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Comparision of observed and predicted cauliflower yield by fao aqua crop model under different drip irrigation levels

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Abstract
A field experiment was conducted at College farm, College of Agriculture, PJTSAU, Rajendra Nagar, Hyderabad during *rabi* 2015-16 to study the feasibility of Aqua Crop model for simulating the yield of cauliflower**.** The experiment was conducted in a split-plot design with eight treatments replicated thrice. Aqua Crop model was used to calibrate cauliflower yield taking field measurements like yield (t ha^{-1}) and water productivity (kg m^{-3}). Crop parameters like date of transplanting, number of days for germination, number of days taken for recovery, number of days taken from transplanting to flowering, number of days taken from transplanting to maturity were recorded for each treatment for crop in put parameters. Climatic data for the *rabi* 2015-16 was given as input for climatic files and other input parameter required for calibration was given and model was calibrated until the simulated yield and water productivity attain a near value as measured. Then the prediction error, RMSE, R^2, model efficiency were calculated in order to know the efficiency of model.

Keywords: cauliflower yield, Crop parameters, prediction error

Introduction
Aqua Crop model is water driven simulation model that estimates crop yield and biomass with respect to water application (Steduto *et al.,* 2009) [2]. The model simulates attainable yields of major herbaceous crops as a function of water consumption under rain-fed, supplemental, deficit, and full irrigation conditions. Aqua Crop simulates growth, productivity and water use of a crop day-by-day, as affected by changing water availability and environmental conditions.
As compared to other crop simulation models, the Aqua Crop model is a user-friendly and practitioner oriented type of model, as it maintains an optimal balance between accuracy, robustness, simplicity and requires a relatively small number of parameters. The Aqua Crop model represents an effort to incorporate current knowledge of crop physiological responses into a tool that can predict the attainable yield of a crop based on the water supply available. The model is aimed at a broad range of users, from field engineers and extension specialists to water managers at the farm, district and higher levels. It can be used as a planning tool or to assist in making management decisions (strategic, tactical or operational).
Aqua Crop is an effective tool to optimize cauliflower yield and irrigation water use. It is a dynamic model that simulates the attainable yield of crop as a function of water consumption under various management and environmental conditions. The results of calibration and testing of the model in simulating crop yield so far provided confidence in its performance (Steduto *et al*., 2009) [2].

Materials and Methods
Experimental design and layout
The experiment was laid out in split - plot design with two main treatments (0.6 ETc and 0.8 ETc) irrigation levels and four sub-treatments (1.6 lph, 2.2 lph, 3.0 lph and 4.0 lph) were randomly allotted. The dripper lines were laid at 1.2 m apart with an emitter to emitter spacing on lateral of 40 cm for 1.6, 2.2, 3.0 and 4.0 lph. The field layout plan of the experiment is presented in Fig 1.
Aqua Crop was used to simulate cauliflower marketable yield compared to those of observed in field experiment with a view to assess the performance of the model under drip irrigation levels. The results of simulated yield and irrigation water applied are discussed in succeeding paragraphs.

In the present study, the Aqua Crop was accomplished by using the observed values from the field experiment conducted during *rabi* season 2015-16. The field data of 2015 were used as input parameter to simulate the model output. The model predicted and observed experimental data difference were minimized by trial and error approach in which one specific input variable was chosen as reference variable at a time and adjusted only those parameters that were known to influence the reference variable the most. The procedure was repeated to arrive at the closest match combination. The crop parameters and their coefficient obtained during model evaluation were presented in Table 2.

Model Input Parameters

Weather and Soil data-

The weather data required by Aqua Crop are the daily values of minimum and maximum air temperature (°C), reference crop evapotranspiration (ETo), and rainfall (mm) (Raes *et al*., 2009, Steduto *et al*., 2009) [2]. The required input soil parameters for Aqua Crop are the saturated hydraulic conductivity (Ksat), volumetric water content at saturation (sat), field capacity (FC), and permanent wilting point (PWP).

Crop parameter

These parameters include canopy growth and canopy decline coefficient; crop coefficient for transpiration at full canopy; WP for biomass; soil water depletion thresholds for the inhibition of leaf growth and of stomatal conductance, and for the acceleration of canopy senescence; reference harvest index; and coefficients for adjusting the Harvest Index in relation to inhibition of leaf growth and of stomatal conductance.

Model Statistics

Simulation performance was evaluated by calculating statistical co-efficient of determination (R^2), prediction error (Pe), model efficiency (E), root mean square error (RMSE) and mean absolute error (MAE).The computed values of RMSE determined the degree of agreement between the simulated values with their respective observed values, and a low RMSE value that approaches 1 was desirable. The co-efficient of determination (R^2), Prediction error (Pe), Model efficiency (E), Root mean square error (RMSE) and mean absolute error (MAE) were calculated by the following equations.

$$R^2 = \left[\frac{\sum(O_i-\bar{O})\,(S_i-\bar{S})}{\sqrt{\sum(O_i-\bar{O})^2\,\sum(S_i-\bar{S})^2}}\right]^2 \quad \text{--- (3.8)}$$

$$Pe = \frac{(Si - Oi)}{Oi} \times 100 \quad \text{--- (3.9)}$$

$$E = 1 - \frac{\sum_{i=1}^{i=N}(Oi-Si)^2}{\sum_{i=1}^{i=N}(Oi-\bar{O})^2} \quad \text{---- (3.10)}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(O_i - S_i)^2} \quad \text{--- (3.11)}$$

$$MAE = \sqrt{\sum_{i=1}^{N}\frac{(Si - Oi)}{N}} \quad \text{---- (3.12)}$$

Where,

N = No. of observations

O_i = Observed value

S*i* = Simulated value

Ō = observed mean

S = simulated mean

The model is said to perform better when values of E and R^2 approaches one and when Pe and RMSE approaches zero.

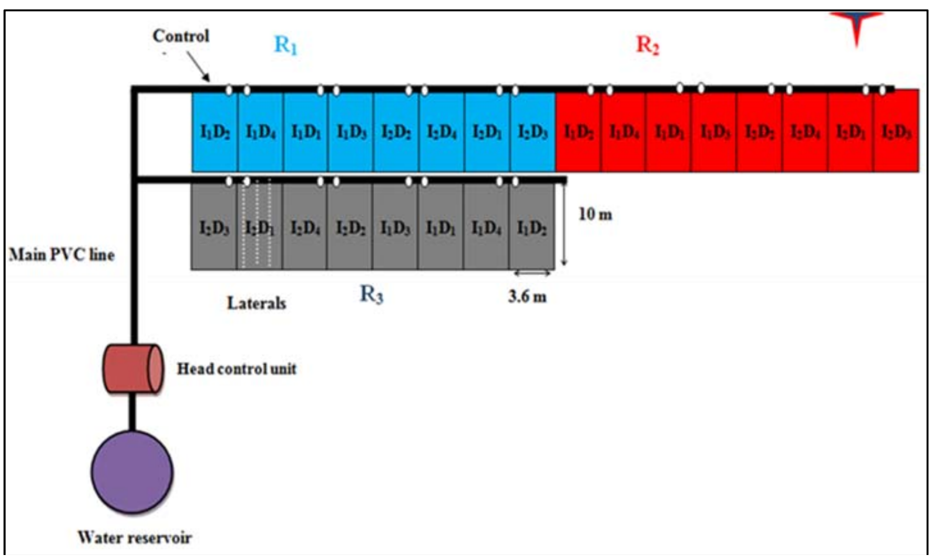

Fig 1: Experimental layout of *rabi* cauliflower under drip irrigation

Results and Discussion

Yield (t ha^{-1})

The correlation coefficient (R^2 =0.90) between observed and simulated yield by Aqua Crop was significant. The RMSE and MAE for yield was found to be 0.13 and 0.44 t ha^{-1} respectively with an overall model efficiency of 95%. So the model prediction was good with similar results given by kiptum *et al.,* (2013) [1] for cabbage. The observed field values for yield with its Aqua Crop simulated values and prediction error were presented in Table 1.

The result showed that the marketable yield simulated by Aqua Crop tend to follow closely the trend in the observed data, but with slight under and over estimations with acceptable range of prediction error.

The model evaluation revealed that the crop coefficients such as, canopy growth coefficient, canopy decline coefficients and stomatal stress coefficient would influence yield and water productivity compared to other parameters.

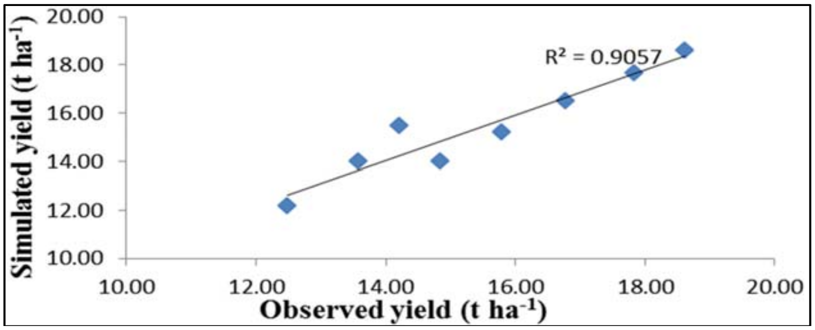

Fig 2: Observed and simulated cauliflower yield under different irrigation regimes with Aqua Crop model.

Water Productivity

The results of prediction error between observed and simulated water productivity by Aqua Crop model were presented in Table 1 and Fig 3. The results of simulated water productivity by Aqua Crop were in agreement with observed data with a higher error values as compared to yield.

Similar results were obtained by Kiptum *et al.*, 2013 [1] for cabbage in deficit irrigation and Wellens *et al.,* 2013 [4] in semi-arid regions.

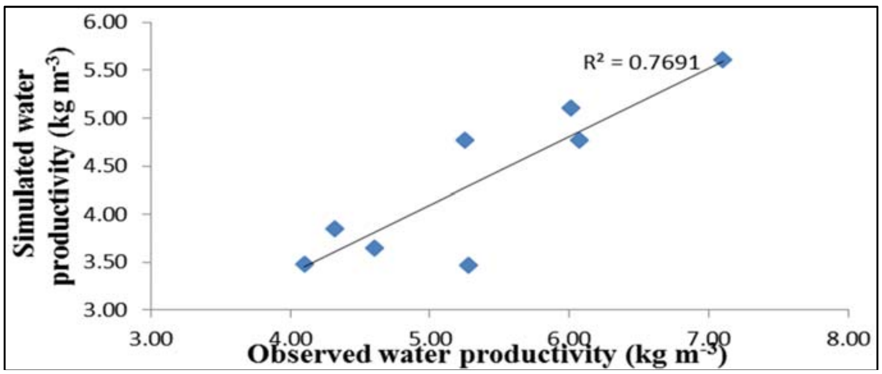

Fig 3: Observed and simulated water productivity of cauliflower under different irrigation levels with Aqua Crop model

Table 1: Performance statistics of Aqua Crop model under different irrigation levels during calibration

Model output parameters	Mean		RMSE	E	MAE	R^2
	Observed	Simulated				
Yield (t ha^{-1})	15.51	15.48	0.13	0.95	0.44	0.90
Water Productivity (kg m^{-3})	5.34	4.34	0.07	0.85	0.63	0.76

Table 2: Crop parameters and their coefficient found during model evaluation

Parameters	Values	Units
Base temperature	10	^{0}C
Cut off temperature	30	^{0}C
Canopy growth coefficient (CGC)	11.9	%
Canopy decline coefficient at senescence (CDC)	10.1	%
Maximum basal crop coefficient (K_{cb})	1.40	Unit less
Time from transplanting to recovery	10	Days
Time from sowing to start of sencence	87	Days
Time from sowing to maturity	102	Days
Length of flowering stage	35	Days

Conclusion

Aqua Crop model is feasible in stimulating yield of cauliflower with a model efficiency of 95%. Aqua Crop model was used to calibrate cauliflower yield by taking field measurements like yield t ha^{-1} and water productivity (kg m^{-3}). Crop parameters like date of transplanting, number of days for germination, number of days taken for recovery, number of days taken from transplanting to flowering, number of days taken from transplanting to maturity were recorded for each treatment for crop in put parameters.

The correlation coefficient (R^2 = 0.90) between observed and simulated yield by Aqua Crop was significant. The RMSE and MAE for yield was found to be 0.13 and 0.44 respectively with an overall model efficiency of 95%.

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