



Model Validation of Aqua Crop for Brinjal (*Solanum melongena*) Crop at Madakasira Region, Anantapur District, Andhra Pradesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Crop simulation models play a vital role for estimating the effects of soil, water, nutrients on grain and biomass yields and water productivity of different crops. Among the various crop simulation models, Aqua Crop model was adopted for predicting the crop water requirement in the Madakasira region, Anantapur district, Andhra Pradesh. The Brinjal crop was selected for the study and was irrigated through two different methods i.e., drip and flood irrigation. The model generated the crop yield and crop water requirement for the drip and flood irrigation of Brinjal crop was compared with the actual field results of crop yield and crop water requirement. The simulated crop yield and crop water requirement for the Brinjal crop under flood irrigation was 5.23 t/ha and 326 mm. The actual crop yield and crop water requirement for the Brinjal crop under flood irrigation was 4.2 t/ha and 335 mm. The simulated crop yield and crop water requirement for the Brinjal crop under Drip irrigation was 5.76 t/ha and 318.3 mm. The actual crop yield and crop water requirement for the Brinjal crop under drip irrigation was 4.8 t/ha and 290 mm. From the results, it was clear that the model simulated the actual conditions of the crop. The benefit cost ratio was done for the

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experimental field data which clearly shows that the crop yield under drip irrigation has achieved the higher cost benefit ratio. Therefore, Aqua Crop model was suitable for simulating the crop conditions under any circumstances.

Keywords: Aqua Crop; brinjal; crop water requirement.

1. INTRODUCTION

Crop simulation models use quantitative descriptions of ecophysiological processes to predict plant growth and development as influenced by environmental conditions and crop management which are specified for the model as input data. Among the various models available, Aqua Crop has a capability in predicting the attainable yields under water limiting conditions in arid, Semi arid and drought prone environments. In the present study, the model was used at the Madakasira region, Anantapur district, Andhra Pradesh because of the water limiting conditions. In order to overcome this problem, there is a need to calculate the crop water requirement. The crop water requirements are usually met from the effective rainfall and irrigation water. The change in the soil moisture before and after the crop seasons is negligible. There is a surplus amount of water needed for cultivating the Brinjal crop in the semi-arid region. There is a lot of demand for the water in the semi-arid regions due to its scarcity. In order to apply irrigation water efficiently, the water requirement of crops is estimated accurately. So, Aqua Crop 5.0 model, a computer program developed by FAO is used. In this model, Evapo Transpiration (ET) is one of the most important and difficult parameter to measure in the field. The Penman Monteith method had been successfully recommended by FAO to calculate ET under different conditions and showed higher accuracy than the other methods. Therefore, many research studies were conducted on the Aqua Crop model which showed better results. Abedinpour et al. [1] conducted experiment on performance evaluation of Aqua Crop model for maize crop in a semi-arid environment show that model predicted maize yield with acceptable accuracy under variable irrigation and nitrogen levels. Amiri [2] conducted experiment on Calibration and Testing of the Aqua Crop Model for Rice under Water and Nitrogen Management showed that the agreement between the observed and predicted rice grain yield and final biomass with R^2 of 0.81 and 0.82 and RMSE of 13 and 10% respectively. Geerts et al. [3] conducted experiment on using Aqua Crop

to derive deficit irrigation schedules which showed that the model can be an illustrative decision support tool for sustainable agriculture based on deficit irrigation. Javier et al. [4] conducted experiment on simulation of corn (*Zea mays* L.) production in different agricultural zones of Colombia using the Aqua Crop model revealed that the modeling in each of the locations showed similarity between the field data and the simulated data in each of the sites. Maniruzzaman et al. [5] conducted experiments on validation of the Aqua Crop model for irrigated rice production under varied water regimes in Bangladesh showed that FAO Aqua Crop model was able to predict rice growth and yield with acceptable accuracy under different water regimes, making this model a suitable candidate to facilitate local scenario studies related to irrigation scheduling, yield prediction or studies related to climate change and adaptation. Ruzica et al. [6], conducted experiment on assessment of the FAO Aqua Crop model in the simulation of rainfed and supplementally irrigated maize, sugar beet and sunflower. Shahjahan et al. [7], conducted experiment on Simulating yield response of rice to salinity stress with the Aqua Crop model showed that model would be a useful tool in assessing the potential impact of these future changes as well as other climatic parameters on rice yield in the coastal region. These results showed that the Aqua Crop model can be used in impartial decision-making and in the selection of crops to be given irrigation priority in areas where water resources are limited. Margarita et al. [8], conducted experiment on Combining the simulation crop model Aqua Crop with an economic model for the optimization of irrigation management at farm level showed that the changes in cropping patterns induced by the agricultural policy will encourage water savings more than an increase in water prices. Hence, the objective of the study was to estimate the crop water requirement of Brinjal crop in the madakasira region using Aqua Crop 5.0 model, comparison of the model results and field results of the crop water requirement and comparison of the yield of Brinjal crop with surface and drip irrigation systems.

2. MATERIALS AND METHODS

2.1 Study Area

The research was conducted at the Agricultural Farm, College of Agricultural Engineering, Madakasira, Anantapur (district), Andhra Pradesh. It is located in arid ecological zone and is designated as rain shadow region. The area has Latitude of 13°56'56.89' N and longitude of 77°18'42' E. The elevation is 641.604 metres MSL. The annual rainfall of Madakasira is 506 mm and it is found to drought prone area. In Madakasira the predominant soils are sandy loam soils. The experiment field was selected for experimentation under each irrigation system. The average air temperature is 28.42 °C, whereas the maximum air temperature is 40.3°C

and the minimum air temperature is 15.5 °C. The average minimum relative humidity is 41%, and the average maximum relative humidity is 89%. The average wind speed is equal to 10.3 km/hr while the annual precipitation ranges from 280 - 835 mm.

2.2 Soil Description

The most of the Madakasira region is characterized by sandy loam soils with gravel. A total effective soil depth is in average about 180 cm while the depth of the top layer is about 40-50 cm representing about one-third of the whole soil profile. The experimental plot was tested for its suitability and nutrient content in Regional Agricultural Research Station, Tirupati.

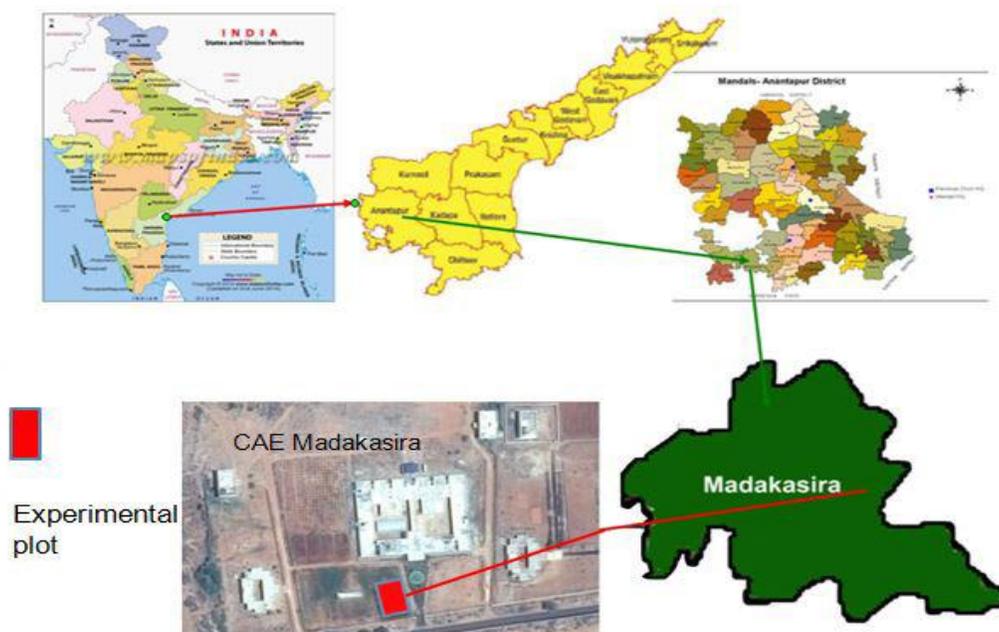


Fig. 1. Study area

Table 1. Pre-cropping soil sample analysis report of the experimental plot

Soil property	Observation	Index
Colour	Red and calcareous	
PH	7.1-7.5	Moderate
EC	5.2 mmhos/cm	High
Salt content	0.11-0.12	High
Macro nutrients(kg/ha)		
Nitrogen	65	Low
Phosphorus	8-9	Low
Potassium	46-60	Low
Organic carbon	0.5	Low

2.3 Irrigation Water Analysis

The water for irrigation for cultivation of Brinjal crop was taken from bore existed at College of Agricultural Engineering, Madakasira. The irrigation water sample parameters were analyzed. The P^H of the irrigated water is 7.44. The EC for the irrigated water is 1215 µs/cm. The other parameters of the irrigated water were listed below.

Table 2. Irrigation water sample parameters

Parameter	Value
P ^H	7.44
EC (µs/cm)	1215
Nitrate(mg/lit)	0.0
Iron(mg/lit)	0.0
Alkalinity (mg/lit)	600
Hardness(mg/lit)	284
Sulphate (mg/lit)	16
Chloride(mg/lit)	540
Fluoride(mg/lit)	1.9

2.4 Crop Details

The Brinjal seeds were taken from PHS seeds company.

Table 3. Details of the crop under experimentation

Crop name	Brinjal
Company name	Manikanta nursery
Variety	F-1 hybrid uttam 4140
Duration	95 days
Row spacing	60 mm
Plant spacing	50 mm

2.5 Data Collection

2.5.1 Climate data

Climate data for the present study have been collected from the Agricultural Research Station, Pavagada, Karnataka. The following parameters have been calculated from the above collected weather data:

- Rainfall.
- Average minimum and maximum air temperature in °C.
- Average Relative Humidity in %.
- Wind speed in m/s.
- Wind direction.
- Sun duration hr.mm.

- Atmospheric pressure.

2.5.2 Crop data

In the crop data, the date 1 day after transplanting is 22nd march 2016. The crop type is fruit producing crop, cropping period is 22nd march 2016 to 18th August 2016. The length of growing cycle is 150 days in the experimentation.

2.5.3 Management data

In management data there are two options 1. Irrigation data and 2. Field data.

2.5.3.1 Irrigation data

In irrigation data there are calculations for net irrigation water requirement, Irrigation schedule and general irrigation schedule. In this data irrigation method, quality of irrigation water and irrigation events have to be specified as per the experimentation plan.

2.5.3.2 Field data

In field data, the experimentation plot having no mulches and the height of the bunds is 25 cm.

2.5.4 Soil data

In soil data there are two options 1. Soil profile data and 2. Ground water data

2.5.4.1 Soil profile data

In soil profile data, number of horizons is given as 1 and type of soil with thickness of 1.50 m.

2.5.4.2 Ground water data

In ground water data, ground water depth is 2 m below the ground surface, salinity is taken as 5.2 dS/m

2.5.5 Simulation data

In simulation data, total crop period is taken as 150 days, initial conditions of the soil were properly given, project, field data have to be specified.

2.6 Planning and Design of Experiment

A scheme of experiments has been planned and performed. The experimental field with total area of 195 m² was selected for experimentation. The

total area was divided into 2 plots i.e., 1 plots for drip irrigation & 1 plots for flood irrigation. The plot for drip irrigation having 97.5 m² (6.5× 15 m) area was selected for experimentation. The plot for flood irrigation having 97.5 m² (6.96× 14 m)

area was selected for experimentation. The spacing for Brinjal crop 60× 40m was selected for experimentation. Brinjal crop was allotted with 9 laterals. For each lateral 38 seedlings were transplanted at 40 cm spacing.

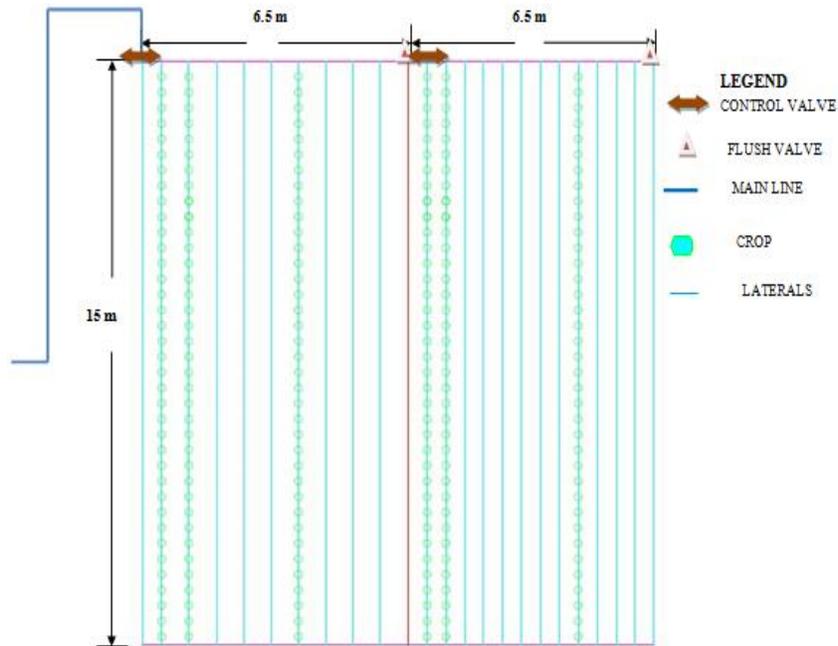


Fig. 2. Layout of drip irrigation field at CAE Madakasira

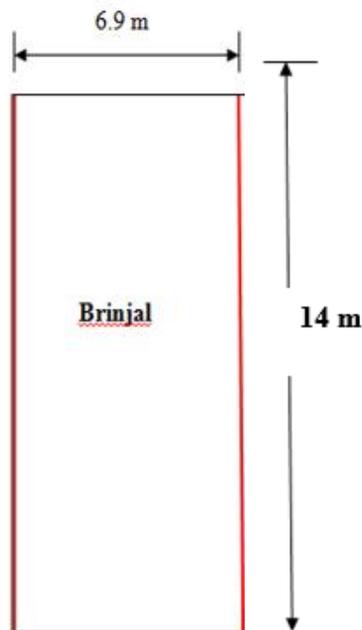


Fig. 3. Layout of flood irrigation at CAE Madakasira

2.7 Flood Irrigation

Surface irrigation is defined as the group of application techniques where water is applied and distributed over the soil surface by gravity and implying that the water distribution is uncontrolled.

2.8 Field Preparation for Flood Irrigation

FYM (Farm Yard Manure) was applied to the soil before ploughing the soil. The field was ploughed well to bring to optimum tilth. The ploughing provides opening of soil, crushing of clods, destroy the weeds and utilize the micro nutrients for crop growth.

2.9 Drip Irrigation

Drip irrigation system was installed at College of Agricultural Engineering, Madakasira for irrigation for Brinjal crops. Water was pumped through 10 hp motor through water meter for measuring quantity of water. The main components of the drip irrigation system include head control unit, Water carrying unit and water distribution unit. The head control unit consists of Non return valve, pressure gauge. The layout consists of 40 mm mains and sub mains. The experiment was planned for two plots, two plots contain four separate sub mains and are controlled by four separate control valves. Each sub main is fitted with flush valve at the end for flushing/ cleaning. The field was laid with 16 mm inline laterals with a spacing of 40 cm. The discharge of each dripper is 4 lph.

2.10 Sowing

The Brinjal seeds are sowed at an interval of 40 cm row to row spacing and plant to plant spacing.

2.11 Weeding

Weeds are a major problem in Brinjal crop. The weeds are removed from time to time, in order to enhance the growth and productivity of crop. Normally 5-6 manual weeding and hoeing are required to check weed growth and to keep the field clean.

2.12 Harvesting

Brinjal were harvested when they have attained full size. A total of 4 pickings were done for this crop.

2.13 Weighing

The Brinjal were weighed after harvesting the crop so that the yield can be assessed.

2.14 Aqua Crop 5.0 model

Aqua Crop is a crop water productivity model developed by the Land and Water Division of FAO (Rome). It simulates yield response to water of herbaceous crops, and is particularly suited to address conditions where is a key limiting factor in crop production.

Aqua Crop-5.0 is a program developed by Food and Agricultural Organization of the United Nations (October 2015) to evaluate the ETo (Evapotranspiration), NIR(Net Irrigation Requirement), Dry yield, above-ground Biomass, simulated Canopy Cover (CC), Salinity stress with the help of field data stored in an observation file data.

2.15 Model Input Data

The initial data that are given for the model in order to get the irrigation crop water requirements are summarized as the following:

1. Climate data
2. Crop data
3. Management data
4. Soil data
5. Simulation data

2.16 Crop Water Requirement

The crop water requirement is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by various crops to grow optimally. The crop water requirement always refers to a crop grown under optimal conditions, i.e., a uniform crop, actively growing, completely shading the ground, free of diseases, and favourable soil conditions (including fertility and water). Accurate crop water requirement data are essential in irrigated agriculture. An appraisal of economic returns from irrigation projects and proper design and operation of irrigation scheme depends, to a large extent, on the reliability of available information on crop water requirements. Precise knowledge of crop water requirements is also needed for efficient use of limited irrigation water.

The evapotranspiration rate is normally expressed in millimeters (mm) per unit time. The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, month or even an entire growing period or year. The crop water requirement can be determined by multiplying the reference Evapotranspiration with the crop coefficient.

$$ET_C = ET_o \times K_c$$

ET_C – Crop evapotranspiration
 ET_o – Reference evapotranspiration
 K_c – Crop coefficient

2.17 Pan Evaporation Method

Evaporation pans provide a measurement of the combined effect of temperature, humidity, wind speed and sunshine on the reference crop evapotranspiration ET_o. Many different types of evaporation pans are being used. The best-known pan is the Class A evaporation pan (circular pan)

The E pan is multiplied by a pan coefficient, K pan, to obtain the ET_o.

$$ET_o = K_{pan} \times E_{pan}$$

Where ET_o = Reference evapotranspiration, K pan = pan coefficient, E pan = pan evaporation

2.18 Determination of K Pan

When using the evaporation pan to estimate the ET_o, in fact, a comparison is made between the evaporation from the water surface in the pan and the evapotranspiration of the standard grass. Of course, the water in the pan and the grass do not react in exactly the same way to the climate. Therefore, a special coefficient is used (K pan) to relate one to the other. The pan coefficient, K pan, depends on:

- The type of pan used.
- The pan environment: if the pan is placed in a fallow or cropped area.
- The climate: the humidity and wind speed
 For the Class A evaporation pan, the K pan varies between 0.35 and 0.85. Average K pan = 0.70.

2.19 Crop Coefficient

The K_c is the crop coefficient for a given crop and is usually determined experimentally.

The K_c values represent the integrated effects of changes in leaf area, plant height, crop characteristics, irrigation method, rate of crop development, crop planting date, degree of canopy cover, canopy resistance, soil and climate conditions, and management practices. Each crop will have a set of specific crop coefficient and will predict different water use for different crops for different growth stages. The K_c factor for the Brinjal crop varies from 1.05 to 1.19 and 0.94 to 0.99 at different crop stages under conventional till and non-conventional till [9].

3. RESULTS AND DISCUSSION

The results of estimation of crop water requirements of the Madakasira region for different crops under different irrigation systems to maximization of crop production were discussed in this chapter.

3.1 Rainfall Analysis

The average annual rainfall of Madakasira region over 5 years (2011 – 2015) is 506 mm. By comparing all 5 years lowest rainfall occurred in 2011 about 280.67mm and in 2012 year second lowest rainfall occurred about 395.8 mm. In 2015 rainfall occurred about 835 mm.

The results indicated that the maximum rainfall occurred during the month of October with 265 mm in 2014 and minimum rainfall occurred in the month of December with 4.67 mm in 2011. The average monthly rainfall in September is observed more about 130 mm rainfall per month.

3.2 Comparison of Model and Observed Results of Crop Yield

The model results shows that the simulated yield for the Brinjal crop reduces in the flood irrigation when compared with the Drip irrigation. Also, similar results were obtained with the observed data. It is clear that the model is simulated with the experimental data.

From the model results, ET of the Brinjal crop is 5 mm/day for both the flood and the drip irrigation. The Dry yield for the Brinjal crop through drip and flood irrigation are 5.76 and 5.23 tonne/ha. The biomass yield for the Brinjal crop through drip and flood irrigation are 112.5 and 104 Kg. The net irrigation requirement for the Brinjal crop through drip and flood irrigation are 326.3 and 318 mm/day.

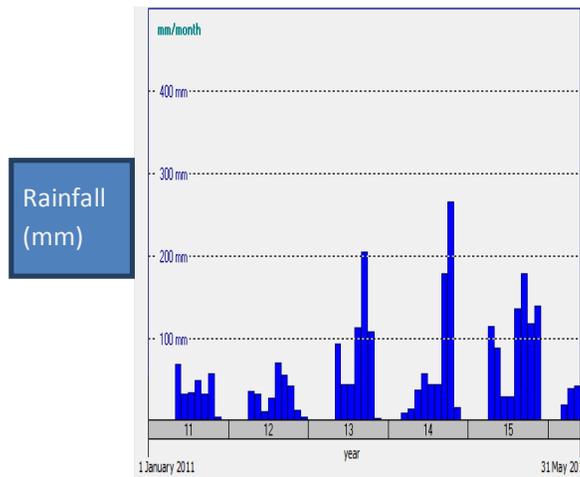


Fig. 4. Monthly rainfall for the period of 2011 to 2015

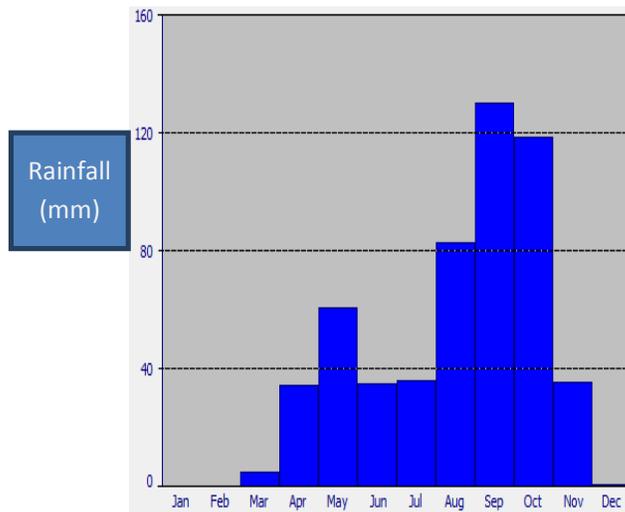


Fig. 5. Average monthly rainfall for the period of 2011 to 2015

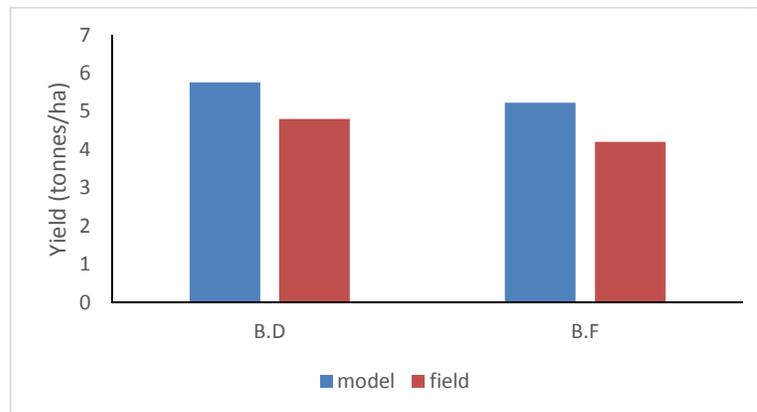


Fig. 6. Yield difference between model and field results
B.D – Brinjal crop in Drip irrigation and B.F – Brinjal crop in Flood irrigation

Table 4. Output parameters from Aqua Crop 5.0 model

S. No	Crop	ET (mm/day)	Dry Yield (tonne/ha)	Biomass (Kg)	NIR (mm/day)	Salinity stress of root zone (%)
1	Brinjal- Drip irrigation	5	5.76	112.5	326.3	22
2	Brinjal- Flood irrigation	5	5.23	104	318	22

3.3 For Brinjal Crop – Flood Irrigation

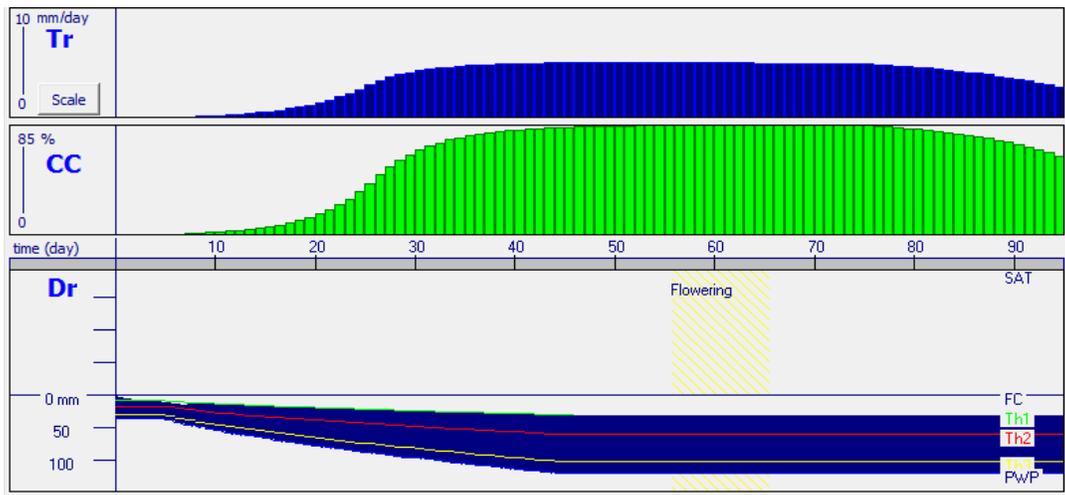


Fig. 7. Model generated evapotranspiration (Tr), canopy cover growth (CC) and root zone depletion (Dr) for brinjal crop in flood irrigation For brinjal crop – drip irrigation

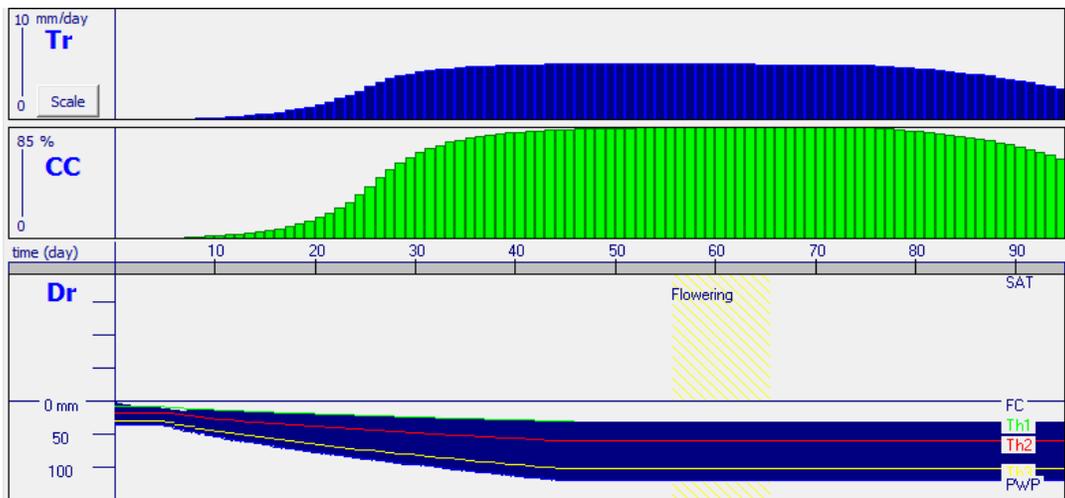


Fig. 8. Evapotranspiration (Tr), canopy cover growth (CC) and root zone depletion (Dr) for brinjal crop in drip irrigation

From all these results observed evapotranspiration is about 5 mm/day. The green canopy cover development starts from 40th day and maintain that level of development upto 80th day. The flowering stage starts from 60th day.

Table 5. Observed field results of crop water requirement for the Brinjal crop

Crop Name	Field	
	Drip irrigation	Flood irrigation
Brinjal	290 mm	335 mm

The actual crop water requirement for the Brinjal crop for the drip irrigation and flood irrigation are the 290 mm and 335 mm.

Table 6. Comparison of Crop water requirement

Crop name	Aqua crop model		Field	
	Drip irrigation	Flood irrigation	Drip irrigation	Flood irrigation
Brinjal	318.3 mm	326 mm	290 mm	335 mm

From the table, it clearly shows that the model calculated results of crop water requirement for drip and flood irrigation are 318.3 and 326 mm. The field results of crop water requirement for drip and flood irrigation are 290 and 335 mm. The Aqua Crop model simulated the actual field and crop conditions partially.

3.4 Comparison of Yield for Different Irrigation Systems

The yield of Brinjal crop obtained through drip irrigation and flood irrigation is about 4.8 and 4.2 t/ha. From the results, drip irrigation system produces more yield than flood irrigation which gives less yield than the drip irrigation system. Mintu et al. 2018, produced the similar results that the drip irrigation produces more yield for the Brinjal crop when compare to the other conventional methods.

Table 7. Yield comparison for different irrigation systems from field data

	Drip Irrigation	Flood Irrigation
	Brinjal	Brinjal
Yield (tonne/ha)	4.8	4.2

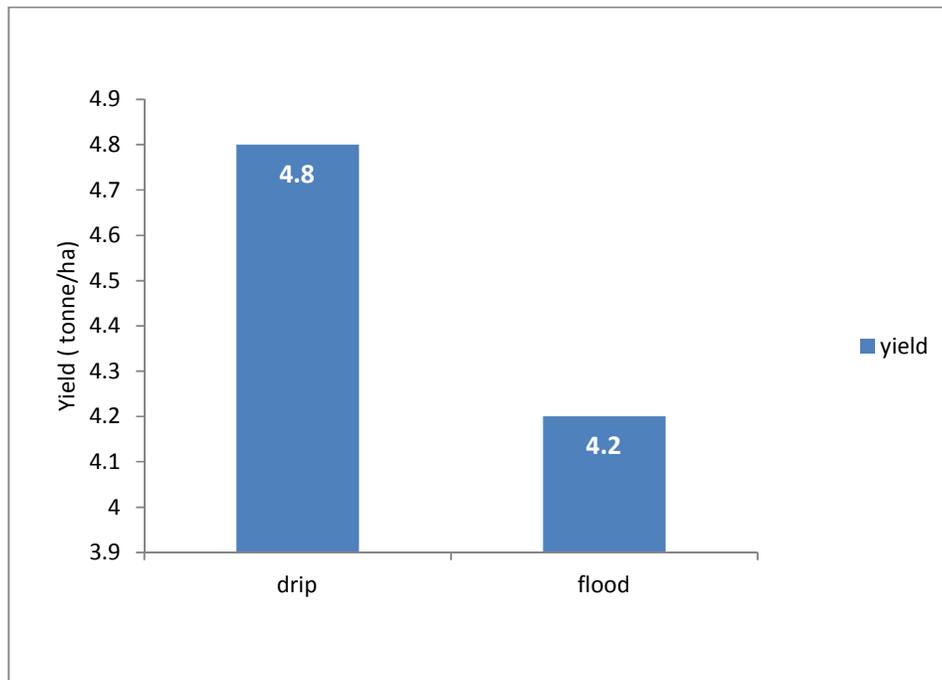


Fig. 9. Yield difference between drip and flood irrigation for brinjal crop from field data

3.5 Cost Economics

Benefit – cost ratio: A Benefit Cost Ratio (BCR) is a ratio attempting to identify the relationship between the cost benefits of a proposed project.

1. Brinjal – Drip irrigation system
 Total input cost = (Seedlings+FYM+Installation material) =Rs. 2220/-
 Total output cost = (Yield output cost) = Rs. 3885/-
 B:C ratio = $\frac{3885}{2220} = 1.75$
2. Brinjal – Flood irrigation
 Total input cost = (Seedlings + FYM + Material cost) = Rs. 1590/-
 Total output cost = (Yield output cost) = Rs. 1720/-
 B:C ratio = $\frac{1720}{1590} = 1.08$

According to the benefit cost-ratio, the total input and output cost of the Brinjal for the drip irrigation system is Rs. 2220 and 3885. The benefit cost ratio is about 1.75. The total input and output cost of the Brinjal for the flood irrigation system is Rs. 1590 and 1720. The benefit cost ratio is about 1.06. From the above results, it clearly states that the drip irrigation system has achieved higher cost benefit ratio.

4. CONCLUSIONS

The Aqua Crop model is very useful for simulating the crop under the semi-arid conditions. The simulated crop yield and crop water requirement for the Brinjal crop under flood irrigation was 5.23 t/ha and 326 mm. The actual crop yield and crop water requirement for the Brinjal crop under flood irrigation was 4.2 t/ha and 335 mm/day. The simulated crop yield and crop water requirement for the Brinjal crop under Drip irrigation was 5.76 t/ha and 318.3 mm. The actual crop yield and crop water requirement for the Brinjal crop under drip irrigation was 4.8 t/ha and 120 mm. From the results, it is clear that the model simulated the actual conditions of the crop. The benefit cost ratio was done for the experimental field data which clearly shows that the crop yield under drip irrigation has achieved the higher cost benefit ratio. Therefore, Aqua Crop model is suitable for simulating the crop conditions under any circumstances.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our

area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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