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Application of DSSAT model to simulated thermophilic crops in central and southern Europe

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Abstract

This study presents applications of DSSAT version 4.5 software package to simulate thermophilic crops. The results are used to identified adaptation options to reduce impacts of climate changes, pest and diseases in thermophilic crops in the central and south-eastern Europe, specifically in Elbe River lowland and Romania. For the Czech Republic, experimental research at farm level includes: (1) testing thermophilic assortment of vegetables in Elbe lowland conditions; (2) monitoring the meteorological data, phenological phases, soil characteristics, leaf area and the amount of aboveground biomass on farmer vegetable fields. For Romania, the focus is put on crop water use efficiency under current and future climate scenarios for thermophilic species (maize) in different agricultural sites from south and south-eastern regions. CERES Maize and CROPGRO-vegetables modules embedded in DSSAT were used.

Key words: CERES Maize, CROPGRO-tomato, plant protection, climate change

Introduction

Due to climate change, the breeding of new and improved vegetable crop varieties can lead to an extension of areas suitable for the profitable cultivation of vegetables. Some thermophilic vegetables that currently grow mostly in the southern Europe (e.g., melons, eggplants, tomatoes and peppers) can become more suitable for cultivation in lowland areas in central Europe (Potop et al. 2013, 2014a-d). Determine prospective areas for growing thermophilic vegetables in the lowlands in the Czech Republic using regional climate models and crop models can be useful tools. The crop growth models may provide information on plant production based on projected climate conditions, and also how management practices may be used to maximize the crop yield optimizing the application quantities and the time of application during the crop cycle. The principle of crop growth models is to incorporate in the basic algorithms the results of measurable biotic processes and their linkages with the abiotic conditions. The water use efficiency (WUE) also, is a measure of cropping system performance in the use of available water for reproductive growth (the ratio of the net gain in dry matter over a given period, divided by the water loss).

Among the crop simulation models that have been used for assessing the impact of climate change on agricultural crops, the Decision Support System for Agrotechnology Transfer (DSSAT) model has been largely used worldwide (Hoogenboom et al., 2010).

There were three main objectives in this study: (1) parameterisation of CROPGRO-tomato model and simulation of crop growth cycle of Thomas cultivar in filed conditions in the Elbe River lowland; (2) application of the CERES-Maize in combination with the climatic predictions RegCMs/SRES A1B at high resolution (10 km) to assessing the impact of climate change upon maize crop in southern Romania, and (3) monitoring of the biotic factors, as pests and diseases on the yield of maize hybrids in field conditions in southern Romania.

Materials and methods

Filed experiment

For the Czech Republic, experimental research at farm level includes: (1) testing thermophilic assortment of vegetables in Elbe lowland conditions; (2) monitoring the meteorological data, phenological phases, soil characteristics, leaf area and the amount of aboveground biomass on farmer vegetable fields.

The main field experiment tasks were followed: the establishment of field trial, installation of meteorological sensors in crop canopy to monitor microclimate of fields (relative air humidity, soil moisture, air and soil temperatures, rainfall) service of instrumentation and data download, service of field trials (cultivation, weeding, irrigation, fertilization, standard protection against diseases and pests) with high growth areas of market vegetables, such as celery, cucumber, tomato, eggplants, pepper and green bean vegetables) (Fig. 1a). Czech study area is located in the warmest areas of the middle Elbe lowland, a region specialising in the growing and marketing of vegetables. Here the studied field was cropped with Thomas F1 tomato (*Solanum lycopersicum* L.) (Fig. 1a, bottom). This new variety is an early season tomato with a large red fruit (57-67 mm; weight of fruit ~ 120 grams) which is quickly ripens (Table 1). Fruit does not crack even on the adverse weather conditions and is widely preferred by growers. It has a disease tolerance at Mosaic Virus-ll and Yellow Leaf Curl Virus.

Table 1 Overview on the length of growing period of tomato (*Solanum lycopersicum* L.)

Growth period	Planting or sowing period (month)	Harvest period (month)
P – H *3 – 5* months*	-half of March – sowing in greenhouse - outplanting second half of May (without cowering)	<u>*cultivars of bush tomatoes for fresh market*</u> (by hands) -beginning of July (2 x weekly) -final (end of September – beginning of October)

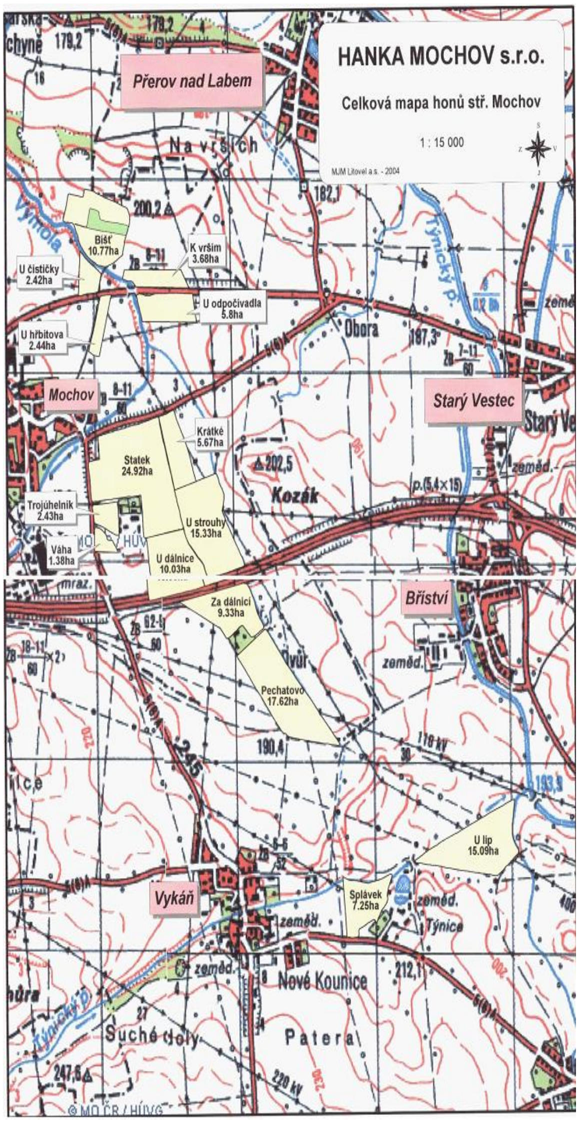
*Growing periods are distinguished as being the time from planting until harvest (P-H). *3 – 5 months means from planting to first harvest – last harvest*

Culture measures were all according to commercial practice. Leaves were picked weekly from bottom up to 3 to 4 leaves above the coloring truss. The main reasons for leaf removal are prevention of diseases and obtaining faster fruit ripening. The number of fruit per truss was set to 9 and more. Fruit production (fresh weight harvested fruits) was continuously registered. Phenology observation was done weakly. Leaf area index (LAI), Leaf area ratio (LAR), dry matter (i.e. above-ground crop mass partitioning in stem, leaves and generative organs: flower and trusses of fruits) and soil sampling were measured periodically. The first soil sampling was done before planting, which is allow to determine the initial condition, content of mineral nitrogen in the soil layers. Plant density was 2.3 plants m^{-2}. Irrigation was applied according to the soil moisture once or twice per week with a dose of 15 mm. Crop management options adopted in this study were to those practiced by the local farmers in the study area.

For Romania, the focus is put on crop water use efficiency under current and future climate scenarios for maize crop in different agricultural sites from south region, respectively Caracal agricultural area which is located in the south part of the Oltenia region, in a vulnerable area to drought conditions. The researches in the experimental field plots included: 1) testing of some maize hybrids in specific conditions (PR36V74, LG 34.75) from southern Romania 2) monitoring the meteorological data, phenological phases and biotic factors. The experiments were conducted on a mold clay-iluvial soil with 2.8% humus and a pH of 6.8 (Fig. 1b)

Input data in crop model

The CERES Maize and CROPGRO vegetables models, both included in the DSSAT version 4.5 software program (Hoogenboom et al., 2010), were used in this study to perform crop yield simulations of maize (Romania) and tomato (Czechia), respectively. The Czech study has connected daily weather data recorded at Poděbrady station (φ=50°08´N, λ=15°08´E, at 189 m) from the Czech Hydrometeorological Institute and fields experimental data at farm Hanka Mochov s.r.o. (φ=50º08´N, λ=14º47´E, at 193 m) measured by Czech University of Life Sciences Prague. The area around farm represents irrigated arable lands mostly cultivated with vegetables, where the model will be calibrated and validated. To run CROPGRO model, minimum inputs was used and these include weather, soil properties, plant characteristics and experimental data. We used the daily weather dataset requirements of the model, such as rainfall (mm), solar radiation (MJ m^{-2} d^{-1}), t_{min} and t_{max} (°C). According to this dataset, the CROPGRO was further calculated daily potential evapotranspiration (PET) by Priestley and Taylor (1972) method.



geographical position: φ=50.246 N, λ=14.606 E, h=192 m

geographical position: φ=50.146 N, λ=14.806 E, h=187 m.

Fig. 1a Map of fields location at the Czech farm and geographical position of experimental fields


Fig. 1b Some aspects from maize experimental fields (0.2 ha) from geographical position: 44.11398 N; 24.39982 E, (Left –overview of experimental plot; Right: *Ostrinia nubilalis* attack on maize)

The daily solar radiation (R_G) at Poděbrady station (1961-2013) is calculated by Ångström-Prescott formula (Ångström, 1924, Prescott 1940) based on the fraction of daily total atmospheric transmittance of the extraterrestrial solar radiation (R_A), a fraction of actual (n) and potential sunshine duration (N) during the day:

$$R_G = R_A * (A + B * (n/N)) \quad \text{(Eq. 1)}$$

where A and B are empirical coefficients determined for the particular site. The Ångström-Prescott coefficients at Poděbrady were A=0.21 and B=0.54.

Soil properties, used as input for CROPGRO-tomato at Mochov farm (Czechia), are provided in Table 2.

Table 2 Soil properties used as input for CROPGRO at Mochov farm (Czechia)

Soil layer (cm)	SLHV	CEC	SLOC	SLNI	SLCL	SLSI	SLSA
0-20	7.7	23.6	2.27	0.12	34.6	50.4	15.0
20-60	7.6	23.4	2.41	0.13	35.7	49.1	15.2
> 60	7.6	23.4	2.41	0.13	35.7	49.1	15.2

SLHV - soil pH in water, *CEC* - cation exchange capacity (mmol/100g), *SLOC* - soil organic carbon (%), *SLNI* - total soil nitrogen (%), *SLCL*- clay (%), *SLSI* - silt (%), *SLSA* - sand (%)

Initial input dry mass was set to 2.25, 1.71 and 0.01g for leaves, stem and generative organs, respectively. Initial LAI and LAR were 0.0578 m^2 m^{-2} and 0.0185 $m^2.g^{-1}$, respectively. Starting date for the simulation corresponds with outplanting date of the crop in the field, which was set at day 141 (21 May in BBCH 501 phenological stage). The simulation period ended at day 273 (30 September), a reasonable estimate for the date when plants are stopped in practice.

For Romania, the simulation model CERES-Maize as well as the Seasonal Analysis Program, integrated in the DSSAT, were used in assessing the impact of climate change upon maize crop. The model was run for current climate conditions (1961-1990) as well as for the 2021-2050 and 2071-2100 regional climate scenario-anticipated conditions, considering the direct effect of increased CO_2 concentrations (from 330 to 450 ppm) upon the photosynthesis processes. The results simulated under climate change conditions were compared to those obtained for the current climate. In order to analyse the historical meteorological data (air temperature, rainfall, wind, sunshine duration for the period 1961-2013) and agrometeorological information (soil moisture, maize phenology data and yields crop maize) has been used considered as representative for agricultural areas Caracal weather station (φ=46º6‘0“N, λ=24º21‘26“, at 106 m). Used as inputs, the management variables of maize crops resulted from calibrating and validating the model and they take different values according to the agro-climatic area analyzed: mean seeding date ranges between 15-22 April, average seed density 45.000-60.000 pl/ha, distance between rows 12-12.5 cm and seeding depth 7.8 cm.

Results

Tomato responses

Monthly and daily series of temperatures (minimum and maximum), rainfall and solar radiation for the period 1961–2013 were analysed. Mean monthly maximum and minimum temperatures, solar radiation and rainfall for the period 1961-2013 at Czech experimental site are shown in the Fig. 2. During growing season (GS) of tomato, daily totals of R_G values across the experimental site varied from 16.7 to 30.8 MJ $m^{-2}d^{-1}$. The average t_{max} and t_{min} during the GS are 20.8 (the highest t_{max} = 38.8 °C; 1.08.1994) and 10.4 °C, respectively. The mean precipitation total in the GS is 328 mm, while the highest daily amount reached in 2.06.2013 (88 mm). The summer GS (tmean≥15°C) corresponds to the beginning of the transplanting of thermophilic vegetables. The mean dates of the start and end of the GS for tmean≥15°C are May 21 to September 7, and the mean length of the GS is 109 days. For field thermophilic vegetables, a shift in the beginning date of the GS in the spring months is more advantageous than a change in the growing season length. The risk of spring frost after May 15 is low (Potop et al 2013, 2014d).

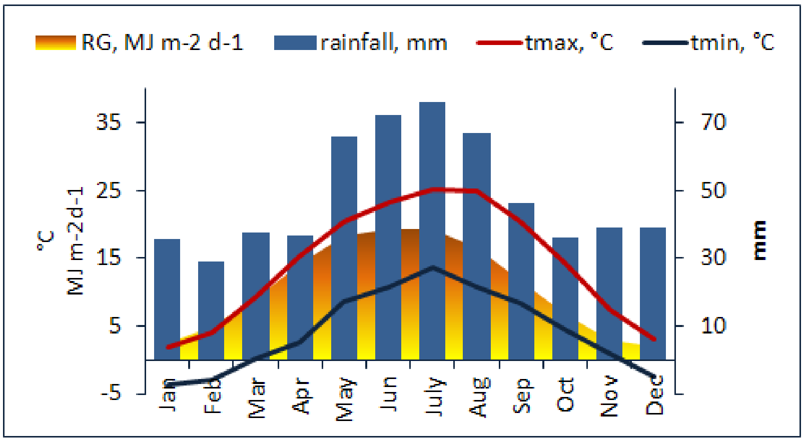


Fig. 2 Monthly averages of air temperatures (maximum and minimum), solar radiation and rainfall for the period 1961-2013

Additionally, the ALADIN-Climate/CZ and RegCM regional climate models were adopted to calculate possible shifts in the start, end and length of the climatological growing season under the SRES A1B scenario for two future periods (2021–2050 and 2071–2100) over the Elbe lowland (Potop et al. 2014b). The growing season is projected to lengthen considerably by the end of the 21st century compared with the mid-21st century and the reference period 1971–2000. Projected future climate conditions could result in significant shifts in the median of start and end of the growing season to earlier and later dates, respectively, relative to the current climate.

The length of both vegetative and reproductive tomato phenological cycles was rather strongly affected by adverse weather events during experimental period.

The field experiment was carried out in 2012 and 2013. The year 2012 was characterized by dry and hot weather, and 2013 was wet with large temperature fluctuations. When comparing the years 2012 and 2013, the decisive risk factor for yield formation of tomato was a thermal stress caused by the large differences between night and day air temperature in the flowering stage in 2012, and the low night temperatures and heavy torrential rains during June in 2013 (Fig. 3). Moreover, in 2013 at the stage of early flowering and fruit formation was observed up to 20 cases when the night air temperature dropped below 15 ° C.

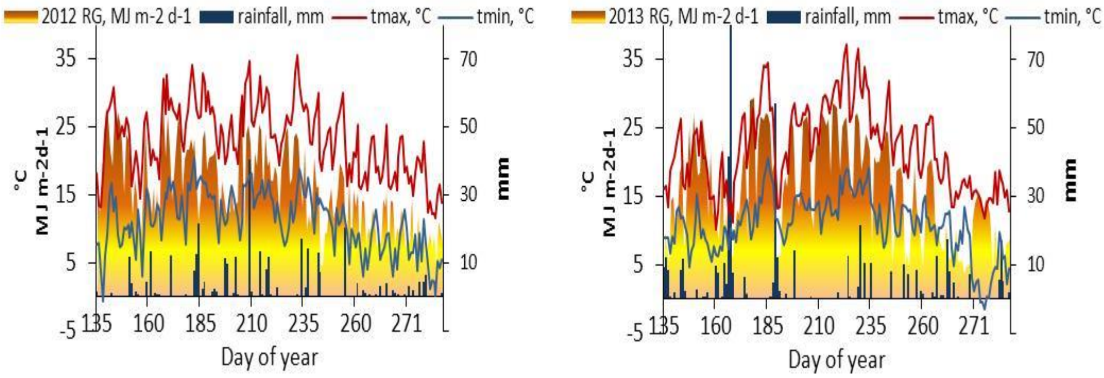


Fig. 3 Daily air temperatures (maximum and minimum), solar radiation and rainfall during experimental years (2012-2013)

We can note that the developmental stage of a vegetative unit at which the leaves are removed influenced LAI strongly and therefore crop growth rate. Early leaf pruning decreased LAI as well as biomass. Plant density influences LAI and dry mass. Fruit pruning increases assimilate allocation to the vegetative plant parts and would influence LAI. A reduced fruit load will increase dry mass per unit of ground area, due to higher weights of the vegetative plant parts. An increase in the number of fruits per truss decreased crop growth rate, as LAI was negatively influenced. CROPGRO-tomato in both years overestimated LAI for Thomas cultivar. Possible reason for overestimation of LAI is extreme meteorological conditions during experimental years, which creates large differences between observed and simulated LAI.

Maize responses

In Caracal area, the mean annual air temperature rose by 0.5 °C in the 1981-2013 period in comparison with climatic period of reference (1961-1990). In terms of monthly data the highest values were recorded in winter and summer months (Table 4). As regards precipitation, a trend of decreasing in the annual precipitation amounts could be observed. The mean monthly values register in general a decrease in ten months out of the twelve month (Table 4).

Fig. 4 provides the soil moisture trend for maize crop at Caracal station during the highest water demands of the plants (July- August) over 1971-2013 period. It highlights that the prevailing droughty years (≤50% AWC- available water content of the soil) in both months.

Table. 4 Mean monthly air temperature and monthly rainfall amounts in Caracal over 1981-2013 period, compared with baseline climate period (1961-1990)

Interval	Monthly air temperature (ºC)											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1961-1990	-2.3	0.1	5.2	11.7	17.1	20.5	22.5	21.8	17.8	11.4	5.3	0.2
1981-2013	-1.2	0.7	5.8	11.7	17.5	21.4	23.5	22.9	17.8	11.7	5.0	0.0
Deviation	1.1	0.5	0.6	0.0	0.5	0.9	1.0	1.2	0.0	0.3	-0.3	-0.2
Monthly rainfall amounts (mm)												
1961-1990	38.7	38.9	40.0	47.9	63.1	73.2	60.4	46.3	32.1	32.4	47.7	45.2
1981-2013	31.9	29.6	36.9	43.9	51.6	60.2	51.8	41.0	38.5	39.3	41.0	40.5
Deviation	-6.8	-9.3	-3.1	-4.0	-11.5	-13.0	-8.6	-5.3	6.3	6.9	-6.7	-4.7

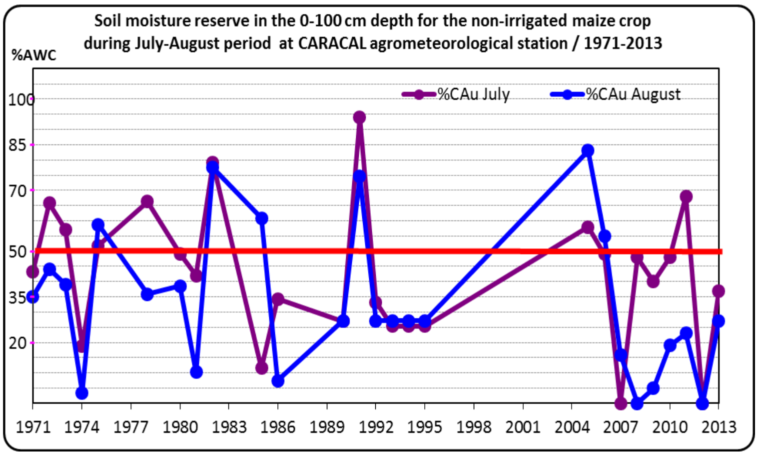


Fig. 4 Soil moisture trend for the maize crop during July-August period at Caracal (1971-2013)

Changes in yield levels and the length of vegetation period, as well as in cumulated precipitation and evapotranspiration during the vegetation season were quantified. In current clime conditions, the average maize yield is 5094 kg/ha at Caracal. Analysing the simulated results highlighted that for maize average grain yields tend to decrease by 14.4% over 2021-2050, and by 36.5% over 2071-2100 (Fig. 5, left). Also, according to the climate predictions, a shortening by 15-25 days of the vegetation period in maize crops is possible over both periods due to increasing of air temperatures, as well as due to water stress during grain filling (July-August). Being also a C4 plant, maize benefits less from the effect of increased CO_2 concentrations upon photosynthesis (Fig. 5, right).

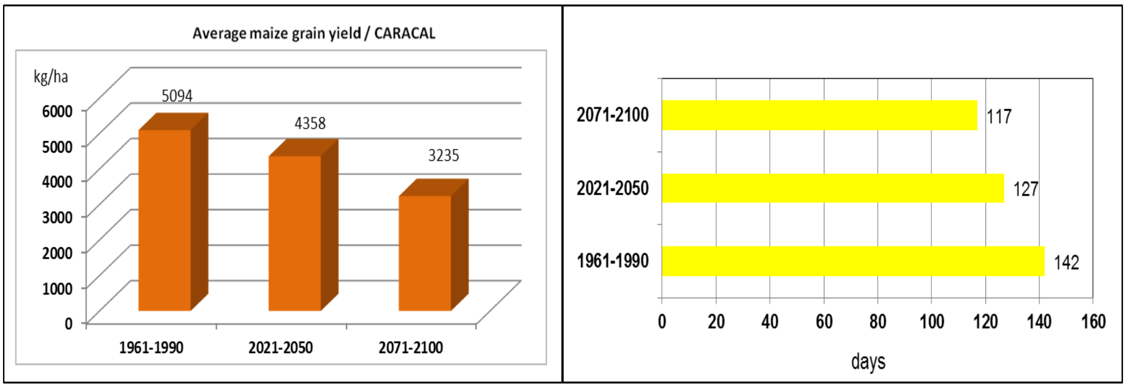


Fig. 5 Maize grain yields and changes of the growing season duration of maize crops in the current and future climate (RegCMs/ 2021-2050 and 2071-2100/ SRES A1B scenario).

The predicted WUE of maize crop increased by 9.9…12.5%, with an earlier sowing date (April 1 and 11) in comparison with current dates (April 10).

Monitoring biotic factors in maize canopy

For maize pest control is neccessary a strict monitorization of the target pests and the aplication of preventive control measures. During April-August 2013 were systematically monitorized the main pest development in corn crop (Fig.1b) as *Tanymecus dilaticollis*, *Ostrinia nubilalis*, black cutworm, *Agrotis segtum, Autographa gamma* and the invasive species *Diabrotica virgifera virgifera*. In the first case study, were the hybrid LG 34.75 was studied, the dicotyledonous weeds were dominant and their control was performed only in vegetation (Table 5).

Table 5 Production results of different variants in the first study case

Variant	Product and dose	Yield (kg ha^{-1})	TKM (g)	HM (kg)
1	Zeagran 2 l/ha Crew 1 l/ha Sprayguard 0.1 l/ha	8345	230.3	67.8
2	Zeagran 1.5 l/ha Dicopur Top 0.8 l/ha CREW 1 l/ha Sprayguard 0,1 l/ha	8512	232	68.7
3 (untreated)	-	6855	217	67.2

TKM - thousand-grain mass, HM - Hectoliter mass

Both herbicides Zeagran and Dicopur top had a good activity in controlling the annual and perennial dicotyledonous weeds, and their mixture increased the perennial weeds control efficacy (variant 2), especially the *Convolvulus arvensis*. Crew herbicide had a good activity against annual and perennial monocotyledonuous weeds. Significant increases yield values of 1657 kg/ha in the variant 2 and of 1469 kg/ha in the variant 1 highlighted the importance of weed control in the maize crop.

In the second study with maize hybrid PR36V74, weeds control scheme was achieved in 3 variants (Table 6). The best results were obtained in the first variant, were treatments were applied pre emergent (after sowing) and post emergent. Adengo herbicide consist of two active substances with a large spectrum of annual weeds control and with high residual activity, beeing able to preserve it's activity after rain. The presence of perennial weeds, both dicotyledonous (*Cirsium arvense, Convolvulus arvensis*) and monocots (*Sorghum halepense*) required the use of two herbicides, Bromoxinil and Equip. The weeds control efficacy was very good and the yield increased with 3486kg/ha.

Table 6 Production results of different variants in the second study case

Variant	1	2	3	Untreated
Preemergent Weed control treatment	ADENGO 0,4 l/ha		MERLIN DUO 2.0 l/ha	-
Postemergent weed control treatment	1) Buctril Universal 0.8 l/ha 2) EQUIP 2.5 l/ha 3) -	1) - 2)- 3) LAUDIS 2.25 l/ha	1) Buctril Universal 0.8 l/ha 2) EQUIP 2.5 l/ha 3) -	-
Foliar fertilization	Boron 2.0 l/ha+ Wuxal macromix 3.0 l/ha	Boron 2.0 l/ha+ Wuxal macromix 3.0 l/ha	Boron 2.0 l/ha+ Wuxal macromix 3.0 l/ha	-
Yield (kg ha^{-1})	8341	7855	8173	4855
TKM (g)	283.3	262.2	271.8	253.4
HM (kg)	71.0	69.5	70.5	69.2

The variant 2 had just vegetation treatments with 2.25 l/ha LAUDIS herbicide. This herbicide disturbs the photosynthesis process and has a double systemic action. Also, control very well the annual weeds species. The perennial species, especially the dicotyledonous can regenerate, and therefore, in our experiments the yield was lower in this variant. In the third variant were the treatments were made with the herbicide MERLIN DUO the results were similar with the ones from the variant 1 but it was noticed after the application a reinfestation with annual weeds. The yield increased in this variant with 3318 kg/ha. Besides high efficacy in weeds control, in this study was noticed the importance of fertilization in obtaining significant yield increases.

Discussion

Studies on the response of tomato to climate change are very limited. For instance, in the studie of Ventrella et al. (2012) reported that tomato appears to be more sensitive to climate change than the winter durum wheat in southern Italy. Moreover, the results showed that under future climate scenarios tomato yields will be limited more by high temperature than by water availability. In this context, water scarcity and pedological droughts in south and south-east Romania can cause drastic yields decreases, particularly during the excessively droughty agricultural years such as: 2006-2007 and 2011-2012, and the higher/lower than optimum temperatures are reflected by metabolically reactions in plants, causing thermal stress especially in summer and winter, while every modification in the trend of their lows can easily aggravate frost injury in sensitive plants. For this reason the adaptation of crop species to climate change can be mainly based on the experience obtained from their reactions to extreme climate events by implementing climate change risk adaptation and management plans as well as on the new researches approaching the regional and local effects related to the behavior of genotypes in current and predictable climate change conditions (Sandu et al., 2010; Mateescu and Stancalie, 2010, 2012; Mitrica et all, 2013).

Conclusion

This simulation study provided details relating to the responses of thermophilic crops to weather extreme events under current and future climate and also how management practise may be used to maximize the crop productions in the central and south-eastern Europe, specifically in Romania and Elbe River lowland and. In our future work, we plan to calibrate a field vegetable crop growth model in Elbe River lowland.

The results of CERES-Maize simulation showed that the future climate evolutions may have important effect upon maize crop and these are conditioned by an interaction between the following factors: current climate changes on a local scale, severity of climate scenario-forecasted parameters, how the increased CO_2 concentrations influence photosynthesis, and the genetic nature of plant types. Maize crop being a C4 plant is vulnerable to climate change, mainly in the case of a scenario predicting hot and droughty conditions.

The very significant influences of the weed suppression on maize grain yield in comparison with untreated variants emphasize the importance of treatments to control weeds in maize crop. Depending on the actual conditions on the field (weed spectrum of maize crop and climatic conditions) one of the proposed variants for weed control can be selected. Climatic conditions in 2013 were unfavorable for the evolution of pest and diseases (especially cold period between emergence of maize and the stage of 4 leaf that influenced the evolution of thermophilic insect *Tanymecus dilaticollis* and subsequent drought during the period of laying eggs by the european corn borer) in maize crop and therefore the attack degree and implicitely the stress generated by pests and diseases did not influenced the yield.

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Summary

Tato studie představuje využití aplikace DSSAT programu verze 4.5 pro simulaci růstu a vývoje teplomilných plodin. Výstupy modelu budou využity pro snížení negativních dopadů klimatické změny na produkci teplomilných plodin a rozvoj fytopatogenů ve střední a jihovýchodní Evropě, konkrétně pak v Polabské nížině a v Rumunsku. Současně bude řešena problematika možného přizpůsobení se této klimatické změně a jejího využití v zemědělské produkci. V České republice probíhá experimentální výzkum na úrovni zemědělských podniků a zahrnuje: (1) testování sortimentu teplomilných zelenin v klimatických podmínkách Polabské nížiny; (2) sledování agrometeorologických prvků, půdních vlastností, růstových fází a fyziologických parametrů (LAI, LAR, relativní rychlost růstu, suchá biomasa) rostlin v průběhu vegetace v polních podmínkách. V případě Rumunska je kladen důraz na využití vody teplomilnými plodinami (kukuřice) v podmínkách současného a budoucího klimatu v různých zemědělských regionech jižního a jihovýchodního Rumunska. Pro simulaci jsou v programu DSSAT použity moduly kukuřice CERES a zeleniny CROPGRO. Pro studii v České republice jsou využívána denní meteorologická data stanice Poděbrady (φ = 50° 08' N, λ = 15° 08' E, 189 m n. m.) spravované Českým hydrometeorologickým ústavem a data ze stanic spravovaných Českou zemědělskou univerzitou v Praze umístěných v porostech na experimentálních pozemcích farmy Hanka Mochov s. r. o. (φ = 50° 08' N, λ = 14° 47' E, 193 m n. m.). Experimentální plochy, kde je model ověřován a kalibrován, jsou součástí pozemků s vybudovanými závlahami a využívanými převážně k pěstování zeleniny. Vstupní meteorologická data do modelu jsou denní úhrn srážek (mm), globální záření ($MJ.m^{-2}.d^{-1}$), t_{min} a t_{max} (°C). Z těchto dat je následně modelem vypočtena metodou Priestley a Taylor denní potenciální evapotranspirace (PET). Denní globální záření (R_g) je vypočteno dle vzorce Ångström-Prescotta. Půdní parametry využité v modelu jsou sledovány ve třech hloubkách 0 - 20 cm, 20 – 60 cm a >60 cm. Jsou to

SLHV - pH půdního roztoku, CEC - kationtová výměnná kapacita ($mmol.100g^{-1}$), SLOC - celkový obsah organického uhlíku (%), SLNI - celkový obsah dusíku (%), SLCL – jíl (%), SLSI – prach (%), SLSA – písek (%). Počáteční datum simulace bylo stanoveno na den výsadby rostlin 21. května (141 den Juliánského kalendáře) a konec simulace na termín odpovídající průměrnému počátku prvních mrazů 30. září (273. Juliánský den), tedy poslední sklizni s vysokou tržní jakostí plodů. V době výsadby byly rostliny rajčat odrůdy Thomas ve vývojové fázi BBCH 501, hmotnost suché biomasy listů 2,25 g, stonku 1,71 g a generativních orgánů 0,01 g a vypočtená hodnota LAI byla 0,0578 $m^2 m^{-2}$, LAR (Leaf Area Ratio) 0,0185 $m^2.g^{-1}$.

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