Evaluation of the DSSAT CSM-CROPGRO-Tomato Simulation Model for Processing Tomato (*Lycopersicon esculentum* Mill.) Production in Northern Italy

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Abstract

Italian processing tomato market has its dominance at global level but very few studies have been made on modelling this crop. The Cropping System Model CSM-CROPGRO-Tomato model of DSSAT (Decision Support System for Agrotechnology Transfer) software, was tested using datasets collected from field experiment in Legnaro, northern Italy. The experiment was carried out in 2009 using four different transplanting dates starting from 11th March (TD1, TD2, TD3, and TD4) with ten-day intervals, four processing tomato varieties, and two agronomic practices (mulched and non-mulched soil). Plants under mulched conditions in all transplanting dates gave better performance in terms of yield, growth and water use efficiency. Under mulched conditions, NPT 63 variety had significantly better yield and water use efficiency than the other three varieties. Mulching the soil was a useful tool to decrease water consumption levels at the transplanting dates studied. Evaluating the model using non-mulched experimental datasets showed that index of agreement (d-Stat) values between observed yield and model simulation for the first planting date with the four varieties ranged between 0.69 and 0.99. The model was able to simulate growth development better for all varieties under TD2, TD3, and TD4 conditions. In order to validate simulation ability of the model for the final yield, further work should be done regarding the genotype coefficients for each variety under study.

INTRODUCTION

Italy, as a major producing Mediterranean country, dominates the global processed tomato products market (FAO, 2007). The World Processing tomato Council in 2006 stated that Italy produces and supplies 18% of total world production in 2005 of processing tomato (*Lycopersicon esculentum* Mill.), and northern Italy produce more than 40% of its production. Few models have been used for the simulation of tomato in greenhouse and in field conditions (Rinaldi et al., 2007), and few of them simulate crop growth, development and yield. DSSAT is a package of cropping system models that includes programs to create databases on crop experiments (including crop management treatments as well as measurements made on soil and crop in the experiments), on soil parameters and on climatic data. In this study we have used a beta-version of DSSAT (v4.5.0.2), which was released as an alpha-version later in 2011 (Hoogenboom et al., 2011). CSM-CROPGRO-Tomato simulation model was evaluated using only the non-mulched experimental datasets, which is the condition this model was developed with.

We studied processing tomato production grown in open field in order to compare the influence of mulching vs non-mulching treatments, to assess the CSM-CROPGRO-Tomato model, and to evaluate its simulation under northern Italy weather conditions.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Farm "L. Toniolo" of Padova University (45°21'N; 11°58'E) in northern Italy from March to September 2009. Four

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processing tomato varieties (*Lycopersicon esculentum* Mill.): Augusto F1 (AUG) and Tiziano F1 (TIZ) from De Ruiter company, and Safaix (SAF) and NPT 63 (NPT) from S&G company, were used. Seeds were sown in greenhouse at ten-day intervals between the four sowing dates beginning from 11th March. Forty days after sowing the plantlets were transplanted in open field at four different transplanting dates (TD1, TD2, TD3, and TD4) at 10 days intervals. Two agronomic practices were used, mulched and non-mulched soil. The experimental area, 1296 m^2, was divided using a split-split plot design. Drip irrigation system was used to irrigate different blocks of the experiment. The amount of irrigation water was recorded for each plot using water meters, which helped to determine the amount of water used in irrigation. Standard fertilisation was applied: N (150 kg ha^{-1}), P_2O_5 (150 kg ha^{-1}), and K_2O (200 kg ha^{-1}) (Rinaldi et al., 2007). Four samples of biomass were taken at two weeks interval beginning from one month after transplanting. Plants under mulching condition were ready for harvesting after 30 days from the last sampling, which was earlier than plants under non-mulched conditions with about 10 days.

During growing cycle several variables have been measured and recorded such as (1) daily meteorological parameters, (2) soil parameters, (3) vegetative parameters, and (4) yield parameters. Meteorological parameters were maximum and minimum temperature, sunshine hours, precipitation, global solar radiation, relative humidity, and wind speed/direction. Soil profile information was collected through measurements in the field in addition to lab physical and chemical analysis. Vegetative parameters were fresh/dry biomass, leaf area, n^o leaves, canopy height, fresh/dry fruit weight, and n^o fruits. Yield parameters were fresh/dry biomass, fresh/dry fruit weight, and n^o fruits. These parameters were determined according to the model minimum datasets required.

RESULTS AND DISCUSSION

Experimental Data

Comparing yield of the four different tomato varieties we can see that NPT had the best performance (80 t ha^{-1}) followed by TIZ, SAF, and AUG respectively (Fig. 1). The comparison of crop yield with or without mulching showed that mulching the soil enhanced the yield of all the varieties under study. This effect could be due to the increased soil water retention and soil temperature at the plant root zone, which ameliorate root growth development but mainly by protecting the plant from weeds competition.

Rinaldi et al. (2007) in their work on modeling tomato stated that water stress can modify the water use efficiency. Therefore, irrigation amount was taken into consideration in order to evaluate water use efficiency for each variety under study. Figure 2 shows, accordingly with yield results, that TD4 under mulched conditions had better water use efficiency (22 t m^{-3}) followed by the other three transplanting dates. Significant positive influence for water use efficiency was observed under mulched conditions at all transplanting dates, which could be due to an increase of root expansion under mulched conditions (Rinaldi et al., 2007).

Plants under mulched conditions showed significantly lower level of water received by the plant through rainfall plus irrigation (between 5500 and 3300 m^3 ha^{-1}) than those under non-mulched conditions at all transplanting dates (Fig. 3). Under non-mulched conditions, water received at TD1 was the highest (8300 m^3 ha^{-1}), whereas at TD2, TD3, and TD4 were 7000, 6700, and 5500 m^3 ha^{-1}, respectively. This effect was due to the lower evapotranspiration rate in early transplanting dates as temperature is relatively low.

Model Outputs

Evaluating simulation ability of CSM-CROPGRO-Tomato model using the experimental data sets showed that index of agreement (d-Stat) values (Willmott, 1982) between observed and simulated yields for TD1 were relatively low for all the varieties under study (Table 1). Total dry matter of the four tomato varieties showed high fitting between observed and simulated yield for TD1, TD2, TD3, and TD4. For AUG variety, low simulation ability was observed for its yield of TD1, TD2, and TD3 conditions.

Comparison between observed and simulated total biomass of the four processing tomato varieties showed different trends (Fig. 4) with d-Stat values ranging between 0.68 and 0.99. Simulation of total biomass under TD1 condition didn't show good fitting with the observed value especially at the end of the growing cycle, whereas for the other transplanting dates it was relatively high.

CONCLUSIONS

Processing tomato plants under mulched conditions in all transplanting dates gave better performance in terms of yield, growth and water use efficiency. Under mulched conditions, NPT 63 had significantly better yield and water use efficiency than the other three varieties. Mulching the soil is a useful tool to decrease water adding levels at the transplanting dates studied.

As an initial model evaluation, it was observed that with default cultivar coefficient values, the model was performing in relatively good way when simulation was compared with the real observations. The model simulates yield very well for the first planting date with all the varieties. It was able to simulate growth better for NPT 63 and Safaix F1 varieties under TD1, TD2, TD3 conditions. As earlier the planting date was, the better the model final yield simulation was. This indicates that under northern Italian conditions it would be possible to calibrate the model and to simulate the possible yield of different processing tomato varieties under study. In order to validate simulation capability of the model for the final yield, further work should be done regarding the genotype coefficients for each variety under study. CSM-CROPGRO-Tomato model is not yet designed for mulched conditions and further studies should be done in this regard.

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Tables

Table 1. Statistical comparisons of simulated vs. observed fruit fresh weight values using CSM-CROPGRO-TOMATO model in the validation phase.

Transplanting date	Variety	Yield ($t\ ha^{-1}$)			
		Observed	Simulated	RMSE[α]	d-Stat[β]
TD1	AUG	0.33 ± 0.23	0.46 ± 0.65	0.53	0.63
	NPT	0.61 ± 0.48	0.52 ± 0.74	0.41	0.88
	SAF	0.50 ± 0.43	0.50 ± 0.70	0.35	0.90
	TIZ	0.29 ± 0.20	0.46 ± 0.65	0.53	0.61
TD2	AUG	0.89 ± 0.64	0.77 ± 0.75	0.22	0.97
	NPT	1.12 ± 0.86	1.02 ± 0.90	0.11	1.00
	SAF	0.81 ± 0.53	0.86 ± 0.80	0.32	0.94
	TIZ	0.75 ± 0.70	0.78 ± 0.77	0.08	1.00
TD3	AUG	0.72 ± 0.52	1.07 ± 0.80	0.51	0.86
	NPT	1.08 ± 0.77	1.09 ± 0.82	0.29	0.97
	SAF	0.91 ± 0.69	1.09 ± 0.75	0.25	0.97
	TIZ	0.89 ± 0.68	1.05 ± 0.78	0.21	0.98
TD4	AUG	1.26 ± 0.92	1.03 ± 0.83	0.28	0.98
	NPT	1.22 ± 1.01	1.14 ± 0.92	0.16	0.99
	SAF	0.97 ± 0.72	1.13 ± 0.86	0.23	0.98
	TIZ	0.85 ± 0.66	1.06 ± 0.85	0.29	0.96

[α] Root Mean Square Error.
[β] d-Index of agreement, (Willmott, 1982).

Figures

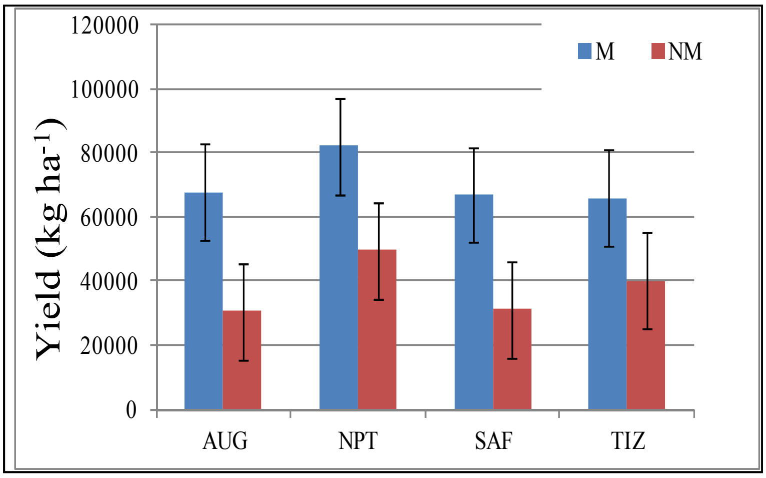

Fig. 1. Influence of mulched (M) and non-mulched (NM) treatments on the yield ($kg\ ha^{-1}$) of the four different processing Tomato varieties. Vertical bars represent 95.0% confidence interval for the mean of each treatment.

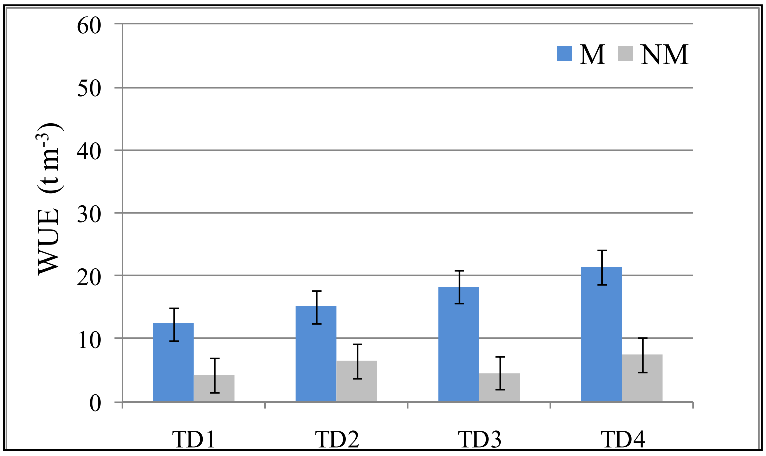

Fig. 2. Influence of mulched (M) and non-mulched (NM) treatments on the water use efficiency (t m^{-3}) of the four different processing Tomato varieties. Vertical bars represent 95.0% confidence interval for the mean of each treatment.

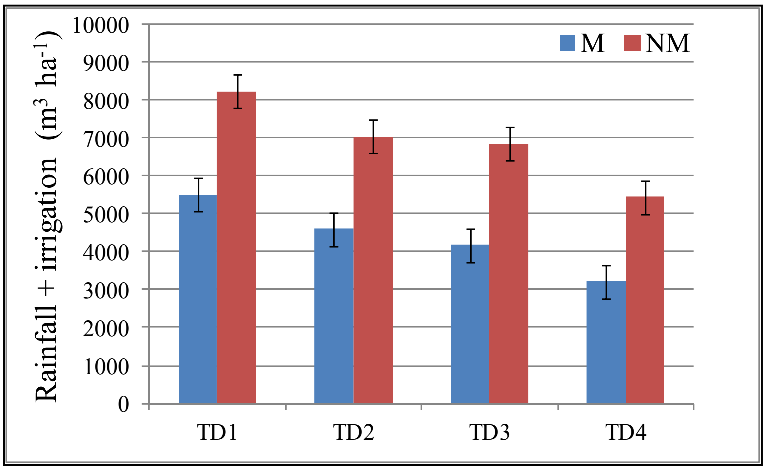

Fig. 3. Influence of mulched (M) and non-mulched (NM) treatments on the water received by plants (m^3 ha^{-1}) through rainfall and irrigation of the four different transplanting dates. Vertical bars represent 95.0% confidence interval for the mean of each treatment.

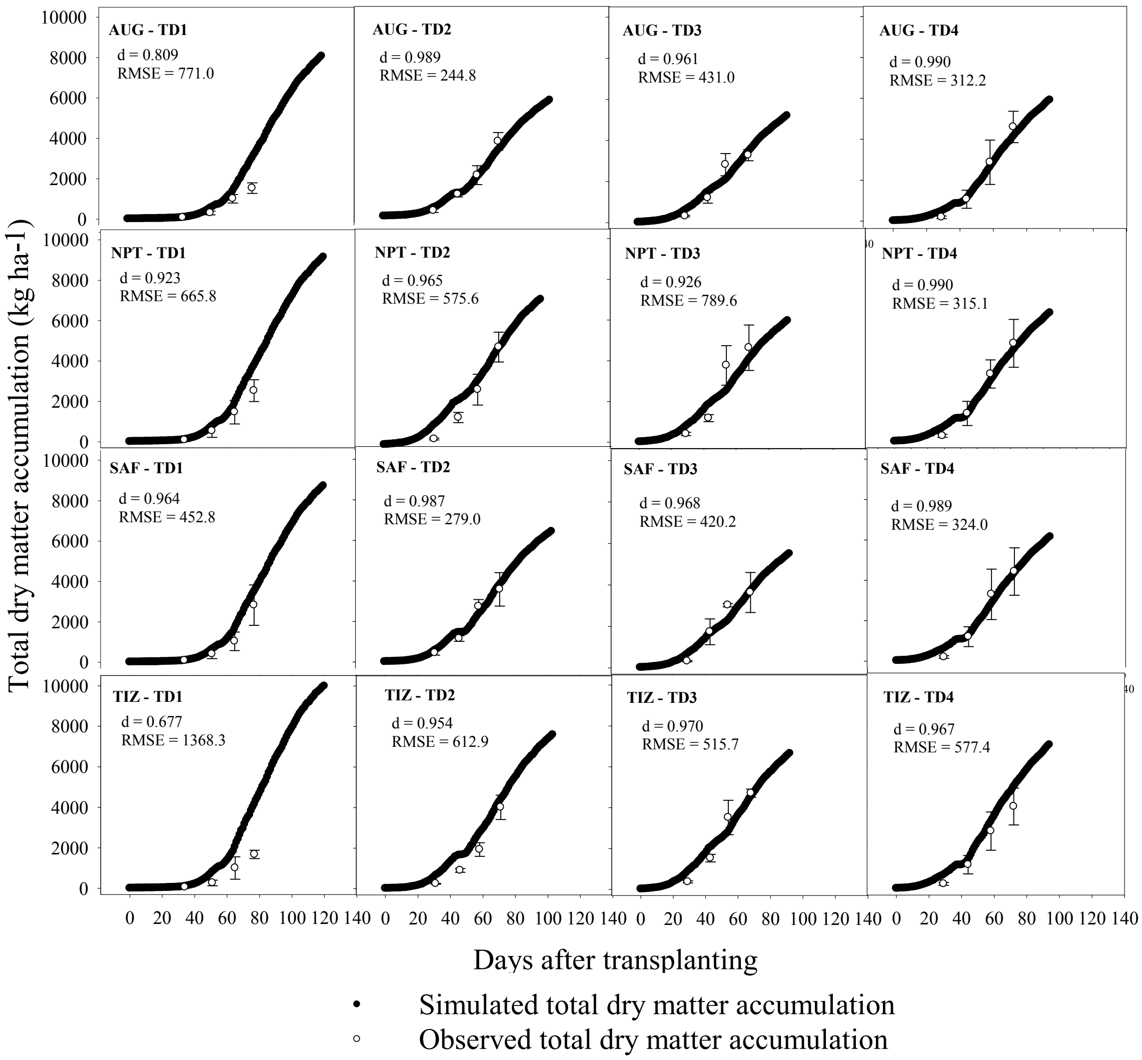

Fig. 4. CSM-CROPGRO-Tomato model simulation of the total plant biomass during growing cycle of the four processing Tomato varieties under conditions of the four different transplanting dates.