Current Journal of Applied Science and Technology

40(9): 18-29, 2021; Article no.CJAST.68509
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Validation of Aqua Crop 5.0 Model for Okra (*Abelmoschus esculentus*) Crop at Madakasira Region, Anantapur District, Andhra Pradesh

P. Sivamma[1], N. Naga Hari Sairam[1*], G. Raghavendra[2], M. Muralee Krishna[2] S. V. Swapna Priya[2], Sampath[2] and Venkanna[2]

[1]Dr. NTR College of Agricultural Engineering, Bapatla, India.
[2]College of Agricultural Engineering, Madakasira, India.

Authors' contributions

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

Article Information

DOI: 10.9734/CJAST/2021/v40i931344
Editor(s):
(1) Dr. Orlando Manuel da Costa Gomes, Lisbon Polytechnic Institute, Portugal.
Reviewers:
(1) José Franciraldo de Lima, Center of the Federal University of Campina Grande, Brazil.
(2) Elia Mercedes Alonso-Guzman, Universidad Michoacana de San Nicolás de Hidalgo, Mexico.
Complete Peer review History: http://www.sdiarticle4.com/review-history/68509

Original Research Article

Received 02 March 2021
Accepted 09 May 2021
Published 10 May 2021

ABSTRACT

Crop simulation models were developed to estimate the effects of soil, water, nutrients on grain and biomass productivity and water consumption in different crops. In this study, the Aquacrop model was adopted to predict the volume of water consumed by crops in the Madakasira region, Anantapur district, Andhra Pradesh. The culture of okra was selected for the study, using two irrigation methods: flood and drip. The model estimated the productivity of the crop and the amount of water needed for drip irrigation and flooding in that crop. the results were compared with field productivity, and their respective water requirements, and demonstrated yields of 4.3 t / ha in the flood irrigation system, with average water consumption of 326.6 mm / day, and in the field these values were 3.5 t / ha average water consumption of 386 mm / day. And when using the drip irrigation system, the results obtained were: 5.2 t / ha with water consumption in the order of 320 mm / day, in comparison to the field crop that was 4.3 t / ha, consumption water of 300 mm / day. From the results, it was clear that the model simulates the real conditions of the culture. The cost-benefit ratio was made for experimental field data that clearly show that the yield of the crop under drip irrigation has reached the highest cost-benefit ratio. Therefore, the Aquacrop model was adequate to simulate the conditions of the crop in any circumstances.

**Corresponding author: E-mail: sairam.nethi@gmail.com;*

Keywords: Aquacrop; okra; crop water requirement.

1. INTRODUCTION

Land and water are the vital natural resources for the development of any country. Among these resources, utilization and management of water in water scarce regions is very crucial due to its demand. In the agricultural lands especially, amount of water supplied to the crops is either high or low. 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 Okra 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. Several computer models are now available to estimate the crop water requirement. Among them, Aquacrop 5.0, a computer program developed by FAO calculates the summarized irrigation water requirements of a complex scenario. In this model, evapotranspiration (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 Aquacrop model which showed better results. Mansour et al., [1] evaluated the Aquacrop model of two Egyptian wheat varieties Gemeza-9 and Misr-1 (M-1) under the two modern irrigation systems, sprinkler and drip, and the application of algae solution. This study concluded that it is possible to recommend the use of aquacrop simulation model for wheat varieties in the future, to predict the water productivity in these semiarid areas, especially under different irrigation systems. Saad et al., [2] validated the Aquacrop model for the Maize cross 321 using the data from the two experimental fields conducted at North delta. The results indicate that the model was able to simulate the well maize water productivity under different irrigation regimes, nitrogen fertilization levels and mulching application at North Delta. Abedinpour et al., [3] 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. Montoya et al., [4] evaluated the Aquacrop model for a potato crop under different conditions. The results showed that the acceptable goodness of fit was found between the observed and simulated values. Amiri [5] conducted experiment on Calibration and Testing of the Aquacrop Model for Rice under Water and Nitrogen Management showed that the agreement between the observed and predicted rice grain yield and final biomass. Syed et al., conducted an experiment on modelling the maize yield and soil water content with aqua crop under full and deficit irrigation managements. Finally, the results demonstrated that Aquacrop is a useful decision-making tool for investigating the deficit irrigations and maize growth in the region. Akumaga et al., [6] evaluated the Aquacrop ability to simulate the yield of rainfed maize in the Nigeria. Finally, the results showed that the model simulates the final grain yield reasonably well. Geerts et al., [7] conducted experiment on using Aquacrop 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., [8] conducted experiment on simulation of corn (*Zea mays* L.) production in different agricultural zones of Colombia using the AquaCrop 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., [9] conducted experiments on validation of the AquaCrop model for irrigated rice production under varied water regimes in Bangladesh showed that FAO AquaCrop 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., [10] assessment the FAO AquaCrop model in the simulation of rainfed and supplementally irrigated maize, sugar beet and sunflower. Shahjahan et al., [11] evaluated the Simulating yield response of rice to salinity stress with the AquaCrop model showed that model would be a useful tool in assessing the potential impact of these future changes. These results showed that the AquaCrop 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., [12] studied on combining the simulation crop model AquaCrop 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 Okra crop in the madakasira region using AquaCrop 5.0 model, comparison of the model results and field results of the crop water requirement and comparison of the yield of Okra crops with surface and drip irrigation systems.

2. MATERIALS AND METHODS

2.1 Study Area

The research was conducted at the Agricultural Farm, Mdakasira, Andhra Pradesh. It is located in arid ecological zone, mainly it 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 28.42ºC, whereas the maximum air temperature is 40.3ºC and the minimum air temperature is 15.5ºC. The average minimum relative humidity is 41%, and the average maximum relative humidity is 89%. 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 soil of the experimental plot was tested for its suitability and nutrient content in Regional Agricultural Research Station, Tirupati.

2.3 Irrigation Water Analysis

The water for irrigation for cultivation of Okra crop was taken from bore existed at College of Agricultural Engineering, Madakasira.

2.4 Water Sample Analysis

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.

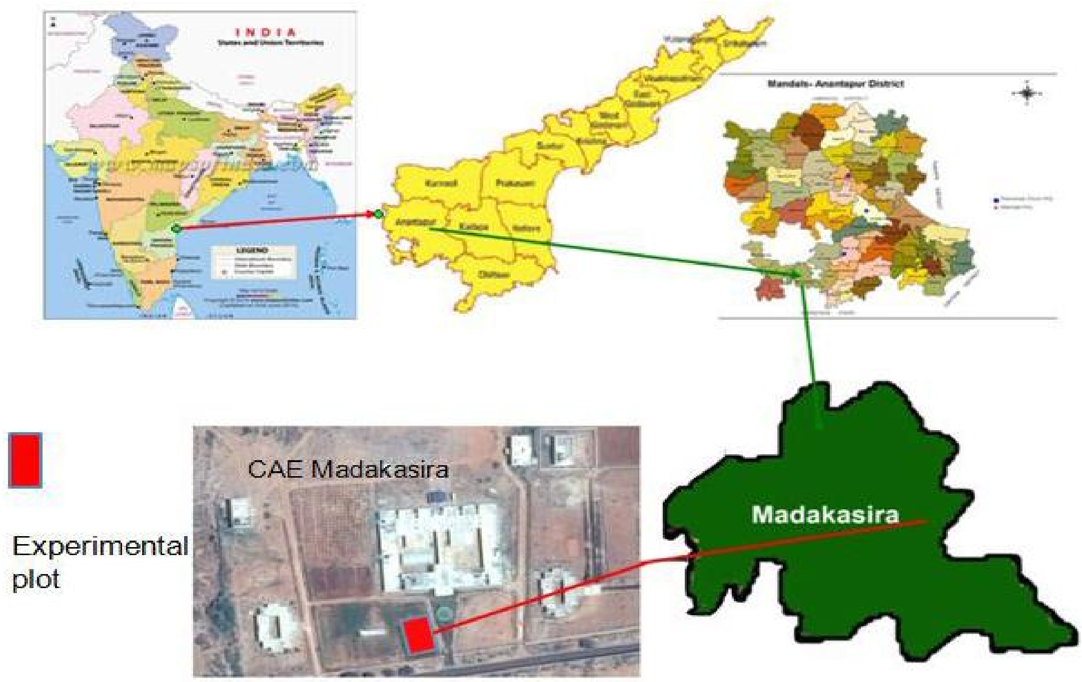

Fig. 1. study area

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

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

Table 3. Details of the crop under experimentation

Crop name	Okra
Company name	PHS seeds
Variety	F-1 hybrid Okra usha
Duration	95 days
Row spacing	40 mm
Plant spacing	40 mm

2.5 Crop Details

The Okra seeds were taken from PHS seeds company.

2.6 Data Collection

2.6.1 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 º C
- Average Relative Humidity in %
- Wind speed in m/s
- Wind direction
- Sun duration (H)
- Atmospheric pressure

2.6.2 Crop data

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

2.6.3 Management data

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

2.6.3.1 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.

2.6.3.2 Field data

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

2.6.4 Soil data

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

2.6.4.1 Soil profile data

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

2.6.4.2 Ground water data

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

2.6.5 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 specified.

2.7 Planning and Design of Experiment

A scheme of experiments has been planned and performed. The experimental field with total area of 195 m^2 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 97.5m^2 (6.5× 15m) area was selected for experimentation. The plot for flood irrigation having 97.5m^2 (6.96× 14m) area was selected for experimentation. The spacing for Okra crop 50× 40m was selected for experimentation. Okra crop was allotted with 13 laterals.

2.8 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.

2.9 Field Preparation for Flood Irrigation

Before ploughing the soil, FYM (Farm Yard Manure) was applied to 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.

2.10 Drip Irrigation

Drip irrigation system installed at College of Agricultural Engineering, Madakasira for irrigation for Okra crops. Water was pumped through 10 hp motor through water meter for measuring quantity of water. The main components of the drip irrigation system includes 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.

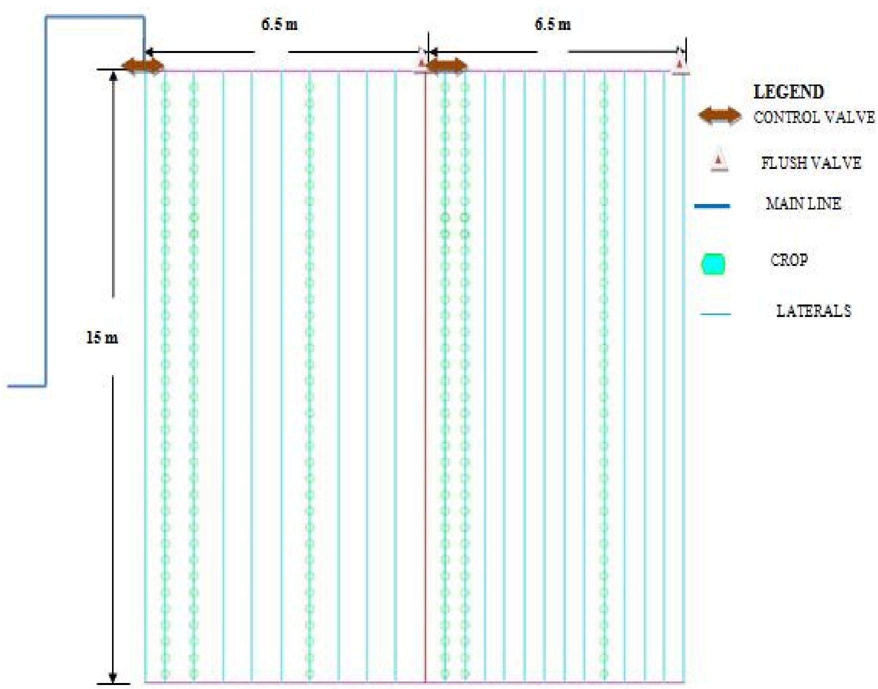

Fig. 2. Layout of drip irrigation field at CAE Madakasira

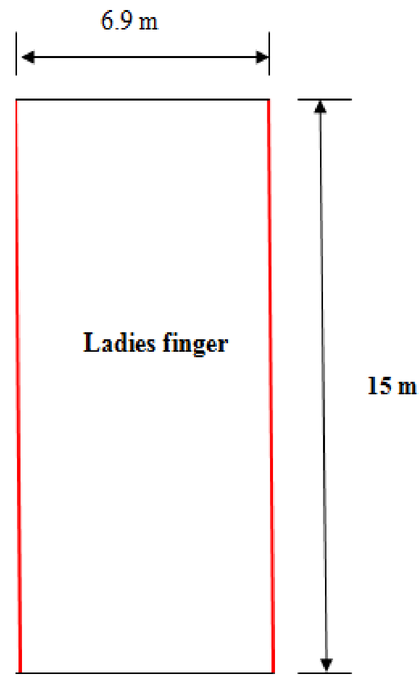

Fig. 3. Layout of flood irrigation at CAE Madakasira

2.11 Sowing

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

2.12 Weeding

Weeds are a major problem in Okra crop. The weeds are removed from time to time, inorder 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.

2.13 Harvesting

Okra were harvested when they have attained full size. A total of 7 pickings were done for this crop.

2.14 Weighing

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

2.15 AquaCrop 5.0 model

AquaCrop 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.

AquaCrop-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.

2.16 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

2.17 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

2.18 Pan Evaporation Method

Evaporation pans provide a measurement of the combined effect of temperature, humidity, wind speed and sunshine on the reference crop evapotranspiration ETo. 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 ETo= Reference evapotranspiration, K pan= pan coefficient, E pan= pan evaporation

2.19 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.

2.20 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 okra crop varies from 0.45 to 1.15 at different crop stages [13].

3. RESULTS AND DISCUSSIONS

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 130mm rainfall per month.

3.2 Comparison of Model and Observed Results of Crop Yield

The model results shows that the simulated yield for the Okra 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 Okra crop is 5 mm/day for both the flood and the drip irrigation. The Dry yield for the Okra crop through drip and flood irrigation are 5.2 and 4.3 tonne/ha. The biomass yield for the Okra crop through drip and flood irrigation are 99.8 and 92.8 Kg. The net irrigation requirement for the Okra crop through drip and flood irrigation are 292.45 and 310.5 mm/day.

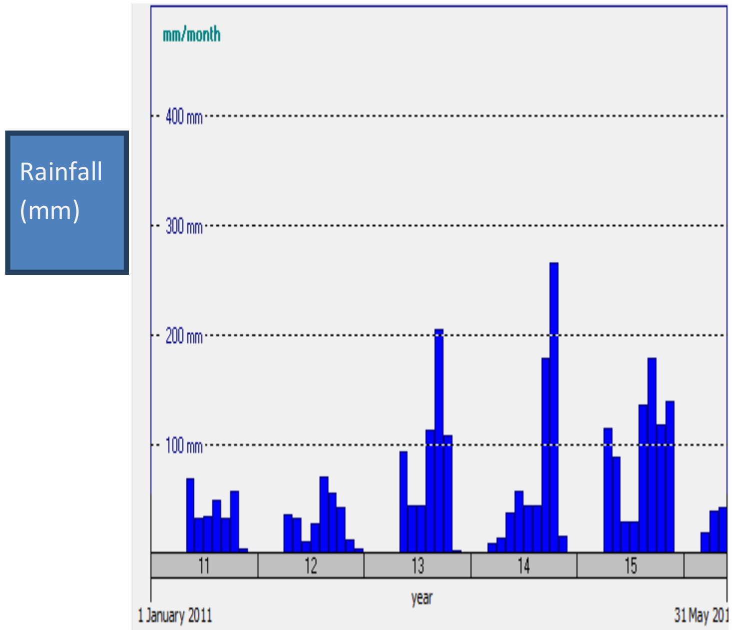

Fig. 4. Monthly rainfall for the period of 2011 to 2015

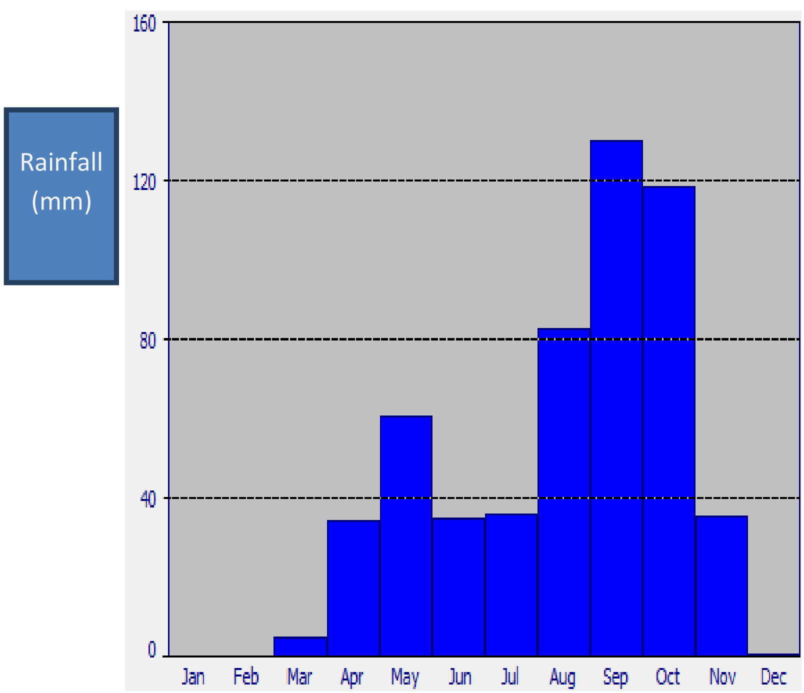

Fig. 5. Average monthly rainfall for the period of 2011 to 2015

Table 4. Output parameters from Aquacrop 5.0 model

S. No	Crop	ET (mm/day)	Dry Yield (tonne/ha)	Biomass (Kg)	NIR (mm/crop duration)	Salinity stress of root zone (%)
1	Okra- Drip irrigation	5	5.2	99.8	292.45	20
2	Okra- Flood irrigation	5	4.3	92.8	310.5	20

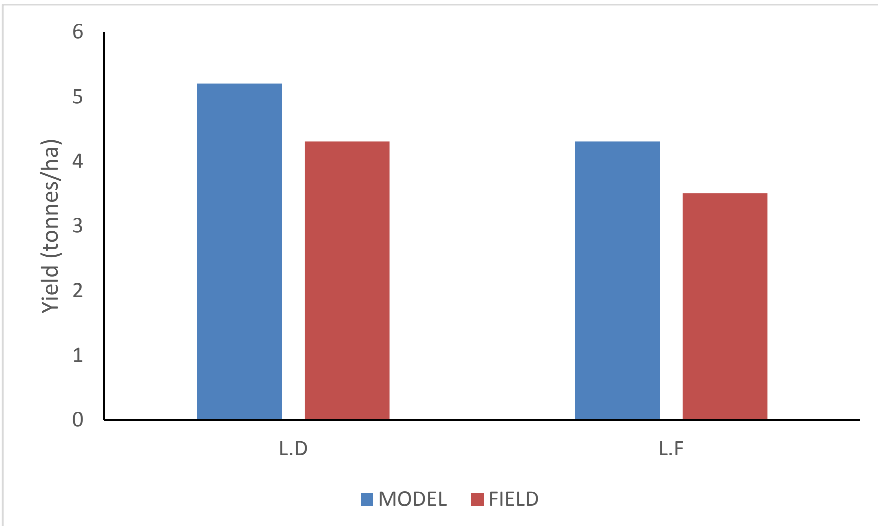

Fig. 6. Yield difference between model and field
B.D –Brinjal crop in Drip irrigation and B.F -Brinjal crop in Flood irrigation

3.3 For Okra crop – Drip irrigation

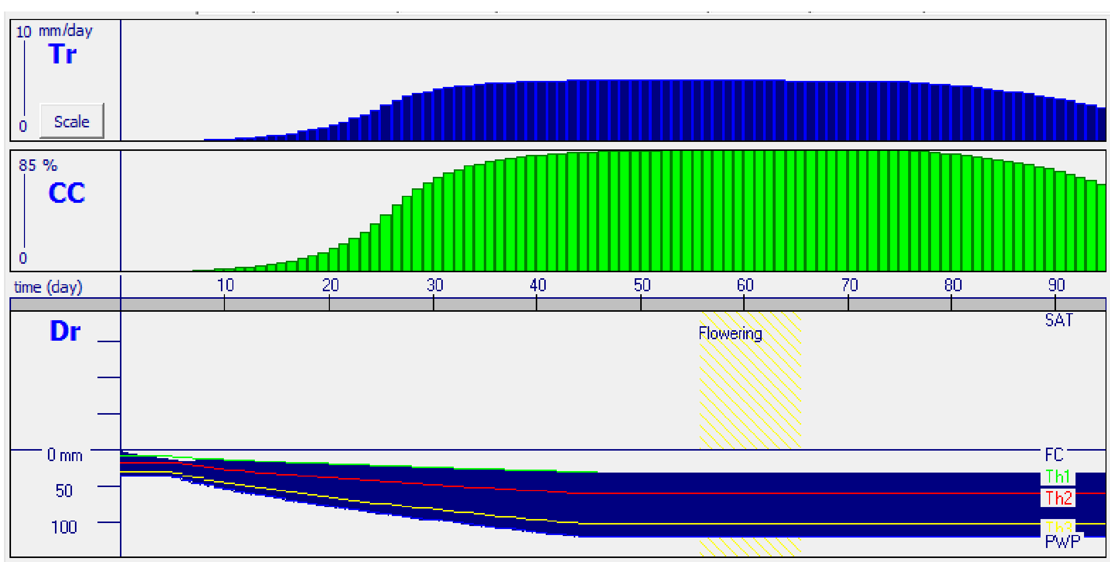

Fig. 7. Evapotranspiration (Tr), canopy cover growth (CC) and root zone depletion (Dr) for Okra crop in drip irrigation

3.4 For Okra crop – Flood irrigation

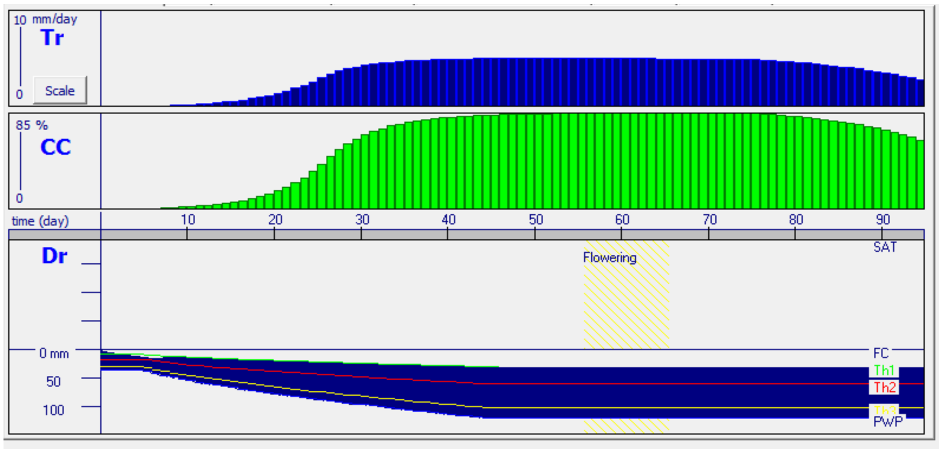

Fig. 8. Evapotranspiration (Tr), canopy cover growth (CC) and root zone depletion (Dr) for Okra crop in flood irrigation

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 80thday. The flowering stage starts from 60th day.

The actual crop water requirement for the okra crop for the drip irrigation and flood irrigation are the 300 and 386 mm.
From the table, it clearly shows that the model calculated results of crop water requirement for drip and flood irrigation are 320 and 326.6 mm The field results of crop water requirement for drip and flood irrigation are 300 and 386 mm. The Aquacrop model simulated the actual field and crop conditions partially.

3.5 Comparison of Yield for Different Irrigation Systems

The yield of Okra crop obtained through drip irrigation and flood irrigation is about 4.3 and 3.5 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 Okra crop when compare to the other conventional methods.

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

Crop Name	Field	
	Drip irrigation	**Flood irrigation**
Okra	300 mm	386 mm

Table 6. Comparison of crop water requirement

	Aquacrop model		**Field**	
Crop Name	Drip irrigation	Flood irrigation	Drip irrigation	Flood irrigation
Okra	320 mm	326.6 mm	300 mm	386 mm

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

	Drip Irrigation	**Flood Irrigation**
	Okra	**Okra**
Yield (tonne/ha)	4.3	3.5

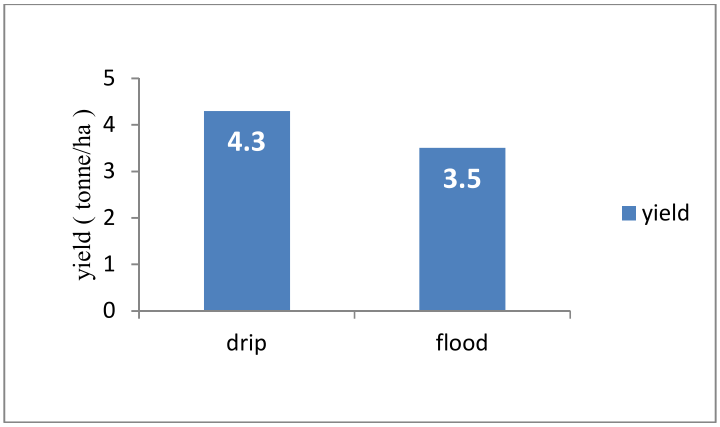

Fig. 9. Yield difference between drip and flood irrigation for Okra crop from field data

3.6 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. Okra – Drip irrigation system

Total input cost = (Seedlings +FYM + Installation material)

= Rs. 2520/-

Total output cost = (Yield output cost)

= Rs. 4360/-

B:C ratio $=\frac{4360}{2520}= 1.73$

2. Okra – Flood irrigation

Total input cost = (Seedlings + FYM + Material cost) = Rs. 1375/-

Total output cost = (Yield output cost) = Rs. 1457/-

B:C ratio $= \frac{1457}{1375} = 1.06$

According to the benefit cost-ratio, the total input and output cost of the okra for the drip irrigation system is Rs. 2520 and 4360. The benefit cost ratio is about 1.73. The total input and output cost of the okra for the flood irrigation system is Rs. 1375 and 1457. 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 Aquacrop model is very useful for simulating the crop under the semi-arid conditions. The simulated crop yield and crop water requirement for the Okra crop under flood irrigation was 4.3 t/ha and 326.6 mm. The actual crop yield and crop water requirement for the Okra crop under flood irrigation was 3.5 t/ha and 386 mm/day. This shows that the model is capable of simulating the crop water requirement and the yield successfully under the flood irrigation The simulated crop yield and crop water requirement for the Okra crop under Drip irrigation was 5.2 t/ha and 320 mm. The actual crop yield and crop water requirement for the Okra crop under drip irrigation was 4.3 t/ha and 300 mm. Under the Drip irrigation conditions, the model simulated the actual conditions of the crop. 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, Aquacrop model is suitable for simulating the crop conditions under any circumstances.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Mansour HA, Gaballah MS, Nofal OA. Evaluating the water productivity by Aquacrop model of wheat under irrigation systems and algae. Open Agriculture. 2020;5(1):262-270.
2. Saad AM, Mohamed MG, El-Sanat GA. Evaluating aquacrop model to improve crop water productivity at north delta soils, Egypt, Adv. Appl. Sci. Res. 2014;5:293–304.
3. Abedinpour M, Sarangi A, Rajput TBS, Man S, Pathak H, Ahmad T. Performance evaluation of AquaCrop model for maize crop in a semi-arid environment. Agric. Water Manage. 2012;110: 55-66.

4. Montoya F, Camargo D, Ortega JF, Córcoles JI, Domínguez A. Evaluation of aquacrop model for a potato crop under different irrigation conditions Agric. Water Manag. 2016;164:267-280
5. Amiri E. Calibration and testing of the aquacrop model for rice under water and nitrogen management Commun. Soil Sci. Plan. 2016;80(3):396-406.
6. Akumaga U, Tarhule A, Yusuf AA. Validation and testing of the FAO aquacrop model under different levels of nitrogen fertilizer on rainfed maize in Nigeria, West Africa. Agric. For. Meteorol. 2017;232:225–234.
7. Geerts S, Raes D, Garcia M. using aquacrop to derive deficit irrigation schedules. Agric. Water Manage. 2010;98(1):213-216.
8. Javier GÁ, NéstorRiaño H, Stanislav M. Simulation Of Corn (*Zea mays* L.) production in different agricultural zones of Colombia using the aquacrop model. Agronomiana Colombiana. 2014;32(3):112-115.
9. Maniruzzaman M, Talukder MSU. Validation of the aquacrop model for irrigated rice production under varied water regimes in Bangladesh. Agric. Water Manage. 2015;59:331-340.
10. Ruzica S, Marija C.. Assessment of the FAO aquacrop model in the simulation of rainfed and supplementally irrigated maize, sugar beet and sunflower. Agric. Water Manage. 2011;98: 1615-1621.
11. Shahjahan Mondal M, Abul Fazal M, Saleh M. Simulating yield response of rice to salinity stress with the aquacrop model. Environmental Science: Processes and Impacts. 2015;17:1118-1126.
12. Margarita G, Elías F. Combining the simulation crop model aquacrop with an economic model for the optimization of irrigation management at farm level. European Journal of Agronomy. 2012;36:21-31.
13. Tiwari KN, Mal PK, Singh A Chattopadhyay. Response of okra (*Abelmoschus esculentus* (L.) Moench.) to drip irrigation under mulch and non-mulch conditions Agric. Water Manage. 1998;38: 91-102.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/68509