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APPLICATION OF SOFT COMPUTING TECHNIQUE TO SIMULATE YIELD OF IRRIGATED TOMATO

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Abstract: Field verification of AquaCrop model results for irrigated tomato was carried out to test the AquaCrop model as a soft computing tool to improve water use efficiency. AquaCrop model was calibrated using tomato production data for the year 2013-2015. The calibrated value of harvest index and water productivity was 65% and 35 gm⁻², respectively. Simulations were carried out with formulated schedules for the period 17th October 2014 to 1st March 2015. AquaCrop predicted schedule S₃ (mulch + Irrigation schedule at 75 % ET_c) as the best schedule based on maximum water use efficiency *i.e.* 12.84 qha-cm⁻¹. This schedule S₃ (treatment T6) was tested in the field during 2015-16 along with other treatments. The maximum yield is recorded in treatment T3 (mulch + Irrigation schedule at 80 % ET_c) *i.e.* 263.66 qha⁻¹ followed by T6 (mulch + Irrigation schedule at 75 % ET_c) *i.e.* 262.05 qha⁻¹. But water use efficiency was found maximum for T6 (12.73 qha-cm⁻¹) followed by T3 as (12.12 qha-cm⁻¹). Therefore it is recommended to implement T6 *i.e.* silver mulch + Irrigation schedule at 75 % ET_c for tomato production in western Vidarbha region. The results also confirmed the capability of AquaCrop in predicting the effect of water on the yield of tomato.

Keywords: Crop water productivity, Water use efficiency, AquaCrop, tomato, crop evapotranspiration

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INTRODUCTION

Agriculture, being the major water user, its share in the total freshwater demand is bound to decrease from the present 83% to 68% due to more pressing and competing demands from other sectors by 2050 AD (GOI, 2013). There is a need to increase annual foodgrain production from about 210 million tonnes (2013) to 420 million tonnes by 2015. Since water is a shrinking resource for agriculture, the pathway for achieving this goal has to be higher productivity per unit of water. Thus, the objective of agricultural production in the present era is not only to provide supplementary water for crop production but also to decrease crop water use per unit yield of crop *i.e.* **more crop per drop** (Swaminathan, 2013).

Tomato is a popular and nutritive vegetable crop ranking next to potato in world's vegetable production. Tomato is an important source of minerals and antioxidants, which have a key role in human nutrition to prevent certain cancer and cardio vascular diseases. In 2014-15, in India total area under tomato cultivation was 882 thousand ha, total production was 18735.9 thousand MT and total productivity was 21.2 MTha⁻¹. While, in Maharashtra state total area under tomato was 50 thousand ha, total production was 1200 thousand MT and total productivity was 24 MTha⁻¹ (NHB, 2014).

Accurate crop development models are important tools in evaluating the effects of water deficits on crop yield or productivity. AquaCrop is developed from revision of 'FAO Irrigation and Drainage Paper No. 33 Yield Response to Water' (Doorenbos *et al.*, 1979). It simulates crop yield in response to water, and is particularly suited to address conditions where water is a key limiting factor in crop production. The potential of AquaCrop model in simulating the yield in response to water is proved by various researchers (Araya *et al.* 2010a, Heng *et al.* 2009; Stricevic *et al.* 2011; Abedinpour *et al.* 2012, Andarzian *et al.* 2011).

Tomato has the highest acreage of any vegetable crop in the world, therefore adoption of deficit irrigation could make substantial contribution to saving of water. Thus, considering the need of enhancing water use efficiency, this research study was undertaken.

2. MATERIAL AND METHODS

2.1. Data collection

Meteorological data for the period 23rd October 2013 to 28th February 2016 was obtained from Agro-meteorological Observatory, Dr. P.D.K.V., Akola.

The required crop data was obtained from a field experiment conducted during the year 2013 - 2015 and having following treatments.

Sr. No.	Treatment	Specification
1	T1	40 % ET _c with silver polyethylene mulch
2	T2	60 % ET _c with silver polyethylene mulch
3	T3	80 % ET _c with silver polyethylene mulch
4	T4	100 % ET _c with silver polyethylene mulch
5	T5	100 % ET _c without polyethylene mulch (control)

The soil characteristics at experimental site were studied by Pawar (2014). The same was referred.

2.2. Background of AquaCrop model

FAO Irrigation and Drainage Paper No. 33 (Doorenbos *et al.*, 1979) represented an important source to determine the crop yield response to water through the following equation:

$$\left(1 - \frac{Y_a}{Y_x}\right) = k_y \left(1 - \frac{ET_a}{ET_x}\right) \quad \dots (1)$$

where,

Y_x and Y_a - Maximum and actual yield,
 ET_x and ET_a - Maximum and actual evapotranspiration, and
 k_y - Crop yield factor

2.3. Calibration and validation of model

The data of field experiment conducted during the period 2014-15 and 2013-14, was used for calibration and validation of the model, respectively. The model was calibrated by varying harvest index and water productivity. AquaCrop version 4.0 was used in the study.

2.4. Model performance

Statistical parameters viz. Nash Sutcliffe coefficient (Nash and Sutcliffe, 1970) and coefficient of residual mass (Kale, 2014) were used to judge the performance of the model.

2.5. Formulation of irrigation schedules

Crop evapotranspiration (ET_c) was computed on daily basis using values of crop coefficients (Holsambare, 1988) and reference evapotranspiration (Allen *et al.*, 1998). Seven schedules were formulated considering various levels of water application *i.e.* ET_c as follows.

Table 2 Formulated irrigation schedules

Schedule	Particular
S ₀	- Irrigation scheduling at 100% Etc
S ₁	- Irrigation scheduling at 95% Etc
S ₂	- Irrigation scheduling at 85% Etc
S ₃	- Irrigation scheduling at 75% Etc
S ₄	- Irrigation scheduling at 65% Etc
S ₅	- Irrigation scheduling at 55% Etc
S ₆	- Irrigation scheduling at 45% Etc

2.6. Effectiveness of formulated schedules

The calibrated model was used to evaluate the impacts of different irrigation schedules on performance of tomato. Based on water use efficiency (WUE, Michael, 1979) the best schedule was predicted.

$$WUE = \frac{\text{Total tomato yield, kg}}{\text{Total water applied, m}^3} \dots(2)$$

2.7 Field evaluation of best schedule

The best schedule predicted by AquaCrop model was evaluated in the field along with all previous treatments of the field experiment of which data used to calibrate the AquaCrop model. Thus the experiment now consists of six treatments having four replications as below.

Table 3 Treatment details of field experiment

Sr. No.	Treatment	Irrigation schedule
1	T1	40% ET _c with silver polyethylene mulch
2	T2	60% ET _c with silver polyethylene mulch
3	T3	80% ET _c with silver polyethylene mulch
4	T4	100% ET _c with silver polyethylene mulch
5	T5	100% ET _c without polyethylene mulch
6	T6	Best schedule predicted by AquaCrop model

In order to observe growth and yield of tomato as affected by different irrigation mulch treatments, biometric observation such as plant height, number of branches and leaf area index were observed at 30, 60, 90 and 120 days after transplanting. Polar and equator diameter of tomato, weight of tomato and yield were observed at the time of harvesting. The best treatment was optimized based on WUE.

3. RESULTS AND DISCUSSION

3.1 Calibration of AquaCrop model

The variation of observed and simulated yield during calibration is depicted in Fig. 1.

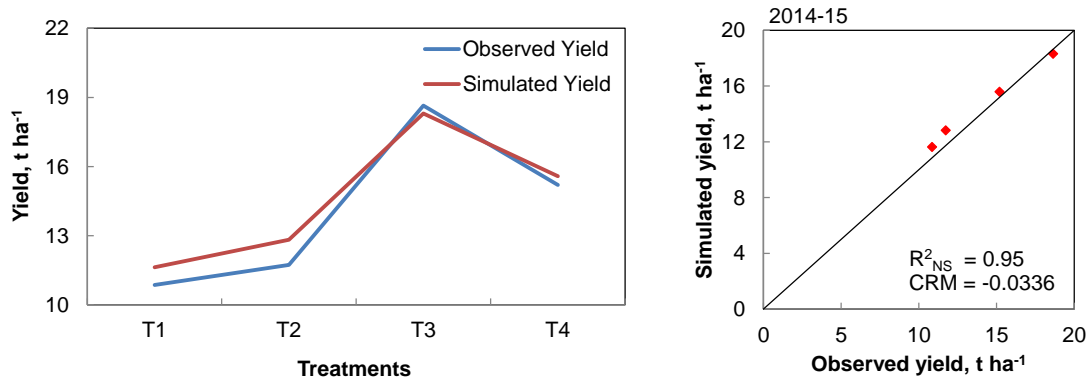


Fig. 1 Comparison between observed and simulated yield over calibration period

The observed yield varied between 10.86 to 18.63 t ha⁻¹, whereas simulated yield varied between 11.63 to 18.30 t ha⁻¹. Observed and simulated yield were in close match, as seen in Fig. 1. Simulated yield of tomato was observed to be more than observed in all treatments except in treatment T3. The scatter diagram also confirmed that the

model slightly overestimated the yield for all treatment except treatment T3. The slightly overestimation of yield by model is supported by coefficient of residual mass as -0.0336. The average variation between observed and simulated yield was found to be 3.92%. It was also supported by good estimate of statistical parameters *i.e.* Nash Sutcliffe coefficient as 0.95 and CRM as -0.0336. As such the model setup was considered as calibrated and calibrated model parameters are presented in Table 4.

Table 4 Calibrated model parameters

Particulars	Measure
Harvesting index, %	65
Water productivity (WP), gm ⁻²	35

3.2 Validation of AquaCrop model

Model validation is in fact the extension of calibration process. Thus model was validated for the period 23rd October 2013 to 3rd March 2014. The variation in observed and simulated yield of tomato for validation period is depicted in Fig. 2.

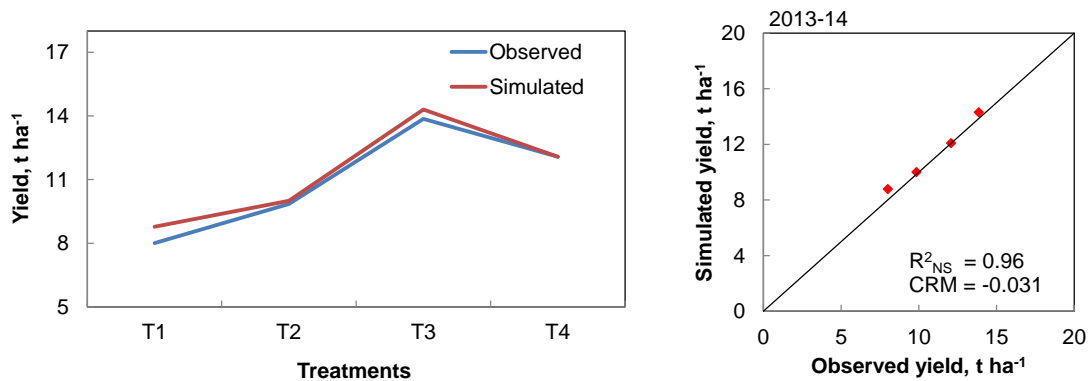


Fig. 2 Comparison between observed and simulated yield for validation period

Likewise calibration, observed and simulated yield were in close match for validation period. Similar to calibration, the model slightly overestimated the yield for all treatment. Considering overall acceptability of results in terms of statistical parameters (Nash Sutcliffe coefficient as 0.96 and CRM as -0.031), the model was considered as validated.

3.3 Response of tomato to various formulated schedules

Water use efficiency (WUE) for different formulated irrigation schedules was estimated and presented in Table 5.

Table 5 Water use efficiency for different formulated schedules

Schedule	Water applied, ha-mm	Simulated yield, qha ⁻¹	Increase in yield %	WUE, q ha-cm ⁻¹
Control, (100% ETC)	190.2	155.80	--	8.19
S1, (95% ETC)	180.7	154.45	-0.87	8.55
S2, (85% ETC)	161.7	160.20	2.82	9.91
S3, (75% ETC)	142.7	183.20	17.59	12.84

S4, (65% ETc)	123.6	132.35	-15.05	10.71
S5, (55% ETc)	104.2	127.64	-18.07	12.25
S6, (45% ETc)	85.6	122.76	-21.21	14.34

Water applied varied from 85.6 to 190.2 ha-mm. The simulated yield varied from 122.76 to 183.20 qha⁻¹. The variation in simulated yield ranged from -21.21 to 17.59 qha⁻¹ compared to control treatment. Fig. 3 depicts variation in simulated yield with reference to water applied.

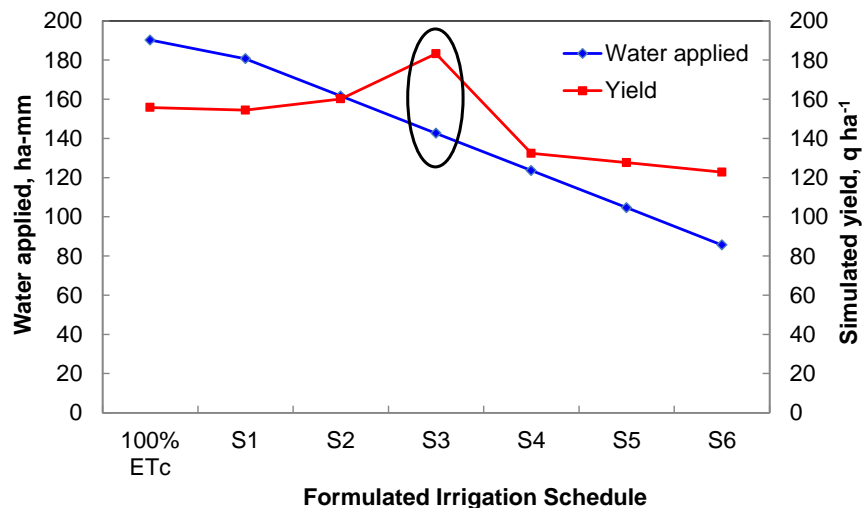


Fig. 3 Variation in simulated yield with reference to water applied

The WUE varied from 8.19 to 14.34 qha-cm⁻¹. The WUE increases as water applied decreases except for schedule S3. In case of schedule S3, WUE increases though water applied decreased. It was due to increased simulated yield. The WUE for schedule S3 is estimated as 12.84 qha-cm⁻¹ and is highest among all formulated schedule except schedule S6. In case of schedule S6, WUE increased due to lowest water applied and lowest simulated yield. Therefore the schedule S3 was emerged as the best formulated schedule.

3.4 Field verification of best schedule predicted by AquaCrop model

3.4.1 Irrigation requirement of tomato

Irrigation water applied during different growth stages of tomato was estimated and presented in Table 6.

Table 6 Crop growth stage wise water requirement

Sr. No.	Crop stage	Water applied per plant, lit					
		T1	T2	T3	T4	T5	T6
1	Common irrigation before transplanting	13.50	13.50	13.50	13.50	13.50	13.50
2	Initial stage	3.22	4.84	6.45	8.06	8.06	6.05
3	Crop development	13.30	19.95	26.60	33.25	33.25	24.94
4	Mid season	18.14	27.21	36.28	45.35	45.35	34.01
5	Late season	7.54	11.30	15.07	18.84	18.84	14.13
Total, lit plant ⁻¹		55.70	76.80	97.90	119.00	119.00	92.63

ha-cm	12.38	17.07	21.76	26.44	26.44	20.58
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(*No rainfall received during the crop season)

The amount of water applied varied from 12.38 to 26.44 ha-cm. It was found maximum for treatment T4 and T5, while minimum for treatment T1. It is observed that maximum water was required by tomato during mid season stage followed by crop development stage, late season, and initial stage, irrespective of treatment.

3.4.2 Water use efficiency

Tomato yield and estimated water use efficiency as influenced by different irrigation/mulch treatments are presented in Table 7.

Table 7 Tomato yield and water use efficiency

Treatment	Consumptive use ha-cm	Yield, qha ⁻¹	Water use efficiency, qha-cm ⁻¹
T1	12.38	180.83	14.61
T2	17.07	192.16	11.26
T3	21.76	263.66	12.12
T4	26.44	214.99	8.13
T5	26.44	145.67	5.51
T6	20.58	262.05	12.73

In field experiment WUE was found varying between 5.51 to 14.61 qha-cm⁻¹. WUE was found highest in treatment T1 and was due to lowest amount of water applied. WUE was found lowest for treatment T5. Yield for treatment T3 and T6 was at par. But WUE for treatment T6 is more as compared to treatment T3. It is because of low consumptive use in case of treatment T6 *i.e.* treatment T6 saves 5% more water as compared to treatment T3. Thus, the field experiment confirmed the best treatment predicted by AquaCrop model as the best. The results also confirmed the capability of AquaCrop in predicting the effect of water on the yield of tomato.

4. INFERENCE

It is suggested to implement drip irrigation with silver polyethylene mulch having scheduling at 75% ETc as it saves 25% water and increases yield by 17.59% as compared to 100% ETc treatment for tomato production in Western Vidarbha region.

5. REFERENCES

1. Abedinpour M, Sarangi A, Rajput T. B. S., Singh Man, Pathak H, and T. Ahmad. 2012. Performance evaluation of AquaCrop model for maize crop in a semi-arid environment. *Agricultural Water Management*, 110: 55–66.
2. Allen R.G., Pereira L.S., Raes D., and Smith M., 1998.. Crop evapotranspiration -Guidelines for computing crop water requirements FAO Irrigation and drainage paper 56, <<http://www.fao.org/docrep/x0490e/x0490e00.htm>>: 24
3. Andarzian A, Bannayan M, Steduto P, Mazraeh H, Barati ME, Barati MA and A Rahnama. 2011. Validation and testing of the AquaCrop model under full and deficit irrigated wheat production in Iran. *Agricultural Water Management*, 100: 1– 8.
4. Araya A, Habtu S, Hadgu KM, Kebede A and T. Dejene. 2010a. Test of AquaCrop model in simulating biomass and yield of water deficit and irrigated barley (*Hordeumvulgare*). *Agricultural Water Management*, 97: 1838–1846.
5. Doorenbos J, Kassam A.H., and Bentvelsen C.I.M.. 1979. Yield response to water, Rome. Food and Agriculture Organization of the United Nations, <<http://www.fao.org/docrep/016/i2800e/i2800e00.htm>>: 6

6. GOI. 2013. State of Indian Agriculture 2012-13. Ministry of Agriculture, Department of Agriculture and Cooperation, Directorate of Economics and Statistics, New Delhi.<<http://www.indiaenvironmentportal.org.in/files/file/State%20of%20Indian%20Agriculture%202012-13.pdf>>dated 07.02.2013 : 27 - 30
7. Heng L. K., Hsiao T, Evett S, Howell T. and P. Steduto. 2009. Validating the FAO AquaCrop Model for Irrigated and Water Deficient Field Maize. *Agron. J.*, 101: 488-498.
8. Holsambare D.G. 1988, Thibak Sinchan Tantra. Continental Prakashan, Vijay Nagar, Pune: 1-61.
9. Kale M. U. 2014. Integrated Storage based optimized Irrigation Planning for Major Irrigation Projects, Unpublished Ph.D. thesis, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola: 85-86.
10. Michael A.M. 1979. Irrigation Engineering: Theory and Practice. Vikas Publishing House, New Delhi: 457.
11. Nash J. E. and J. V. Sutcliffe. 1970. River flow forecasting through conceptual models part 1 - a discussion of principles, *J. Hydrol.*, 10: 282 - 290.
12. NHB. 2014. Statewise, area, production and productivity of tomato, <<http://nhb.gov.in/area-pro/Indian%20Horticulture%202015.pdf>>:177-185
13. Pawar G. S. 2014. Validation of AquaCrop model for irrigated cabbage. Unpublished M. Tech. thesis, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola :27-28.
14. Stricevic R, Cosic M, Djurovic N, Pejic B and L. Maksimovic. 2011. Assessment of the FAO AquaCrop model in the simulation of rainfed and supplementally irrigated maize, sugar beet and sunflower. *Agricultural Water Management*, 98:161-162.
15. Swaminathan M. S. and R. V. Bhavani. 2013. Food production & availability – Essential prerequisites for sustainable food security, *Indian J Med Res* 138: 383-391.