eISBN 978-967-16145-1-8

Konvensyen Kebangsaan Kejuruteraan Pertanian Dan Makanan 2019
21 Mac 2019, Wisma Tani, Kementerian Pertanian Malaysia, Putrajaya

MSAE2019-AIT11

Preliminary Evaluation of ORYZA (v3) Crop Growth Model for MR269 Rice Variety

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Abstract
Rice (Oryza sativa) is a staple food for more than half of the world's population, including about 30 million Malaysians. Rice self-sufficiency level (SSL) in Malaysia is currently at 70% and the level does not satisfy the local demand. Therefore, rice production needs to be increased to 80% by the year 2020 (MOA, 2015). The Malaysian Government aims to increase average rice grain production from 4.5 mt/ha to 6.0 mt/ha (Ismail, 2017). Among the ways to increase the production of rice is by improving crop management, such as finding best sowing dates, and best management practices such as optimum usage of fertilizer rates and rice varieties that suit weather conditions. Simulations of crop models are alternatives to costly trial experiments in exploring opportunities for increasing agricultural system productivity. Existing rice crop growth models have not been rigorously explored to assess productivity of Malaysian rice systems. Prior to scenario studies using a rice crop growth model, performance of the model must first be evaluated. Therefore, this paper reports preliminary evaluation on the performance of a rice crop growth model called ORYZA (v3). The model was evaluated against rice crop physiological properties collected at two farmers' plots at IADA KETARA, Terengganu. The preliminary evaluation indicates that ORYZA (v3) has a potential in simulating the physiological properties of MR269, but the model must be calibrated. Calibration of the model is currently on-going.

Keywords: Crop growth model, ORYZA (v3), nitrogen,MR269, rice

Introduction

Rice is a staple food for more than half of the world's population, including about 30 million Malaysians. In 2012, about 156 million ha of rice were harvested worldwide, and about 88% and 31% of this harvested area were in Asia and South East Asia, respectively (FAO, 2013). About 95% of global rice production occurs on soil that is flooded during at least part of the rice-cropping period (Buresh et al. 2008).

In South East Asia, the highest level of rice productivity are found in irrigated rice system with 95% of rice production compared to the other system like rainfed, upland, deep water and upland rice (Mutert & Fairhurst, 2015). Optimum productivity of rice crop can be achieved by determining the best sowing dates and best management practices (Kumar et al. 2010).

A comprehensive rice crop growth model can be used to understand complex and interactive processes in rice systems and to help farmers in making decision (Svensson, 2012). Simulations of crop growth models are alternatives to costly trial experiments in exploring opportunities for increasing agricultural system productivity, assessing effects of the agricultural systems on the environment, and forecasting the effects of climate change on the production (Gaydon et al., 2017; Kumar et al., 2010).

ORYZA (v3) was the latest result from continuous improvement of ORYZA2000 by the International Rice Research Institute (IRRI) in Los Banõs, Philippines (Li et al., 2017). ORYZA (v3) has not been evaluated for Malaysian rice varieties, site conditions and agronomic practices. Prior to simulation studies using a rice crop growth model, performance of the model must first be evaluated.

Therefore, the objective of this study is to perform preliminary evaluation on the performance of ORYZA (v3) in simulating rice physiological variables.

Materials and methods

Study site description

In this study, experiments were conducted at IADA KETARA, Besut, Terengganu, Malaysia. The IADA KETARA is one of the eight granary areas that was designated under the National Agricultural Policy for double cropping paddies through the introduction of high yield varieties and irrigation facilities. The overall size of the IADA KETARA rice granary is 12,000 ha (Yasar et al. 2015).

Two plots, each with an average size 1 hectare, were selected for this study. Experiments were conducted on Plot A and Plot B from 14 July to 30 November 2017 and from 19 July to 30 November 2017, respectively. Fertilizer was applied 3 times for each plot. For Plot A, fertilizer rates for first, second and third fertilizations were 34, 45 and 21 kg N ha^{-1} respectively. For Plot B the rates were 56, 76 and 35 kg N ha^{-1}. MR269 seeds were manually broadcast on

both plots. MR269 is one of the most common local varieties. These two plots were managed by their owners. A weather station was also installed at the study area. Throughout the experiment, average sunshine hour was about 12 hours day^{-1}. The cumulative rainfall was about 2089 mm from July to the end of December 2017. The ambient temperature ranged from 23 to 35˚C. The average solar radiation was about 15296 watt m^{-2} day^{-1}, and average wind speed was about 0.3 m s^{-1}.

Field sampling

Agronomic samples were collected from Plot A and Plot B. Two quadrants with an area of 0.5 m X 0.5 m, were used for crop sampling in each experimental plot. Coordinates of sampling points were taken using Trimble Juno. The samples include number of plants, green leaf biomass, dead leaf biomass, stem biomass, storage organ biomass, and leaf area index. These samples were taken at three different growth stages, i.e., vegetative stage, reproductive stage and maturity stage. The fresh samples were carefully packed and transported to the laboratory at Universiti Putra Malaysia for separation of rice crop organs. The separated rice crop organs were dried and then weighted. The total area of the green leaves was measured using a bench top leaf area meter (Li-Cor 3100C, Li-cor Inc., Lincoln, NE, USA).

Selection of a crop growth model

ORYZA (v3) crop growth and development model is a process-based model that was developed to simulate the effects of nitrogen (N), water management and weather on rice crop physiological variables (i.e., leaf area index and biomass of crop organs including rice grain production), soil water content, and soil N dynamics (Li et al., 2017). Therefore, the model was selected in this study. ORYZA (v3) is the successor of ORYZA2000 and was recently modified to include the soil N dynamics and has only been evaluated for rice varieties and field practices in the Philippines (Bouman et al. 2001; Li et al. 2017).

Assumptions for preliminary assessment of the model

For simulation, ORYZA (v3) requires inputs of soil properties, crop properties and micrometeorological data. For preliminary evaluation, the soil chemical and some of the soil physical properties were adjusted to suit the actual conditions at the study area. The crop physiological properties were not calibrated for MR269. Instead, default values were used. Information of agronomic practices such as the rates of nitrogen fertilizers, dates of sowing and irrigation schedule were based on actual agronomic practices for both experimental plots. The weather input was prepared using the actual meteorological data collected by the weather station installed at study area.

Evaluation of model performance

Simulations by ORYZA (v3) were evaluated using the measured crop physiological data, namely the biomass of green leaf, dead leaf, stem, and storage organ/panicle, and leaf area index, collected from Plots A and B. Standard deviation of the observations (SD_{obs}, Eq.(1)), root mean square error ($RMSE$, Eq.(2)), correlation analysis (r^2, Eq.(3)) and modelling efficiency index (M_{eff}) were calculated and used to evaluate the performance of ORYZA (v3) (Li et al., 2017; Yuan, Peng, & Li, 2017). The observations are represented by X_i, while the simulations are represented by Y_i. $\bar{X}$ is mean of observations and n is number of data.

$$SD_{obs} = \sqrt{\frac{\sum_{i=1}^{n}(X_i-\bar{X})^2}{n-1}} \quad (1)$$

$$RMSE = \left(\sum_{i=1}^{n}\frac{(Y_i-X_i)^2}{n}\right)^{0.5} \quad (2)$$

$$r^2 = \frac{\left[\sum_{i=1}^{n}(X_iY_i)-\sum_{i=1}^{n}X_i\sum_{i=1}^{n}Y_i\right]^2}{\left[\sum_{i=1}^{n}(X_i)^2-\left(\sum_{i=1}^{n}X_i\right)^2\right]\left[\sum_{i=1}^{n}(Y_i)^2-\left(\sum_{i=1}^{n}Y_i\right)^2\right]} \quad (3)$$

$$M_{eff} = 1.0 - \frac{\sum_{i=1}^{n}(X_i-Y_i)^2}{\sum_{i=1}^{n}(X_i-\bar{X})^2} \quad (4)$$

Typically, model performance is considered good when M_{eff} and r^2 are closer to 1.0, while $RMSE$ must be compared to the SD_{obs} (Gaydon et al., 2017; Yuan et al., 2017).

Results and discussion

ORYZA (v3) performance

Fig. 1 shows comparison of simulated and measured variables over time for Plot A and Plot B. The simulated LAI was close to fit with the measured variables for both plots. However, for other rice physiological variables, the patterns show that the simulations often under-estimated the measurements. ORYZA (v3) shows good estimation of LAI where the M_{eff} is closer to 1 for both Plot A and Plot B.

However, ORYZA (v3) shows poor estimation for the other rice physiological variables based on the values of M_{eff}. The poor results are most likely because simulations were performed using default parameter values. Therefore, the next step is to calibrate the model for RM269 and actual soil conditions. In cases of small measurements, the analysis further demonstrates that the M_{eff} is a better indicator of a model performance compared to r^2. As an example, the total aboveground biomass ($WAGT$) for Plot A, the $r^2 = 1$, but the $M_{eff} = 0.4$. Further inspection of Fig. 1c showed that the model

poorly estimated the *WAGT*, which in agreement with the M_{eff}

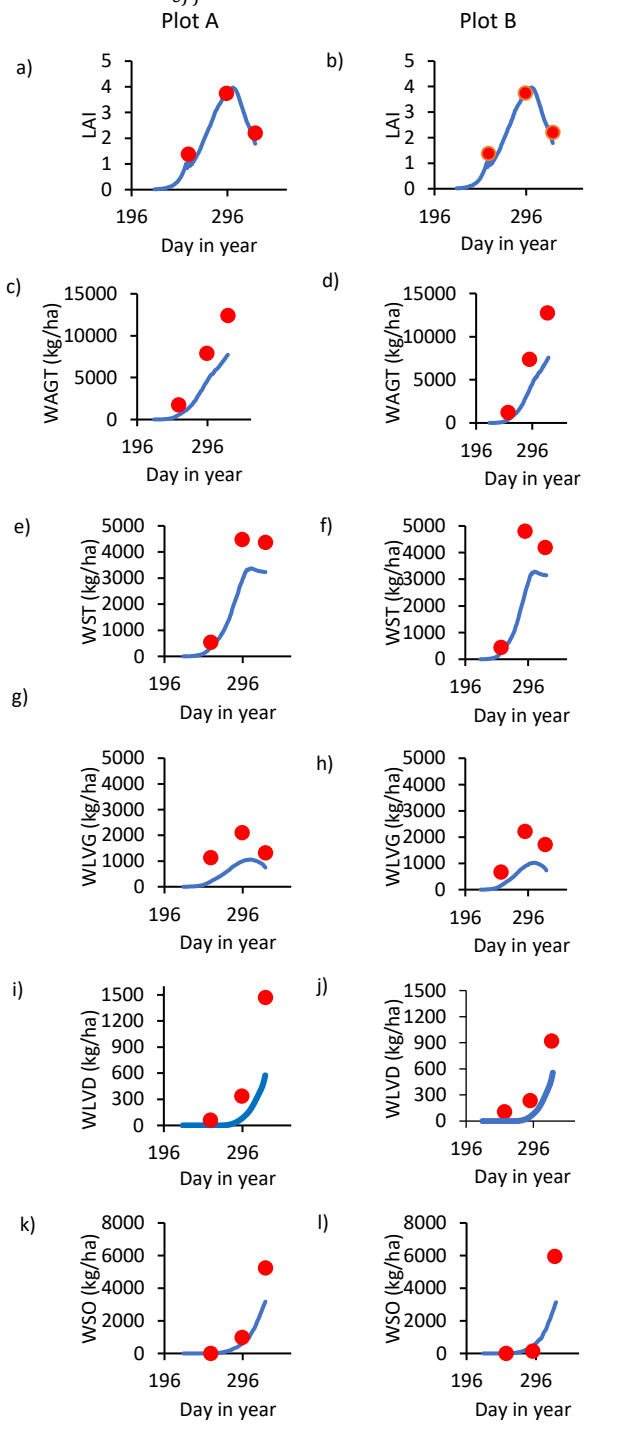

Fig. 1. Simulations (lines) and measurements (circles) of the leaf area index (LAI), total above ground biomass (WAGT), dry weight of stems (WST), dry weight of green leaves (WLVG), dry weight of dead leaves (WLVD) and dry weight of storage organs (WSO)

Table 1. Performance of ORYZA (v3) in simulating physiological variables over the entire growing season for variety MR269 for Plots A and B

Plot	Crop variables	SD_{obs}	$RMSE$	M_{eff}	r^2
A	LAI	1.2	0.3	0.9	1.0
	WAGT	5339.8*	3387.0*	0.4	1.0
	WST	2240.1*	1143.1*	0.7	1.0
	WLVG	514.1*	903.1*	-3.7	0.7
	WLVD	746.5*	537.5*	0.2	1.0
	WSO	2780.2*	1205.9*	0.7	1.0
B	LAI	1.4	0.2	1.0	1.0
	WAGT	5775.1*	3763.3*	0.4	1.0
	WST	2359.1*	1480.9*	0.4	0.9
	WLVG	788.9*	983.2*	-1.3	0.9
	WLVD	435.9*	278.3*	0.5	1.0
	WSO	3393.8*	1751.0*	0.6	1.0

** Unit in kg ha^{-1}*

Conclusion

The preliminary evaluation suggests that ORYZA (v3) has a potential in simulating physiological variables of MR269, but the model must first be calibrated. Calibration of the model is currently on-going.

Acknowledgement

This study was funded by the Higher Institution Centre of Excellence (HICoE) Grant, Institute of Tropical Agricultural and Food Security and Geran Putra IPM (GP-IPM/2017/9583900). All authors would to thank Mr. Kas Wady Zakaria for assisting the sampling activities and the local farmers for their cooperation during experiments.

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