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Tripta Devi
Department of Agronomy, Forages and Grassland Management, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India

Ranbir Singh Rana
Department of Agronomy, Forages and Grassland Management, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India

Corresponding Author:
Tripta Devi
Department of Agronomy, Forages and Grassland Management, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India

Simulation of maize (*Zea mays*) yield by using info crop model under climatic conditions of Kangra district of Himachal Pradesh

Tripta Devi and Ranbir Singh Rana

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Abstract
A field study was conducted on growing maize during *Kharif* season of 2013 and 2014 to simulate the grain yield by using InfoCrop model under climatic conditions of Kangra district of Himachal Pradesh. The field experiment comprised of four dates of sowing *viz*., May 30th, June 10th, June 20th and June 30th and three genotypes *viz*., Girija, Bajaura Makka and HQPM-1. The study concluded that the simulated Leaf area index (LAI), dry matter accumulation, grain yield, days to physiology maturity and vegetative stage matched closely with observed values for all sowing environments. The RMSE value for grain yield was 3.2qha^{-1} for both the year's i.e.2013 & 2014. The model performance was somewhere under estimated or overestimated but found within acceptable limits.

Keywords: Info crop model, maize, leaf area index, dry matter accumulation, grain yield, pre- harvest

Introduction
Globally, Maize is known as queen of cereals because of its highest genetic yield potential among the cereals. Every part of the maize plant has economic value (the grain, leaves, stalk, tassel, and cob) and all are used to produce a large variety of food and non-food products. India is the second most important maize growing country in Asia and is the world's sixth largest producer and fifth largest consumer of maize. In India Maize is the third most important food crop after rice and wheat (Bhatia *et al.* 2013) [4]. Maize can be grown in wider range of agro-climatic zones, ranging from extreme semi-arid to sub-humid and humid regions (Sharma *et al.* 2018) [15]. Among the maize growing countries, India rank 4th in area and 7th in production, representing around 4% of the world maize area and 2% of total production. India MaizeScenario – ICAR-Indian Institute of Maize Research. India produced 21.24 million tonnes of Maize in an area of 8.15 million hectares in 2021-22(https://pib.gov.in/PressReleasePage.aspx). It is second important food crop of Himachal Pradesh after wheat.

It is cultivated in an area of 267.41(000'ha) with a total production of 725.01(000'Metric Ton) (https://agriculture.hp.gov.in/en/production-2/).Reliable and timely forecast of crops yield provide important and useful input for proper, foresighted and informed planning. Crop acreage information and yield forecasting are two components which are crucial for planning and policy making in agricultural sector of the country. Simulating the crop growth and yield using crop models has been increasingly become valuable for decision support. Several crop model being tested and validated for their performance for a given management, variety (ies) and climatic condition (Fagodiya *et al.* 2017) [7]. Crop simulation models are extensively used to comprehend the influence of meteorological parameters, soil properties, crop genotype and crop management practices on various agricultural applications (Dhakar *et al.*2021) [6]. The crop simulation models are useful tools for considering the complex forecast of crop production before harvests which are required for storage, pricing, marketing, import, export etc.

The main factors affecting crop yield are weather, soil and genetic coefficient of the crop. Weather plays an important role in crop growth. Therefore, crop simulation model based on weather parameters, soil parameter and crop parameters can provide reliable forecast in advance

for crop yield (Ananta *et al.* 2015) [2]. InfoCrop is a decision support system which can simulate(predict) the crop growth, development and yield and interactions between a range of factors that affect crop performance, including weather, soil properties and crop management (Aggrawal *et al.* 2006, Shamim *et al.* 2012) [1, 4]. It is a dynamic crop-yield model, developed by Aggarwal and his co-workers from the center for Application of Systems Simulation, IARI, New Delhi. InfoCrop has incorporated 13 crops including rice, wheat and Maize. It has capacity to evaluate the production of major annual crops and has an inbuilt database of Indian soils (Kumar *et al.* 2015) [11]. InfoCrop has been successfully adapted, calibrated and validated for rice (Aggrawal *et al.* 2006) [1], potato (Singh *et al.* 2005) [16], cotton (Hebbar *et al.* 2008) [10] & coconut (Kumar *et al.* 2008) [12]. Quantifying the yield potential of maize crop for a region is a key to understand the yield gaps and identify the important constraints to achieve optimum yield. However, understanding the causes of yield gaps allows farmers to prioritize their strategies in improving yield and profit in a sustainable and eco-friendly manner and maximizes the return on the investment (Mohanty *et al.* 2017) [13].

Materials and Methods

Experimental site

A field experiments were conducted during *kharif* seasons of 2013 & 2014 at research farm of Department of Agronomy, Forages and Grassland Management($32^0 6'$N,$76^0 3'$E) an elevation of about 1290.8 m above mean sea level in North-Western Himalaya CSK HPKV, Palampur (Himachal Pradesh). The field experiments were conducted in randomized block design (RBD) with the combination of four dates of sowing and three varieties, replicated three times. In this study the pre harvest crop yield forecast of maize was estimated using InfoCrop model.

Crop growth simulation model description

Info Crop Model Description

Info Crop, a process based model considers the processes such as crop growth and development (phenology, photosynthesis, partitioning, leaf area growth, storage organ numbers, source: sink balance, transpiration, uptake, allocation and redistribution of nitrogen), effects of water, nitrogen, temperature, flooding and frost stresses on crop growth and development, crop-pest interactions (damage mechanisms of insects and diseases), soil water balance, soil nitrogen balance, soil organic carbon dynamics, emissions of greenhouse gases and climate change module.

Model input requirements

The input data files required for running the Infocrop growth model are crop/variety master, soil texture master and weather data files.

Crop/variety file: is used to enter the crop variety details and its parameters. The attributes of three varieties of maize recommended for region recorded from field experiments were added in the file.

Weather file: Daily bright sunshine hours, daily maximum and minimum temperature, wind speed, rainfall and physiographic attributes of the meteorological stations were entered to prepare the weather file for Palampur region. The model calculates itself the vapour pressure to run the model. For calibration and validation of the model weather data of recorded from Agrometeorological observatory, situated in CSK HPKV, Palampur was used. During crop growing season from May to September 2013, the weekly maximum and minimum temperature ranged between 24.0 to 32.4 ^{0}C and12.9 to 20.8 ^{0}C during the year 2013 and 23.4 to 33.6 ^{0}C and 11.8 to 21.2 ^{0}C during the year 2014, respectively with rainfall of 1333mm during the year 2013 and 2629.4 mm during the year 2014 and sunshine duration ranged 9.1 hours/day during the year 2013 and11.7 hours/day during the year 2014 respectively

Soil texture file: Among the soil analysis prior to planning, composite soil samples from 0-15 cm depth were collected from the experimental field before the sowing of the crop. The soil samples were then air dried, ground, passed through 2 mm sieve and analyzed for various physio- chemical properties such as mechanical analysis (sand %, silt %, clay % and texture) and chemical analysis (pH, Organic matter, Available Nitrogen Kg ha^{-1}, Phosphorus Kg ha^{-1} and Potassium Kg ha^{-1}. For three soil layers depth (mm) the parameters like organic carbon (%), soil texture (sand, silt, clay%), bulk density, hydraulic saturated conductivity and NH4-N and NO3-N content were input in the soil files representing the soils of Palampur conditions.

Crop management: Agronomic attributes required in the model were recorded and updated in the model e.g. Seed rate, leaf area of variety, grain weight, date of sowing, dates of irrigation and fertilizer application etc.

Calibration and validation of model

The two field experiments comprising of three varieties and four dates of sowing were conducted to generate data for calibration and validation of the model. The field experiments were conducted during *kharif* 2013 and 2014 at the research farm of the Department of Agronomy, Forage and Grassland Management, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32 ^{0}6'N, 76 ^{0}3'E and 1290.8m amsl). The crop was grown with all recommended package and practices for the experimental station. The crop was inspected at frequent intervals to monitor the phonological events closely. Data on phenology, leaf area, dry matter accumulation, and yield were recorded for calibration of the model. Crop input parameters for maize were calculated by using information from field experiments and a wide literature survey. Further calibration of these coefficients was done by the observations recorded from the field experiment conducted. These coefficients were used in the subsequent validation and application.

Statistical analysis of the model product

Model performance using the coefficients developed was evaluated by calculating root mean square error (RMSE). The RMSE describes mean absolute deviation between predicted and observed values. The accuracy of simulation is characterized by lower RMSE.

Statistical analysis

The statistical analysis for Randomized Block Design (RBD) was carried out by using the methods suggested by Cochran and Cox (1963). Whenever the effects exhibited significance at five percent level of probability, the critical difference was calculated.

The growth and yield attributes data was subjected to statistical analysis and RBD design. The root mean squared error (RMSE) between predicted and observed values was also used to work out the accuracy of the model.

RMSE indicates less deviation of the predicted values from the

observed values

$RMSE = \sqrt{\Sigma(Pi - Oi)^2 / n}$

Where, n is the number of observations; Pi and Oi are predicted and observed values, respectively.

Results and Discussion

Phenological stages: In order to test the model performance in simulated the phonological stages under different date of sowing, Infocrop model was used. The simulation on phenology (days to 50%tassling, days to 50% physiological maturity) revealed that the RMSE values for days taken to tasseling stage were 6.2 days during the year 2013 and 6.4 during the year 2014 which means good fit of model for this parameter (Fig. 1). In case of the physiological maturity days predicted by model corresponded well with that actually observed in the field (Fig 2). The RMSE values for days taken to maturity were 9.2 days during the year 2013 and 13.1 during the year 2014. The results regarding leaf area index revealed that predicted leaf area index does not matched very closely with observed LAI for all the treatments (Fig. 3). The RMSE values for leaf area index ranged from 0.4 to 1.8. Results supported by the research of (Choudhary *et al.*2014). He used Infocrop model in Maize and revealed that the RMSE values for predicted tasseling, physiological maturity and leaf area index was close to observed with a mean error of 5.7, 7.59 and 0.4with reasonably good accuracy (error % less than 10).

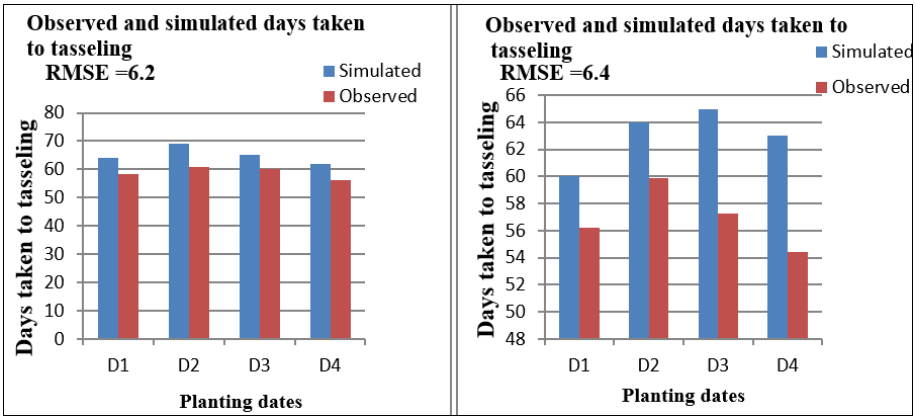


Fig 1: Observed and Simulated days to tasseling stage during the year 2013 and 2014

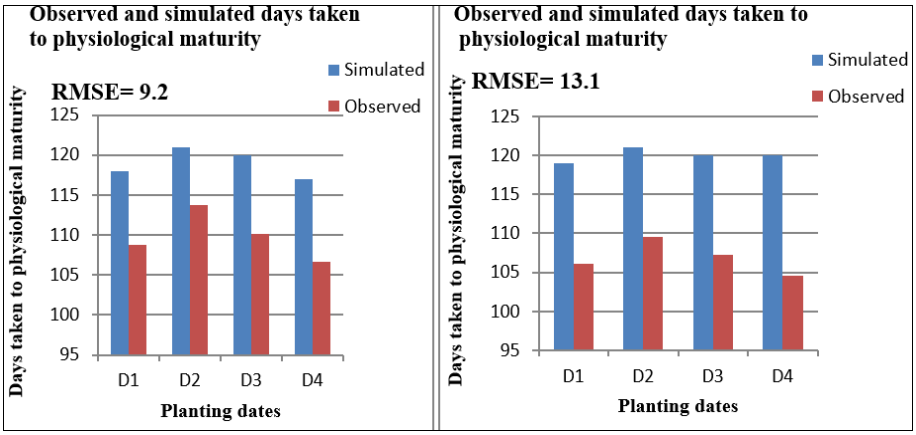
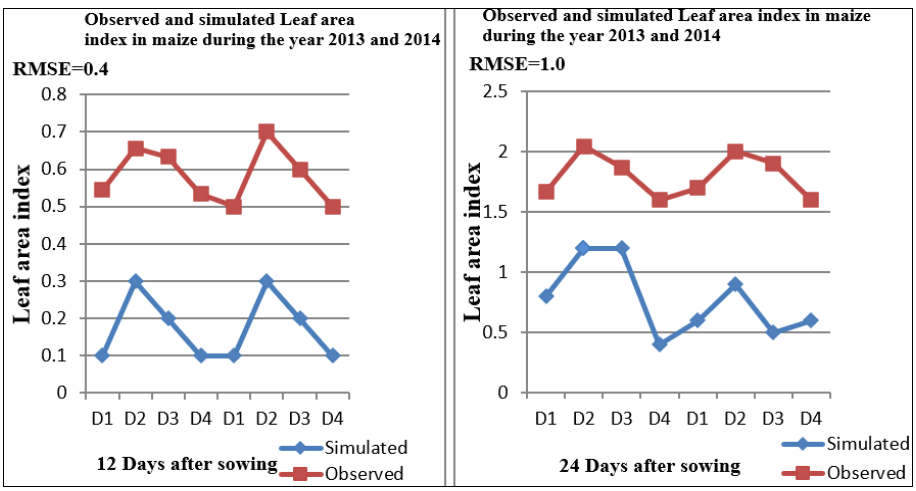


Fig 2: Observed and Simulated days to physiological maturity during2013 and 2014



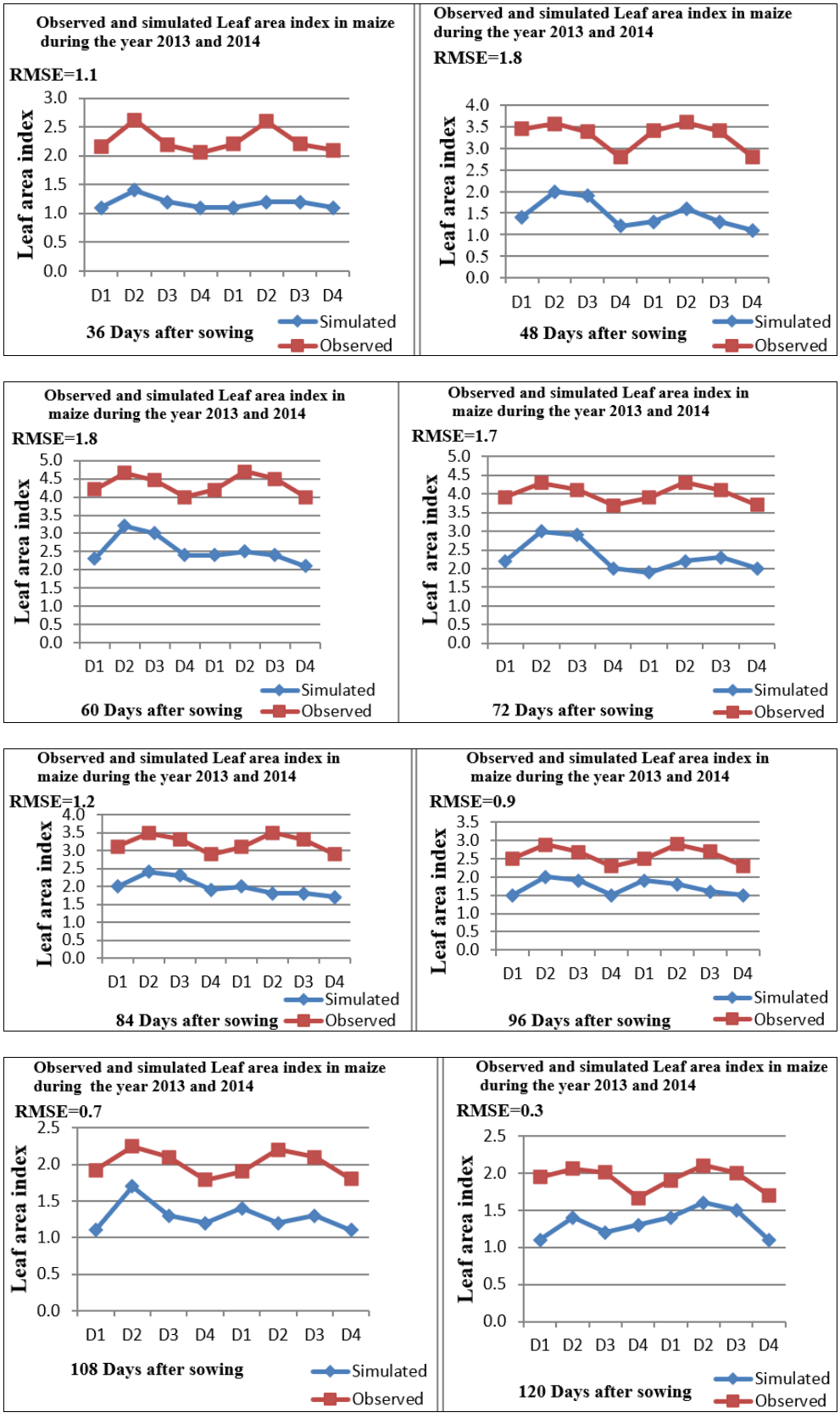


Fig 3: Observed and simulated LAI of maize during the year 2013 and 2014

Grain yield

In case of economic yield simulated yield by model corresponded well with that of actually observed in the field (Fig. 4). The RMSE values for yield 3.2 in 2013 and 2014. Similarly, Ananta *et al*. in 2015 [2] used Infocrop model in Maize and find that the deviation of average actual yield from average pre harvest crop yield was 5.5. From Faizabad, U.P, India, Kumar *et al*. in 2015 [11] used the Infocrop model and reported that model was able to predict the grain yield with reasonably good accuracy (error %less than 10).

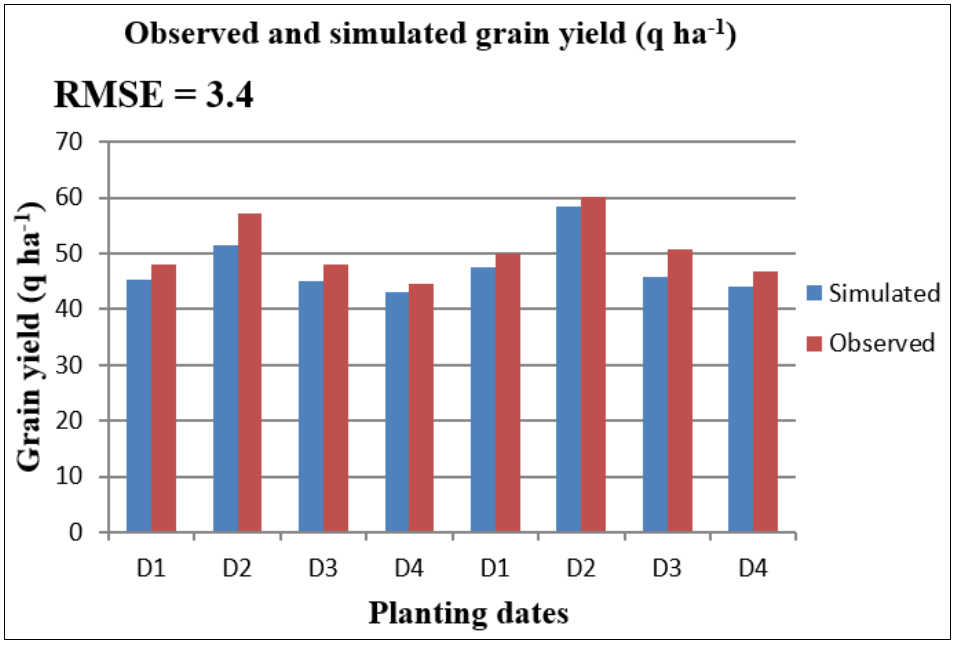
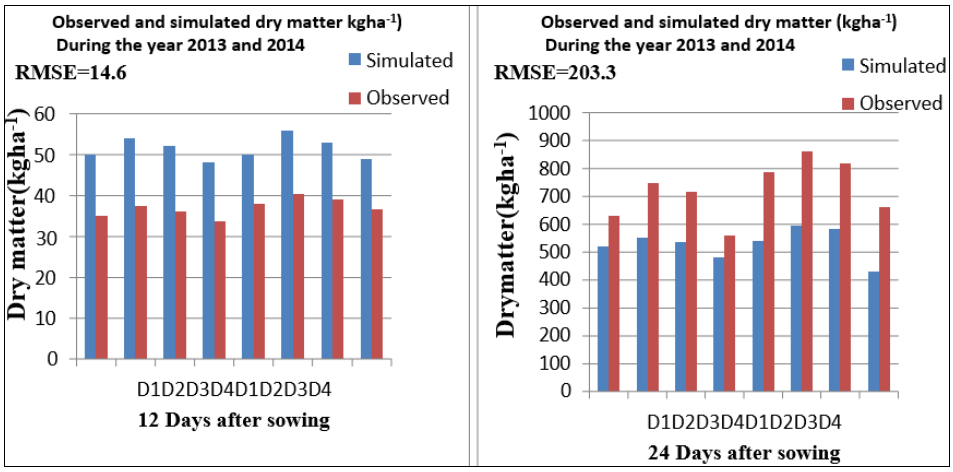
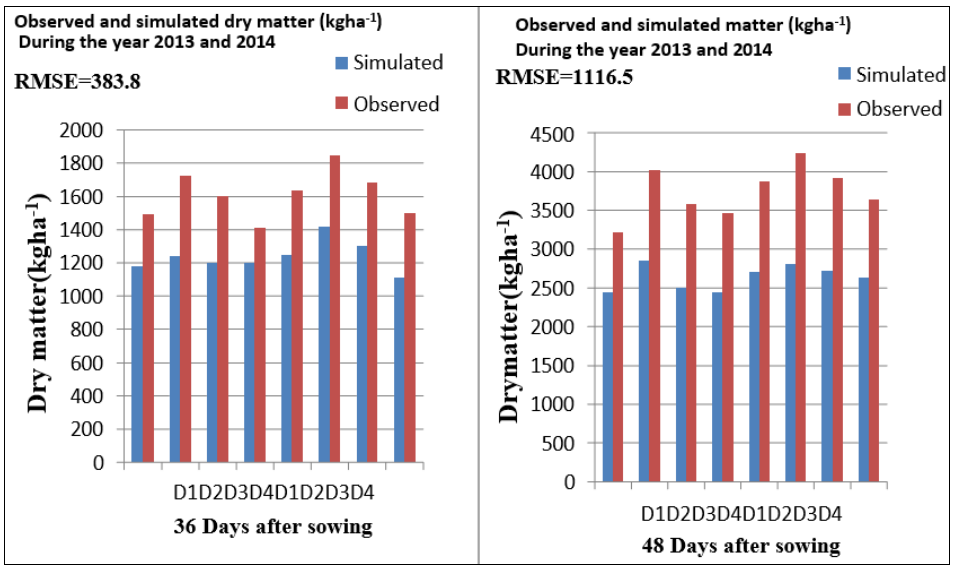


Fig 4: Observed and simulated grain yield qha^{-1}during the year 2013 and 2014

Dry matter

Simulated dry matter accumulation does not match very closely with observed dry matter accumulation for all treatments (Fig. 5). The final RMSE values for dry matter accumulation are 2055.1during the 2013 and 2014.Similar result was found by Fagodiya and his coworkers in 2017 by using Infocrop model in Maize yield prediction resulting 1985 RMSE value for dry matter production





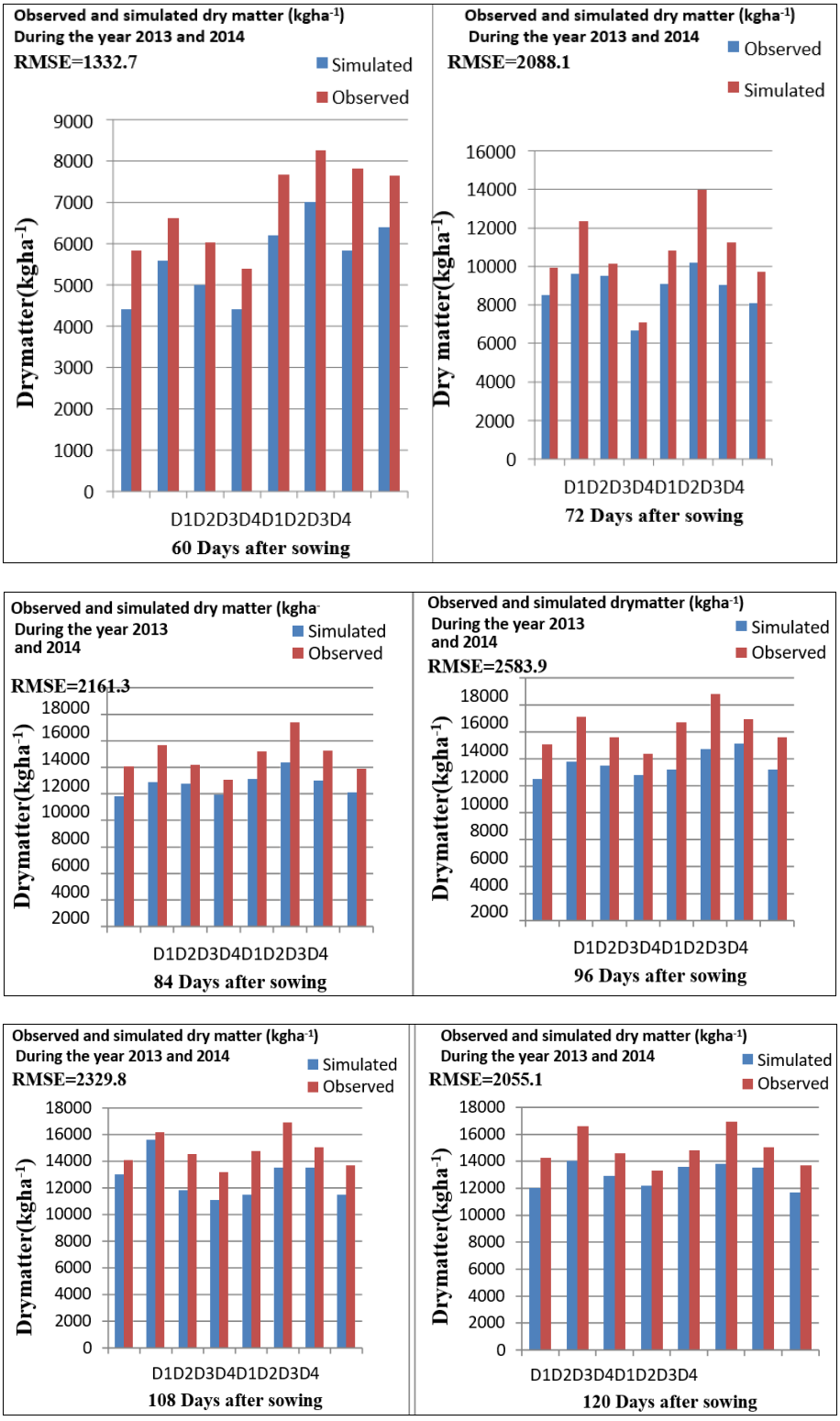


Fig 5: Observed and simulated dry matter (kgha^{-1}) during the year 2013 and 2014

Conclusion

Simulation analysis of Info Crop maize model indicated that this model worked satisfactorily under different date of sowing and calibrated well for the experimental conditions. Model is efficient in simulating the phenology of crop. The model performance was somewhere under estimated or overestimated but found within acceptable limits. However, simulated yield by model corresponded well with that of actually observed in the field. Overall, the InfoCrop maize model worked satisfactorily and calibrated well for Kangra district of Himachal Pradesh and it could be used for simulation of grain yield under different sowing window.

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