Journal of Agrometeorology
ISSN : 0972-1665 (print), 2583-2980 (online)
Vol. No. 25 (3) : 470-473 (September - 2023)
https://doi.org/10.54386/jam.v25i3.2215
https://journal.agrimetassociation.org/index.php/jam

Short Communication

Assessment of growth and productivity of pearl millet (*Pennisetum glaucum* L.) with varied sowing environments and nitrogen concentrations using AquaCrop model

SATHYAMOORTHY, N.K. [1*], **GEETHALAKSHMI**[2], **V., RAMANATHAN, SP**[1]**., SANKAR, T**[1]**., SELVA KUMAR, M**[1]**., PRADIPA, C**[3] **and GOVINDARAJ, T**[1]

[1]*Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu- 641003, India*
[2]*Vice-chancellor, Tamil Nadu Agricultural University, Coimbatore-641003, Tamil Nadu, India*
[3]*Krishi Vigyan Kendra, Sandhiyur, Salem--636203, Tamil Nadu, India*
Corresponding author email: *nks6@tnau.ac.in

Bajra or cumbu or pearl millet (*Pennisetum glaucum* L.) is the predominant crop in India, which is in third position in the area under cultivation of small millets around the world. The most significant non-monetary factor affecting crop yield is sowing time. By providing an appropriate environment during all growth stages, sowing at the best time increases productivity. According to Upadhyay *et al.,* (2001), summer pearl millet (sown on March 15) produced more grain than when it was sown later. In fact, the right planting time is crucial for maximizing cereal grain yields since the best seeding times produce strong and robust plants. Low nitrogen and soil water management limits the grain and biomass yield of pearl millet. Grain yield and soil moisture content can be simulated by using AquaCrop model. Many studies have been conducted for simulating cotton growth and productivity using AquaCrop model (Hamid *et al.,* 2009) and baby corn (Sankar *et al.,* 2023), respectively. However, there is limited information available on the usage of the AquaCrop model under various sowing windows and nitrogen levels in pearl millet. Hence, the current investigation was carried out with the objectives of simulating green canopy cover (CC), above-ground biomass and yield of pearl millet through calibrating and validating AquaCrop model and to evaluate the influences of sowing windows and nitrogen levels on pearl millet growth and productivity.

A field experiment was conducted during *kharif* and *rabi,* 2020-2021 at Coimbatore, Tamil Nadu (Lat.10º to 11º N, Long. 76º to 77º E) on pearl millet hybrid CO (9) with three sowing windows and three nitrogen levels as a main and subplot replicated three times laid in split plot design. Sowing windows consisted *viz*., early sowing – II FN June, mid-sowing - I FN July, and late sowing – II FN July for *Kharif* season and early sowing – II FN September, mid-sowing – I FN October and late sowing – II FN October for *Rabi* season. Nitrogen levels consisted *viz*., 75% of N, 100% of N and 125% of N. The soil is clay loam and type of soil is black, calcareous in nature, low in organic carbon (0.42%) and available nitrogen (218 $kg\ ha^{-1}$), high in available phosphorus (31.2 $kg\ ha^{-1}$) and potassium (635 $kg\ ha^{-1}$). Weather parameters were collected from Agro Climate Research Centre (ACRC), Tamil Nadu Agricultural University (TNAU). The prevailed maximum temperature ranged from 26.0 ºC to 34.5 ºC, minimum temperature varied from 20.0 ºC to 26 ºC, total rainfall was 326 mm, relative humidity varied from 54 % to 84%, wind speed was in the range between 2.8 km/hr and 9.8 km/hr and solar radiation varied from 105 to 428.4 Cal $cm^{-2}min^{-1}$.

Five plants in each experimental plots were selected and tagged to observe biometric observations. The LAI was calculated through manually measured leaf area (maximal length x width) of each plant, multiplied by the correction factor (k = 0.75, Watson, 1947) for pearl millet and plant density. LAI was converted to green canopy cover (CC) using following equation.

$$CC = 1.005\ [1 - \exp(-0.6\ LAI)]^{1.2}$$ Heng *et al., (*2009)

Calibration and validation of AquaCrop model

AquaCrop model was calibrated using simulated and observed canopy cover (CC), biomass, and grain yield at harvest under different sowing times and nitrogen levels during early sowing window (D_1). For each simulation run, separate input files were created and simulations were performed. Validation was performed using mid and late sowing windows (D_2 and D_3) along with nitrogen levels data, also by considering the calibrated crop parameters observed in the field. For each of the simulation

Article info - DOI: https://doi.org/10.54386/jam.v25i3.2215
Received: 06 May 2023; Accepted: 05 August 2023; Published online : 31 August 2023

runs, input files *viz*., weather data, soil characteristics, irrigation applications, phenological days, and sowing density were entered as observed values.

Model evaluation

Goodness of fit was found between the AquaCrop simulated and observed values *viz.,* Canopy Cover (CC), biomass, grain and straw yield of pearl millet by using four statistical variables such as coefficient of determination (R^2), root mean squared error (RMSE), Nash-Sutcliffe model efficiency co-efficient (E) (Nash and Sutcliffe 1970), and Willmott's Index of Agreement (d) (Willmott, 1982).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(M_i - S_i)^2}{n}}$$

$$E = 1 - \frac{\sum_{i=1}^{n}(Mi - S_i)^2}{\sum_{i=1}^{n}(M_i - \bar{M})^2}$$

$$d = 1 - \frac{\sum_{i=1}^{n}(n_i - s_i)^2}{\sum_{i=1}^{n}(|M_i - \bar{M}| + |S_i - \bar{M}|)^2}$$

where, Mi and Si are the measured and simulated values, respectively; n - the number of observations; M - the mean of n measured values

Using data gathered from three sowing windows and nitrogen levels, results of the AquaCrop calibration and validation were discussed in this section.

Calibration and validation of AquaCrop for pearl millet

Calibration was performed with early sowing window and nitrogen levels and the key variables used to calibrate the AquaCrop model for pearl millet growth and production are given in Table 1 along with the default values present in the AquaCrop files.

Table 1: AquaCrop default and calibrated values used in pearl millet simulation.

Parameters	Default	Calibrated
Reference harvest index (%)	45	50
Initial canopy cover (%)	0.49	0.44
Canopy cover (CC) per seedling (cm^2/plant)	6.5	5.0
Maximum canopy cover (%)	90	92
Maximum rooting depth (m)	1.8	1.0

Canopy cover

There was a good agreement between simulated and observed canopy cover (CC) for calibrated sowing windows and nitrogen levels throughout the growing season. The overall goodness of fit was high as shown by low *RMSE*≤8.1 value, good *E* ≥0.95 value, high *d* value ≥0.99 and high R^2 value ≥0.87 (Fig. 1a). Among the crop growing cycle, the highest deviation (-16.5%) between simulated and observed canopy cover was observed during 30 DAS canopy closure days in the AquaCrop model and deviation was reduced to (-) 2.3 % at 45 DAS. Bello and Walker's (2016) also found that CC was underestimated early in the crop stage for full irrigation treatments (W5) and the model was able to accurately simulate CC during 39 days after sowing. Among the nitrogen application, 125% of N significantly increased the canopy cover throughout all stages of the crop and the maximum canopy cover was obtained 99.1 and 92.3% of observed and simulated, respectively during 60 DAS. Validation (Fig. 1b) showed high goodness of fit for CC with low *RMSE* value ≤9.0, high *E* value ≥0.93, high *d* value ≥0.98 and high R^2 value ≥0.79. By simulating LAI from individual leaf area, Van Oosterom *et al.,* (2001) successfully reproduced the LAI, a canopy cover parameter, of pearl millet tillers.

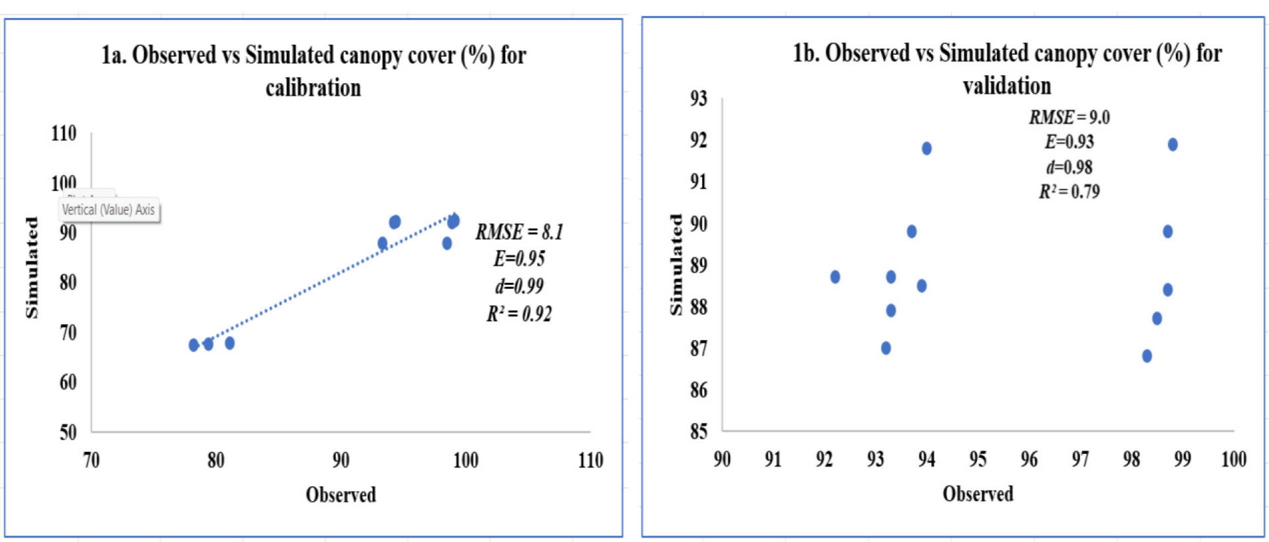

Fig. 1: Observed vs simulated canopy cover (%) of pearl millet. (a) calibration dataset and (b) validation dataset

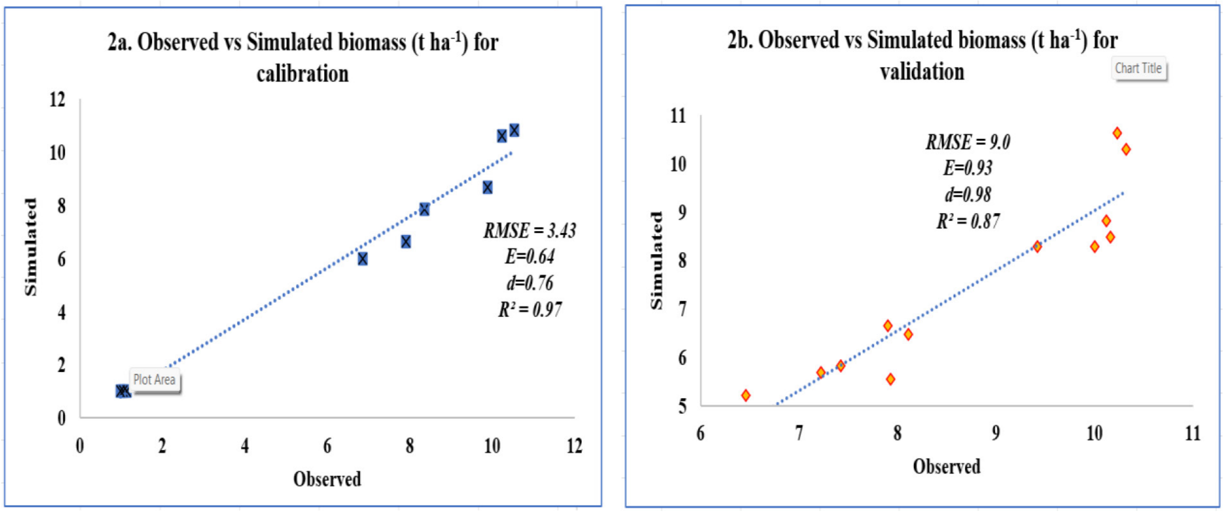

Fig. 2: Observed vs simulated biomass (t ha^{-1}) of pearl millet. (a) calibration dataset and (b) validation dataset

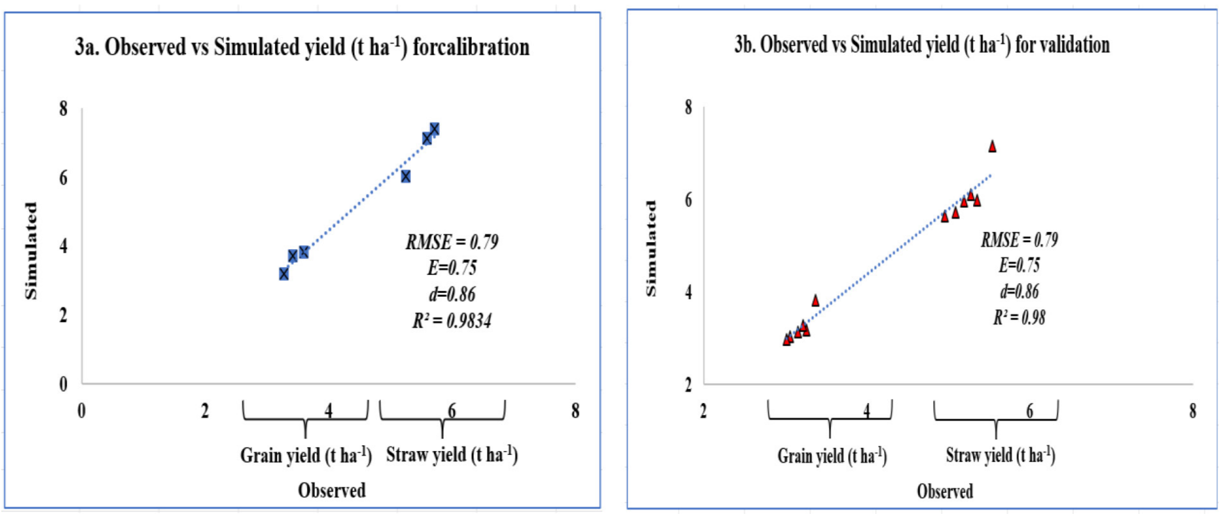

Fig. 3: Observed vs simulated yield (t ha^{-1}) of pearl millet. 3a – calibration dataset and 3b – validation dataset

Biomass of pearl millet

Model calibration indicated a good agreement between simulated and observed biomass throughout the growing season with low *RMSE* ≤3.43 t. ha^{-1}, good *E* ≥0.64, good *d* ≥0.76 and high R^2 ≥0.89 values (Fig. 2a). The performance of the AquaCrop model was assessed by Jin *et al.,* (2014), showed a good agreement between actual and predicted in-season biomass levels. It can be observed that there was a good fit during validation of pearl millet biomass under various sowing windows with different nitrogen levels which was confirmed by low *RMSE* value ≤3.62 t. ha^{-1}, good *E* value ≥0.73, good *d* value ≥0.75 and high R^2 value ≥0.83 (Fig. 2b). A similar result of good agreement with less deviation was also found in baby corn (Sankar *et al.,* 2023). The biomass was found to be low in late sown crop with 75 % N application while the early sown crop with 125 % N application produced the highest biomass throughout all the stages of the crop. At 60 DAS, the observed biomass was 9.42 t ha^{-1} and simulated was 8.28 t ha^{-1} in late sown crop with 75 % N application and early sown crop with 125 % N application had observed biomass of 10.53 t ha^{-1} and simulated biomass of 10.82 t ha^{-1}.

Grain and straw yield of pearl millet

AquaCrop simulated the pearl millet grain and straw yields with a perfect match to the field condition during both calibration and validation with acceptable deviations in the grain yield ranged from -2.4 % to 8.5 % for calibration and from -2.9% to 8.1% for validation. The deviation was less for the grain yield simulation than the straw yield simulation in all sowings and N levels. The overall *RMSE =0.79 t. ha^{-1}, E=0.75, d=0.86, R^2=0.88* values (Fig. 3a) for calibration and *RMSE =0.55 t. ha^{-1}, E=0.88, d=0.74, R^2=0.89* (Fig. 3b) values for the validation dataset were obtained, which indicates a good prediction efficiency of AquaCrop model under different sowing windows and nitrogen levels. According to Suman *et al.,* (2019), for both the calibration and validation periods, the model was verified for simulating pearl millet grain yield (R^2 >0.91) for all moisture conservation measures. Among the sowing and nitrogen levels, the crop with 125% of N level under early sowing showed the highest grain (3.6 and 3.81 t ha^{-1}) and straw yields (5.72 and 7.39 t ha^{-1}) in both field and model simulations. In contrast, late sown crop with 75 % N application showed the lowest observed and simulated grain yield (3.02 and 2.97 t ha^{-1}) and straw yield (4.96 and 5.63 t ha^{-1}).

ACKNOWLEDGEMENT

The authors acknowledge the support provided by ARS, Bhavanisagar, CRS, Aliyarnagar, and ACRC, Tamil Nadu Agricultural University, Coimbatore-641003.

***Conflict of Interest*:** The authors are declaring that there is no conflict of interest in the publication of the paper.

Data Availability: The authors confirm that the data supporting the findings of this study are available within the article.

Author's contributions: **SATHYAMOORTHY, N.K**: Research idea conceptualization, Experiments Conducted, writing original draft. **GEETHALAKSHMI, V:** Research idea conceptualization, Guidance and reviewing manuscript. **RAMANATHAN, SP**: Research idea conceptualization, Guidance and reviewing manuscript. **SANKAR, T:** writing and editing the manuscript. **SELVA KUMAR, M:** writing and editing the manuscript. **PRADIPA, C:** writing and editing the manuscript. **GOVINDARAJ, T**: writing and editing the manuscript.

***Disclaimer*:** The opinions, contents, and views expressed in the research article published in the Journal of Agrometeorology are the authors' own and do not necessarily reflect the position of the organizations they are affiliated with.

***Publisher's Note*:** The periodical remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

Bello, Z. A. (2013). Characterization and modelling of water use by amaranthus and pearl millet (*Doctoral dissertation, University of the Free State*).

Hamid J F, Gabriella I and Theib Y O (2009). Parameterization and evaluation of the AquaCrop model for full and deficit irrigated cotton. *Agronomy J.*, 101: 469–76.

Jin, X. L., Feng, H. K., Zhu, X. K., Li, Z. H., Song, S. N., Song, X. Y and Guo, W. S. (2014). Assessment of the AquaCrop model for use in simulation of irrigated winter wheat canopy cover, biomass, and grain yield in the North China Plain. *PloS one*, 9(1), e86938.

Nash, J. E., & Sutcliffe, J. V. (1970). River flow forecasting through conceptual models part I—A discussion of principles. *J. Hydrol.*, 10(3), 282-290.

Sankar, T., Ramanathan, S. P., Kokilavani, S., Chandrakumar, K., & Kalarani, M. K. (2023). Assessment of AquaCrop model for simulating Baby corn (*Zea mays* L.) growth and productivity under different sowing windows and crop geometries. *J. Agrometeorol., 25*(2), 280-286. DOI: https://doi.org/10.54386/jam.v25i2.2119

Suman, K., Susama, S., Anchal, D., Manoj, K., Sehgal, V. K., and Neelam, P. (2019). Assessing aquacrop model for pearlmillet (*Pennisetum glaucum*) under in-situ water conservation in a rainfed semi-arid environment. *Indian J. Agric. Sci.*, *89*(8), 1349-1355.

Upadhyay, PN., Dixit, A.G., Patel, J.R. and Chavda, J.R. (2001). Response of summer pearl millet to time and method of planting, age of seedling and phosphorus grown on loamy sand soils of Gujarat. *Indian J. Agron*. 46(1): 126- 130.

Van Oosterom, E. J., Carberry, P. S., Hargreaves, J. N. G., and O'leary, G. J. (2001). Simulating growth, development, and yield of tillering pearl millet: II. Simulation of canopy development. *Field Crops Res.*, *72*(1), 67-91.

Watson, D. J. (1947). Comparative physiological studies on the growth of field crops: I. Variation in net assimilation rate and leaf area between species and varieties, and within and between years. *Annals Bot.*, 11(41): 41-76.

Willmott, C. J. (1982). Some comments on the evaluation of model performance. *Bull. American Meteorol. Soci.*, 63(11): 1309-1313.