst the latest report of IPCC (2013) concluded that such fast rising of minimum temperature was lower than previously.

Climate change might impact crop yields considerably and anticipated transformations of agricultural systems in the coming decades to sustain accessible good provision. The global overview (Gornal et al., 2010; Wilby, 2010; Leclère et al., 2014) clear suggest that (i) the various scenarios have different effects (i.e. impacts vary among climate models on both large and smaller scales leading to scenario specific relocations of production systems, while uncertainties with respect to CO_2 effects raise everywhere the range of potential cropland increases); (ii) socio-economic assumptions further stratify regions according to their response to variable biophysical shocks through indirect market effects (price and demand elasticity differentials across regions drive large-scale decommissioning of cropland in given region while boosting output in other region), and (iii) uncertainties concerning changes in precipitation regimes and crop water-use efficiency inflate the potential need for large developments of irrigation.

The negative effects of climate and weather usually prevail over the positive ones. That has adverse impacts on the utilization of vegetable yield potential due to increased risk of: (i) availability of water, (ii) heat and dryness stress, (iii) heavy rain and leaching of nutrients, and (iv) occurrence of pests and diseases. Alerting crop calendar, nutrient and water input levels are requiring minimal financial investment. On the other hand, expansive investment into transport and processing infrastructure can be required to build production capacity in new areas (Leclère et al., 2014). However, such adaptations are limited by large uncertainties regarding future emissions, climate response, crop response, and economic response (Wilby, 2010).

This study deals with projected changes in the occurrence of extreme events in the main vegetable-growing regions in the Czech Republic using two regional climate models (RCMs) under the A1B SRES scenario at a high horizontal resolution of 10 km. We focussed on high-impact phenomena such as dryness (the number of dry days, dry spells and the maximal length of the dry spell), heat waves and heat stress during the growing season of Root, Fruit, Brassicas and Bulb vegetables.

MATERIALS AND METHODS

In this study daily series of precipitation, maximum and minimum air temperatures for baseline climate (1971-2000) and two future climate horizons (2021–2050 and 2071–2100) at 135 grid-points have been used. The distribution of gridded daily series per districts and definition of impact indices are described in detail by Potopová et al. (2015). In order to estimate potential future changes in the extreme events over the growing vegetable areas, we calculated the number of dry days, dry spells, the maximal length of the dry spell, the number of heat waves and heat stress during the growing season of Root, Fruit, Brassicas and Bulb vegetables for current climate and two future climate horizons. For each impact indicator and growing vegetable region (e.g. Fruit region – Břeclav, Znojmo, Hodonin, Brno and Nymburk districts) we calculated changes in the median, maximum and minimum values. For this purpose, future climate projection scenario for two different RCMs, which were driven by two different global circulation models, namely ARPÉGE-Climate and ECHAM5 have been applied. Future change in radiative forcing follows the A1B emission scenario. This scenario leads to a rapid increase in fossil CO_2 emissions until 2050 and a decrease afterwards. As compared to other SRES scenarios, the CO_2 emissions lie in the middle of the scenario range (Jacob et al., 2014).

RESULTS

The length of dry spells

The box plots from Fig. 1 compare the number of dry days during the growing season of Root, Brassicas, Bulb and Fruit vegetables obtained from gridded dataset of current climate and that simulated by RCMs. Two main results can be highlighted: first, comparison between the simulated and observed impact indices shows that the RegCM underestimates the occurrence of dry days over the vegetable-growing areas. The discrepancy in the quantitative aspect of ALADIN-Climate/CZ (Farda et al., 2007) and RegCM seems to cause the differentiated performance between the two simulations. Secondly, the ALADIN-Climate/CZ simulations strengthened possibility of extreme occurrence of dry days in Fruit and Brassicas growing areas at the 2071-2100. While for Root areas during the mid-21st century are projected to be relatively lower changes in the occurrences of dry days relative to baseline climate.

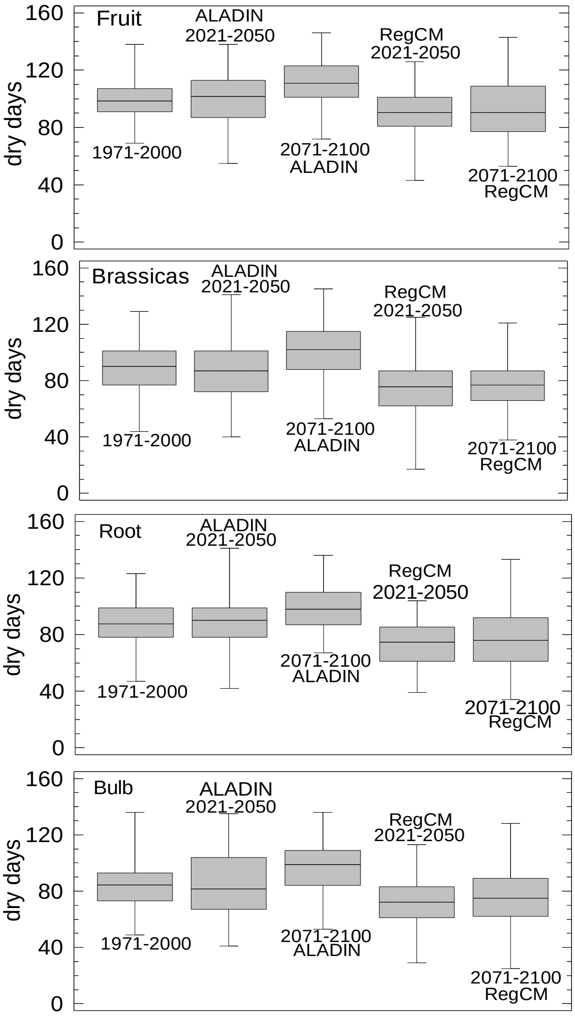

Fig. 1 The comparison between the number of dry days during the growing season of Root, Brassicas, Bulb and Fruit vegetable regions for current climate series (1971–2000) and projected series under the A1B SRES scenario (2021–2050 and 2071–2100).

Comparison of the 95th percentile of the maximum length of dry spells during the growing season of vegetables obtained from gridded dataset for current climate and that simulated by ALADIN-Climate/CZ and RegCM for two future climate horizons are shown in Fig. 2. For the period 2021-2050, a small increase in the length of extended dry spells is projected for all vegetable-growing areas, however, with high inter-annual variability. Substantial lengthening of the dry spells is visible during the period 2071-2100. A combination between changes in length of extended dry spells and the number of dry spells has been investigated. According to the ALADIN-Climate/CZ, more but shorter dry spells are projected in the Bulb and Brassicas regions. For Fruit region with a large increase in the length of extended dry spells, the number of dry spells is decreasing (not shown).

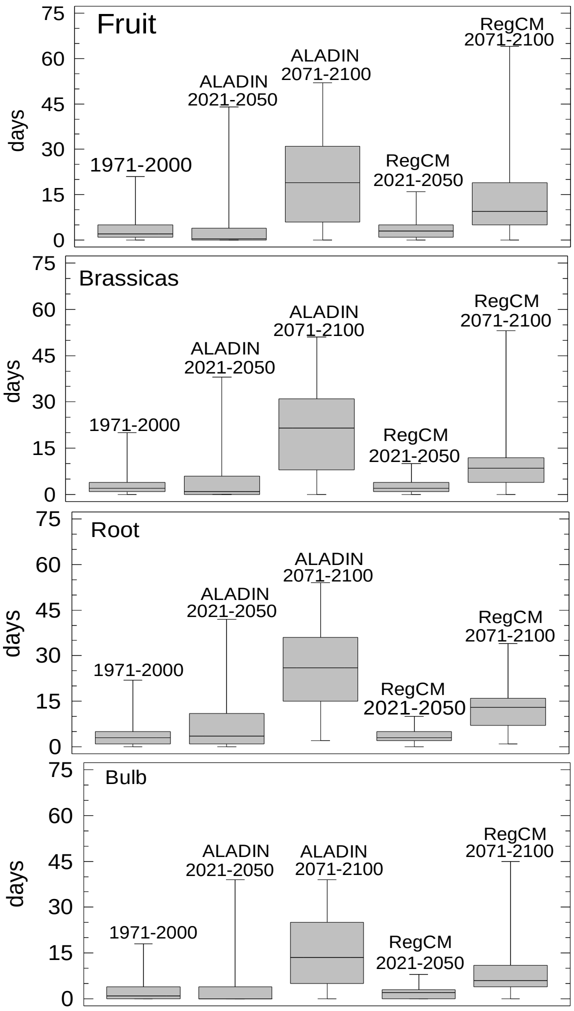

Fig. 2 The comparison between the extended dry periods (in days) during the growing season of Root, Brassicas, Bulb and Fruit vegetable regions for current climate series (1971-2000) and projected series under the A1B SRES scenario for two periods: 2021–2050 and 2071–2100.

The mean number of days with heat stress

Modelling shifts in the occurrence of days with heat stress (Tmax ≥ 32 °C and Tmin ≥ 21 °C) in the main growing areas of Fruit, Brassicas, Bulb and Root are presented in Fig. 3. In ALADIN-Climate/CZ simulation, the increase in the number of days with heat stress is larger than in RegCM simulation. This is more pronounced towards the end of the century than for the earlier time period. For both RCMs, the increase is relatively larger in Fruit planting areas, but towards the end of the century the number of days with heat stress will be increased in all vegetable regions. The number of days with heat stress for all regions is projected to increase by more than 22 during the growing season. Most of this increase is attributed in July for current climate and in August for future climate conditions (10-11 days).

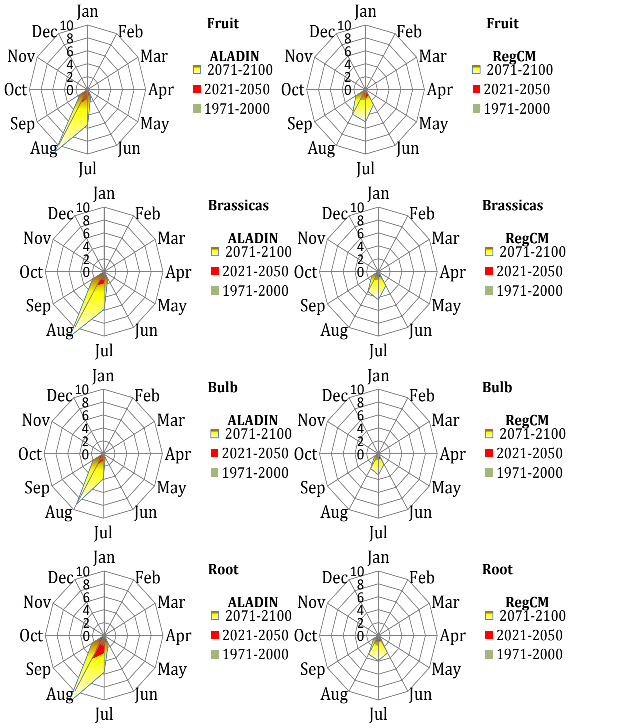

Fig. 3 Modelling shifts in the number of days with heat stress in the growing regions under the A1B SRES scenario for 2021-2050 and 2071-2100 with respect to 1971-2000.

Projected changes in heat and dryness stress

However, through these comparative analyses of current and future climatology, it is able to access relative changing patterns of dryness and heat stress in relation to the crop phenological stage due to climate change. Projected changes in the median values of dry days after sowing/planting, the number of dry days and days with heat stress in critical crop stages, heat waves in summer and extended dry spells in the growing regions are presented in Fig. 4. Overall, results suggest that for all types of vegetables are generally likely to become favourable growing conditions in near future period. The heat and dryness stress in critical crop stages will be greater at the end of the 21st century.

Vegetable growing regions	Dry days after sowing/planting (days)		Dry days in critical crop satge (days)		Heat stress in critical crop stage (days)		Heat waves JJA (days)		Extended dry spells during GS (days)	
	Alad	RegCM	Alad	RegCM	Alad	RegCM	Alad	RegCM	Alad	RegCM
(A) 2021-2050 by ALADIN-Climate/CZ (RegCM)										
Root	-2	-2	2	5	-3	0	0	-3	9	5
Brassicas	3	1	2	2	0	0	0	-2	7	4
Bulb	4	-3	1	2	0	0	0	-1	5	2
Fruit	2	1	2	3	0	0	-1	-3	6	1
(B) 2071-2100 by ALADIN-Climate/CZ (RegCM)										
Root	1	6	-3	4	-13	-2	0	0	-2	3
Brassicas	-3	5	1	1	-4	-3	0	0	-3	2
Bulb	2	2	-4	4	-3	-3	0	0	-7	0
Fruit	5	3	-4	2	-4	-4	0	0	-9	0

Fig. 4 Projected changes in the median values of dry days after sowing/planting, dry days and heat stress in critical crop stages, heat waves in summer (JJA) and the extended dry spells in the growing regions of Root, Brassicas, Bulb and Fruit vegetables. Estimates based on ALADIN-Climate/CZ (Alad) and RegCM for 2021-2050 (A) and 2071-2100 (B).

Changes in short-term temperature extremes can be critical, especially if they coincide with key stages of development. Only a few days of extreme temperature (greater than 32.0 °C) at the flowering stage of Fruit vegetables can drastically reduce yield (Potopová and Turkott, 2015). Because of flower fertility is greater decreased by these excessively high temperatures, the result will be fewer fruits set and reduced yield of tomato grown under open field conditions. Boote et al. (2012) found that hot conditions may result in cone splitting and pollen sterility of tomato, and maximal day temperature in excess of 32 °C and/or minimal night temperature above 21 °C will greatly reduce fruit set.

CONCLUSION

This study investigated potential future changes in the extreme events during the vegetable growing season over the Czech Republic with focus on dryness and heat stress. The results for the changes of impact indicators on vegetables are given for two time slices, two RCMs and climate scenarios, and 23 districts. In the main vegetable-growing regions, vegetable growth can be significantly increased under the A1B emission scenario, indicating that a warming in these areas has potential benefits to Fruit vegetable cultivars in the Czech Republic. However, in the future these considerations should be made for multi-model multi-scenario ensembles.

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