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MODELING THE PHENOLOGICAL DEVELOPMENT, GROWTH, AND SEED COTTON YIELD OF PROMISING CULTIVARS AT DIFFERENT PLANTING TIMES

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Abstract

Understanding the optimal planting time and cultivar selection can significantly enhance cotton production efficiency and sustainability. Such insights are crucial for farmers and agricultural planners to make informed decisions that maximize productivity and economic returns. This study aimed to investigate the effects of different planting dates on the phenological development, growth, and seed cotton yield of two cotton cultivars (FH-142 and CIM-616), as well as to simulate these effects using modeling for better crop management. A study conducted at the Central Cotton Research Institute in Multan, Pakistan, the field experiment utilized a randomized complete block design with split-plot arrangement and three replications. The planting dates were April 1, April 15, and May 1. Results showed that CIM-616 superior performance with the maximum leaf area index (LAI) (4.45), leaf area duration (LAD) (444.55 days), total dry matter (TDM) (1540 g m^{-2}), crop growth rate (CGR) (9.88 g m^{-2} d^{-1}), and net assimilation rate (NAR) (3.35 g m^{-2} d^{-1}) when planted on April 1, followed by April 15, and the least on May 1. Phenological observations revealed that CIM-616 planted on April 1 took the longest duration to reach various growth stages and had the highest plant height (134.33 cm), number of bolls (47), sympodial branches (57), and seed cotton yield (3467.33 kg ha^{-1}). Additionally, the CROPGRO-Cotton model was calibrated and evaluated using the field data. The model's predictions for phenology, LAI, and yield closely matched the observed values, with RMSE values indicating good agreement (e.g., RMSE for days to anthesis was 4.47 for FH-142 and 5.83 for CIM-616). The calibrated model accurately simulated the days to anthesis, maturity, and yield at different planting dates, demonstrating its applicability in predicting cotton growth and yield under varying climatic conditions. The study concluded that early planting (April 1) combined with the CIM-616 cultivar resulted in optimal growth and highest yield, emphasizing the importance of planting time and cultivar selection for maximizing cotton yield in the given agro-ecological conditions. The CROPGRO-Cotton model proved to be a valuable tool for simulating and optimizing cotton production.

Keywords: Phenological Development, Growth, Seed Cotton, Modeling, Planting Date, Cultivar, CROPGRO-Cotton Model, Simulation.

1. INTRODUCTION

Cotton (Gossypum hirsiutum) is growing worldwide, and it is an imperative determinant of crude material for material industry. Cotton is known as critical crop all around, giving wellsprings of food, fuel and also fibre for various enterprises. Fibre is utilized in textile industries for paper making while cotton seed for ruminant domesticated animals. Seed oil is right now refined as oil for human utilization and no doubt its biofuel has great potential (Thorp et al., 2014). Cotton takes part significant function in textile industries and millions of people works in those industries for its cultivation, processing and management. Thus cotton is called as cash crop. In Pakistan cotton accounts 5.5 percent in the value addition of agriculture sector and 1.0 percent in GDP (GOP, 2017

Cotton is a plant of tropical as well as subtropical area; however, it has turned out to be broadly developed as a yearly harvest. Cotton plant depend upon natural factors like temperature, sun based radiation, moisture and micronutrients, which impact specifically on the organic and agronomic execution (Broetto *et al.,* 2013). Planting date is among one of the anticipated elements, which is underneath man control and can be marginally changed according to necessities, and thus it is proclaimed as expected variable. Ideal planting date purpose and choice of appropriate variety for particular developing zones are of most extreme significance for high return and nature of cotton.

Planting date can take up a fundamental part in accomplishing greatest seed cotton yield in a nation like Pakistan where the environment fluctuates in different agro-ecological zones. Early planting cotton brings about taller stems, more bolls and seed cotton yield (Arian *et al.,* 2001). Cotton planting at optimum time gives most extreme developing season which harvests top sunlight based radiation and gathers more biomass (Arshad *et al.,* 2007) while late planting presented to difficult temperature at stand foundation phase and super ideal at conceptive stage (Akhter *et al.,* 2002). Various examinations demonstrated that late planting will reduce yield with low boll weight because of delayed development of cotton (Gwathmey and Clement, 2010). Contrasted with optimum planting date, late-planted cotton had fiber with more prominent fibre and lesser micronaire, while strength as well as length of fibre decreased (Liu *et al.,* 2015). Agronomists have additionally grown newly developed cultivar that adjusted to late planting with the pointing of hastening the yield cycle, while decreasing the vegetative life and thus ideal planting date for a cultivar in an area is thought to be the most critical factor in cotton (Bozbek *et al.,* 2006).

Phenology indicates alternating arrival of crop-cycle occasions and is essential for crop existence and proliferation. Environmental variation significantly affects phenological

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regularity in numerous biological places of the world and it demonstrates the normal for dragging out development period length and progressing phenophases (Lu *et al*., 2006).

Increasing in temperatures causes the difference in phonological events. The perfect soil temperature for cotton foundation lies between 16-28^{o}C while beneath 16°C outcome in moderate rise and maximize the seedlings vulnerability to soil borne diseases. Increase in temperature will change phenology, including begins and span of phenology and level of shocking atmosphere occasions, for example, warm pressure and frosty stuns. These progressions may have critical results for cotton build up yield (Luo *et al.,* 2014). Temperature directs huge numbers of the physical and chemical substance forms inside the plant, which control the rate of development and improvement towards development. Temperature altogether influences phenology, leaf extension, distance between inter node, total dry matter and various plant parts (Sankarnarayanan *et al.,* 2010).

Cotton cultivars that have extensive variety of adoptability require diverse aggregate quantities of growing degree days for their development, advancement, and yield. Concentrates on the timings of phenological incidents, ideal circumstances for each phenophase and association with yield determinate are fundamental to support up cotton efficiency for appropriate planting date and variety under fluctuating natural situations. Thus the objective of this trial was to investigate the best cultivar through its thermal time and to present the impact of planting date on pheno phases as well as seed cotton yield.

Most of the time, mechanistic crop models are used to look into how genetics and the environment might interact in different management scenarios (Ahmad et al. 2023, 2017; Abbas et al. 2023; Ahmed and Ahmad 2020; Ahmed et al. 2018). These tools help to quickly look into the results of many different combinations of factors that affect field crops, land, weather, and how to manage their growth and yield (Jones et al. 2003). Crop modeling is used all over the world to study which crops grow and develop in different climates so that risks are kept to a minimum. Simulation models can help with making predictions and can give new needs and aspects in agricultural research information that is hard to get from long-term field experiments (McCown et al. 2002; Bindi and Maselli 2001). Calibration is the process of setting a model to a reference system. It is done by changing internal factors to match the input/output data set so that the model's representation is homomorphic (Hofmann 2005). Several scientists around the world have used the Decision Support System for Agrotechnology Transfer (DSSAT) to model the growth and output of different crops by using data on the weather, soil, and crops that have been seen in the field (Hoogenboom 2023; Boote et al. 1996).

DSSAT is made up of crop template, organic carbon, and weather parts that make up its modular structure. Also, a specific tool to model how plants, soil, and the climate share energy, light, and water (Mack et al. 2020). Due to CROPGRO is generic, it can be used to model the growth and development of other crop species without making major changes to the source code. Instead, it needs to use external files to explain the species, ecotype, and variety to tell the difference between soybean, peanut, dry bean, and safflower. The species file (Jones et al. 2003) has well-defined cardinal temperatures for

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different stages of growth and development, such as leaf phenology, photosynthesis and seed growth. Using physiological indicators, CROPGRO gives us a way to study plant and environment traits and make predictions about crop growth and development under current conditions like soil, weather, and crop management (Jones et al. 2003; Boote et al. 1998a, b). Additionally, variety files show how different crops either speed up or slow down their growth depending on the length of the day (Boote et al. 2002). It is a process-based model that uses a daily time step to figure out how the features of the land and crops change (Lobell and Asseng 2017). Hence current study was conducted with the objective to evaluate the CSM-CROPGRO cotton model for simulation of phenology and yield under different climatic conditions.

2. MATERIALS AND METHODS

The experiment was performed under field conditions of arid sub-tropical climate to examine the response of growth, phenology and seed cotton yield of promising cultivars at different planting dates on silt loam soils having pH;8.11 at Central Cotton Research Institute, Multan. The design used was RCBD with split plot arrangement and thrice replicates. Cotton crop was planted on three planting dates; April 01, April 16 and May 01 with row-row 75 cm and plant-plant 30 cm distance. Land was prepared in the form of bed-furrows by using pre-planting. Herbicide was sprayed with a device which is fitted on bed shaper at the time of bed-furrows shaping. The seeds were dibbled manually. The furrows were irrigated 72 hours after planting to obtain maximum seed emergence. However, gap filling was done where seed were not germinated. Phosphorous fertilizer was applied 60 kg Phosphorous ha^{-1} in TSP (46% Phosphorous) and 100 Kg ha^{-1} in urea form with three splits. All other practices were kept normal throughout cropping season.

2.1. Weather Condition

Average monthly temperature (^{0}C), Average monthly relative humidity (%), Average daily wind (km h^{-1}) and Average monthly sunshine hours data collected from Central Cotton Research Institute, Multan (CCRI) and recorded (Table 1).

Table 1: Mean weather data recorded during whole crop season

Month	Average Temperature (ºC)	Relative Humidity (%)	Daily total wind km/hr	Sunshine Hours
April	30.01	53.48	5.53	6.26
May	33.96	63.06	6.67	4.83
June	33.11	74.91	7.48	4.53
July	33.66	73.01	7.17	7.16
August	31.77	85.20	7.38	7.72
September	30.58	77.08	4.34	8.00
October	27.01	77.56	2.42	7.44
November	18.03	81.43	2.68	3.71

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Treatments:

The experiment contains following treatments.

Factor A: Planting dates (main plots)

1. April 01 2. April 15 3. May 01

Factor B: Bt. Cotton cultivars (sub plots)

1. FH-142 (FH: Faisalabad Hybrid)
2. CIM-616 (CIM: Cotton Institute Multan)

2.2. Sampling observations

The observation was recorded after the establishment of crop; three randomly selected plants per genotype per replication for all traits from one square meter were recorded at 15 days interval. After pulling the three fresh plant from the soil fresh weight of stem and leaves were measured with the help of calibrated electronic balance and then separately measured the stem, leaves and enveloped it. Sub sample of 5g of leaf for leaf area measured with leaf area meter and image J software (Bakr, 2005). The sub sample was sun dried and put the sample to oven at 60°C and then dry weight measured.

All the management practices (Agronomic) kept constant. Growth and phenology data recorded during the whole crop season and yield related components were observed by harvesting the cotton crop at maturity.

2.3. CSM-CROPGRO cotton model

DSSAT-CSM version 4.8.2 has broad range of applicability in diverse climatic conditions and was developed from CROPGRO-Cotton model (Hoogenboom et al. 2023). It simulates carbon, nitrogen and hydrological processes in soil plant system and transforms them using balanced mass principals. Weather and prevailing soil conditions affect simulation of crop developmental phases such as emergence, first leaf, flower initiation and physiological maturity based on photothermal heat units (Jones et al. 2003).

Data collected from field of experiment in 2017 season was calibrated and evaluated by CROPGRO-Cotton model. Input data i.e. Weather and soil data, Plant characteristics and management of crop was used in Model. Crop genetic coefficients was calculated by Decision support system for Agro-Technology Transfer (DSSAT) program, which analysis based on sub module sensitivity by picking best treatment and unselect other treatments. Data of 2017 year was used for model running and calibration and genetic coefficient calculation and evaluation by running remaining treatments.

CROPGROW-Cotton Model was created by the researchers of IBNAST (International Benchmark Sites Network) venture was keep running inside DSSAT (Hoogenboom et al., 1994) condition. This model has abilities to mimic every day crop growth, development, and yield under various arrangement of climatic and soil conditions with various agronomic administrations and in this way it was chosen for the examination to anticipate

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for future climate perceptions (most extreme temperature, least temperature, precipitation sun oriented radiation), Site data (latitude, longitude, altitude, soil physical, substance and morphological properties),crop administration information with respect to tillage, plant population, planting geometry, seed rate, planting depth, water system application, fertilizer, detail of chemicals and of genetic coefficients that depicts cultivars development and seed cotton/lint biomass and means of treatments in model dialect (A& T files) are required to run the model.

2.4. Model calibration

Calibration is a procedure of altering some model parameters to our own particular conditions. It is additionally vital for getting genetic co-effective for new cultivars utilized as a part of model study. Thus, the model was calibrated with information (that included phenology, biomass, LAI, and yield components) gathered year 2017 against treatment, April planting, cultivar VH-327 that performed best in field trial. Cultivar co-proficient progressively beginning from CSDL (critical short-day length) and PPSEN slope of the relative reaction to advancement to photoperiod with time to PODOUR, the time required for cultivar to achieve pod load under ideal conditions (Photo Thermal Days). 24 numbers set of coefficients control the phenology, development and seed cotton yield (Hoogenboom et al., 1994). To choose the most appropriate arrangement of coefficients an iterative approach proposed by Hunt et al., (1993) was utilized.

2.5. Model Evaluation:

Calibrated model in optimal condition simulation performance check was necessary. CROPGRO-Cotton model which is calibrated was evaluated with remaining treatments. Computing Statistical indices simulated model performance was checked.

$$\text{RMSE} = \left[\sum_{i=1}^{n} \frac{(P_i - O_i)^2}{n}\right]^{0.5}$$

$$\text{MPD} = \left[\sum_{i=1}^{n} \left(\frac{|O_i - P_i|}{O_i}\right) 100\right] / n$$

$$Error\ (\%) = \left(\frac{p - o}{o}\right) 100$$

$$\text{d} = 1 - \left[\frac{\sum_{i=1}^{n} (P_i - O_i)^2}{\sum_{i=1}^{n} \left(|p'_i| + |o'_i|\right)^2}\right]$$

Number of observation is n and predicted value is P_i, and observed value is $O_i$for variable study.

2.6. Statistical analysis

Statistically presented parameters were measured by applying Fisher's analysis of variance technique and *least significant difference test* at 5% probability level applied to compare with treatment means (Steel *et al.*, 1997).

3. RESULTS

3.1. Effect of planting date and cotton cultivars on growth

3.1.1. Leaf area index

Leaf area index (LAI) gradually increased till reproductive stage and obtained maximum value and then exhibited decreasing trend after reproductive phase in an increasing ratio. Different planting time also showed significant difference among LAI patterns. Data regarded to LAI (Table 2) showed that April 01 planting attained maximum LAI (4.45) in CIM-616 as compared to FH-142 (4.35) and delayed planting (May 01) LAI reduced to (4.16) in CIM-616 and (4.07) in FH-142 due to higher photo thermal and heat index accumulation. Genotypic variations exist in maximum LAI that is broad leaf varieties CIM-616 (4.45) attained more LAI than FH-142 (4.35).

3.1.2. Leaf area duration (days)

Leaf area duration (LAD) showed similar trends like LAI and biomass accumulation gradually increased up to 120 days after planting. Significant differences detected in LAD for planting time and cultivar. Data depicted to planting time effect on leaf area duration (Table 2), indicated more LAD which was sowed on April 01 (444 days) in CIM-616 as compared to FH-142 (427 days) but less LAD observed at planting time May 01 in CIM-616 (399 days) and FH-142 (386 days). Significant genotypic variations also exist due to leaf and canopy architecture differences.

3.1.3. Total dry matter production (g m^{-2})

Significant differences were observed in total dry matter production (TDM) for different planting time and different genotype during the whole crop season. Similar trends were indicated like LAI and LAD in total biomass production between different cultivars due to genetic variation. Production of TDM (Table 2) indicated that planting on April 01 accumulate more biomass (1540 g m^{-2}) in CIM-616 as related to FH-142 (1393 g m^{-2}) while less TDM occurred on May 01 planting in FH-142 (1220.11 g m^{-2}) as compared to CIM-616 in (1313 g m^{-2}).

3.1.4. Crop growth rate and Net assimilation rate

Data pertaining to crop growth rate (CGR) & Net assimilation rate (NAR) (Table 2) exhibited highest CGR & NAR for April 01 planting time whereas cotton sowed on May 1 showed least CGR & NAR. Iqbal (2011) observed that CGR significantly influence by planting time and genotype. He was also indicated early planting have more CGR than late planting.

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Table 2: Effect of planting date and cotton cultivars on Growth

Cultivars	Planting Date	Leaf area index	Leaf area duration (days)	Total dry matter production (g m^{-2})	Crop growth rate (g m^{-2} d^{-1})	Net assimilation rate (g m^{-2} d^{-1})
FH-142	**April 01**	4.35	427	1393	9.22	3.25
	April 15	4.21	411	1320	8.63	3.16
	May 01	4.07	386	1220	7.88	3.07
CIM-616	**April 01**	4.45	444	1540	9.88	3.35
	April 15	4.29	417	1390	9.16	3.30
	May 01	4.16	399	1313	8.45	3.19

3.2. Effect of planting date and cotton cultivars on phenology

Number of days taken from planting to germination, planting to first floral buds, planting to first flower, planting to first boll opening & planting to maturation period was more on both cultivars sowed on Aril 1 as compared to the May 1 cultivation (Table 3). It was also concluded that CIM-616 performed better at early planting as compared to FH-142 on all recorded phenology.

Table 3: Effect of planting date and cotton cultivars on phenology

Cultivars	Planting Date	Planting to emergence (days)	Planting to first floral bud (days)	Planting to first flower (days)	Planting to first boll opening (days)	Boll maturation period (days)
FH-142	**April 01**	6.66	41	69	115	156
	April 15	6	40	63	114	153
	May 01	5.66	38	58	110	152
CIM-616	**April 01**	7.66	47	75	119	161
	April 15	7	42	70	116	158
	May 01	6	39	64	113	154

3.3. Yield and yield related component

The data about plant height (Table 4) showed statistically significant influence of planting time and cultivar. Both the cultivars used in this research gave best results on early planting CIM-616 (134.33 cm) and FH-142 (115.33 cm) as compared to the late planting CIM-616 (112.67 cm) and FH-142 (101.67cm).

Data depicted about the number of bolls (Table 4) indicated that early planting had a greater number of bolls in CIM-616 (47) and FH-142 (40) compared to the late planting CIM-616 (39) and FH-142 (34). Buttar and Singh (2006) observed that more number of bolls were obtained in early planting as compared to late planting of cotton crop. Based on planting time number of opened ball was found to be more in early planting CIM-616 (43) and FH-142 (39) compared to late planting CIM-616 (32) and FH-142 (28). Optimum environmental conditions are necessary for the opening of bolls. Based on planting time a greater number of sympodial branches were observed early planting in CIM-616 (57) and FH-142 (50). While minimum number of sympodial branches noted in late planting CIM-616 (25) and FH-142 (24). The data related to average boll weight (Table 4) showed significant influence of planting time and cultivars. Cultivar CIM-616 and FH-142 which

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sowed late, showed more average boll weight (3.51 g) and (3.21 g) respectively as compared to early planting CIM-616 (3.18 g) and FH-142 (3.02). Early planting time gave more weight of 100-cotton seed in CIM-616 (6.79 g) and FH-142 (6.09 g) while less weight was observed at late planting in CIM-616 (5.58 g) and FH-142 (4.81 g). Maximum seed cotton yield was obtained in early planting for both the cultivars CIM-616 (3467.33 Kg ha^{-1}) and FH-142 (3061.33 Kg ha^{-1}) whereas minimum yield was obtained in late planting CIM-616 (2370.67 Kg ha^{-1}) and FH-142 (2171.33 Kg ha^{-1}).

Table 4: Effect of planting date and cotton cultivars on yield and yield related components

Cultivars	Planting Date	Plant height (cm)	Number of total bolls per plant	Number of opened bolls per plant	Number of sympodial braches per plant	Average boll weight (g)	weight of 100-cotton seeds	Seed cotton yield (kg ha^{-1})
FH-142	**April 01**	115.33	40	39	50	3.02	6.09	3061.33
	April 15	108.673	37	34	41	3.11	5.77	2380.67
	May 01	101.67	34	28	24	3.25	4.81	2171.33
CIM-616	**April 01**	134.33	47	43	57	3.18	6.79	3467.33
	April 15	126.33	41	37	45	3.34	6.33	2771.67
	May 01	112.67	39	32	25	3.51	5.58	2370.67

3.4. CROPGRO-Cotton Model Calibration

Calibration is a procedure of modifying some model parameters to our own conditions. It is additionally essential for getting genetic co-efficient for new cultivars utilized in modeling. Along these lines, the model was calibrated with data (that included phenology, biomass, LAI, and yield components) gathered year 201 against treatment, April sowing, cultivar CIM-616 that performed best in field trial. Cultivar co-productive progressively beginning from CSDL (basic short-day length) and PPSEN incline of the relative reaction to advancement to photoperiod with time to PODOUR, the time required for cultivar to achieve last pod weight under ideal conditions (Photo Thermal Days). 24 numbers set of coefficients control the phenology, development and seed cotton yield (Hoogenboom et al., 1994).

Table 5: Calculated Genetic coefficients for three cotton cultivars during CROPGRO-Cotton Model Calibration

ECO #	VRNAME	CSDL	PPSEN	EM-FL	FL-SH	FL-SD	SD-PM	FL-LF	LFMAX	SLAVR	SIZLF	XRFT	WTPSD	SFDUR	SDPDV	PODUR	THRSH
FH0002	FH-142	23.00	0.01	55	09.0	28.0	49	52.00	1..06	290.	126.0	2.61	0.080	30.0	25.00	10.0	71.0
MT0006	CIM-616	23.00	0.01	61	10.0	30.0	51	75.00	1.10	136.	250.0	2.61	0.120	30.0	05.00	18.0	92.0

CSDL= Critical Short Day Length below which reproductive development progresses with no day length effect (for short day plants) (hour

PPSEN = Slope of the relative response of development to photoperiod with time (positive for short day plants) (1/hour)

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EM-FL = Time between plant emergence and flower appearance (R1) (photo thermal days)

FL-SH = Time between first flower and first pod (R3) (photo thermal days)

FL-SD = Time between first flower and first seed (R5) (photo thermal days)

SD-PM = Time between first seed (R5) and physiological maturity (R7) (photo thermal days)

FL-LF = Time between first flower (R1) and end of leaf expansion

LFMAX = Maximum leaf photosynthesis rate at 30 C, 360 vpm CO_2, and high light (mg CO_2/m^2-s)

SLAVR = Specific leaf area of cultivar under standard growth conditions (cm^2/g)

SIZLF= Maximum size of full leaf (three leaflets) (cm^2)

XFRT = Maximum fraction of daily growth that is partitioned to seed + shell

WTPSD = Maximum weight per seed (g)

SFDUR = Seed filling duration for pod cohort at standard growth conditions (photo thermal days)

SDPDV = Average seed per pod under standard growing conditions (#/pod)

PODUR = Time required for cultivar to reach final pod load under optimal conditions (photo thermal days)

THRSH **=** Threshing percentage. The maximum ratio of (seed/(seed+shell)) at maturity. Causes seeds to stop growing as their dry weight increases until the shells are filled in a c

3.4.1. Model Calibration

The data depicted that the model predicted the phenological, physiological and yield attributes closely with observed values (Table 6). The phenological events as day to anthesis in both the cultivars were simulated quite accurately with RMSE value of (2 and 1) for CIM-616 and FH-142. The LAI value of simulation was close with observed in genotype CIM-616 as compared to genotype FH-142 with RMSE value of (1.12) and (0.17) respectively. Calibrated data for maturation days with recorded data showed RMSE value of (2) and (4) for FH-142 and CIM-616 respectively. The simulated pods yield was quite close with observed data within a good range with RMSE value of (236) and (585) for FH-142 and CIM-616 respectively.

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Table 6: Simulated phenology, leaf area index (LAI), maturation days and seed cotton yield (kg ha^{-1}) in CROPGRO-Cotton model during calibration

Cultivars	Anthesis			Maturation Days			Emergence Day			Yield kg/ha			LAI		
	Obs.	Sim.	RMSE	Obs.	Sim.	RMSE	Obs.	Sim.	RMSE	Obs.	Sim.	RMSE	Obs.	Sim.	RMSE
FH-142	70	68	2	155	153	2	5	5	0	3061	2825	236	4.3	4.47	0.17
CIM-616	76	75	1	160	164	4	6	5	1	3467	2882	585	4.4	3.28	1.12

3.4.2. Model Evaluation

The model was evaluated with remaining treatments of the experiment conducted at Multan during Kharif season 2017.

3.4.2.1. Days to Anthesis

The simulated value of model for days to anthesis is in good agreement with observed value. The model results of evaluation are shown in Figure (1) and (2) by plotting 1:1 graph between observed and simulated data. The model predicted days to flowering with RMSE value of 4.472 for Cultivar FH-142 in second and third planting date with d-statistics of (0.6) data showed in table (8). The simulated RMSE value for days to anthesis was 5.83 of cultivar CIM-616 in second and third sowing with d-statistics value of 0.58 data showed in table (7). The model performed well with cultivar CIM-616.

3.4.2.2. Days to Maturity

Maturity days simulation is in accordance to recorded data. Model evaluation results were shown in figure (2) and (2). The model simulated RMSE value for days to maturity was (1) of genotype FH-142 in second and third sowing time with d-stat value of (0.88) showed in table (8). Model predicted the RMSE value for days to maturity was (8) of cultivar CIM-616 in second and third sowing having a degree of agreement value of (0.38) showed in table (7). The model simulation was good for genotype BARI-2016.

3.4.2.3. Leaf Area Index

The observed and simulated LAI values are in good agreement with each other. The model results are depicted in figure (1) and (2). The model simulated RMSE value for leaf area index was (0.48) with degree of agreement (0.12) for cultivar FH-142 in second and third sowing times, showed in table (7 and 8). The model simulated well for CIM-616 cultivar and their RMSE value was (0.56).

3.4.2.4. Yield at maturity (kg/ha)

The observed and simulated yield for all treatments during 2017 Kharif season is compared and shown in figure (1) and (2). The results showed that the RMSE and degree of agreement values for simulated yield of FH-142 was (175.11) and (0.72) respectively, indicated in table (8). Models yield simulated RMSE and degree of agreement value for second and third sowing of CIM-616 was (177.17) and (0.90) respectively, data in Table (7).

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Table 7: Simulated and observed emergence, LAI, anthesis, maturity days and yield of genotype CIM-616 under evaluation of CROPGRO-Cotton model

Variable Name	Mean		RMSE	d-Stat.
	Observed	Simulated		
Anthesis day	69	74	5.831	0.585
Emergence	6	7	1	0.8
Mat Yield kg/ha	2570	2654	177.17	0.90
Maturity day	155	163	8	0.38

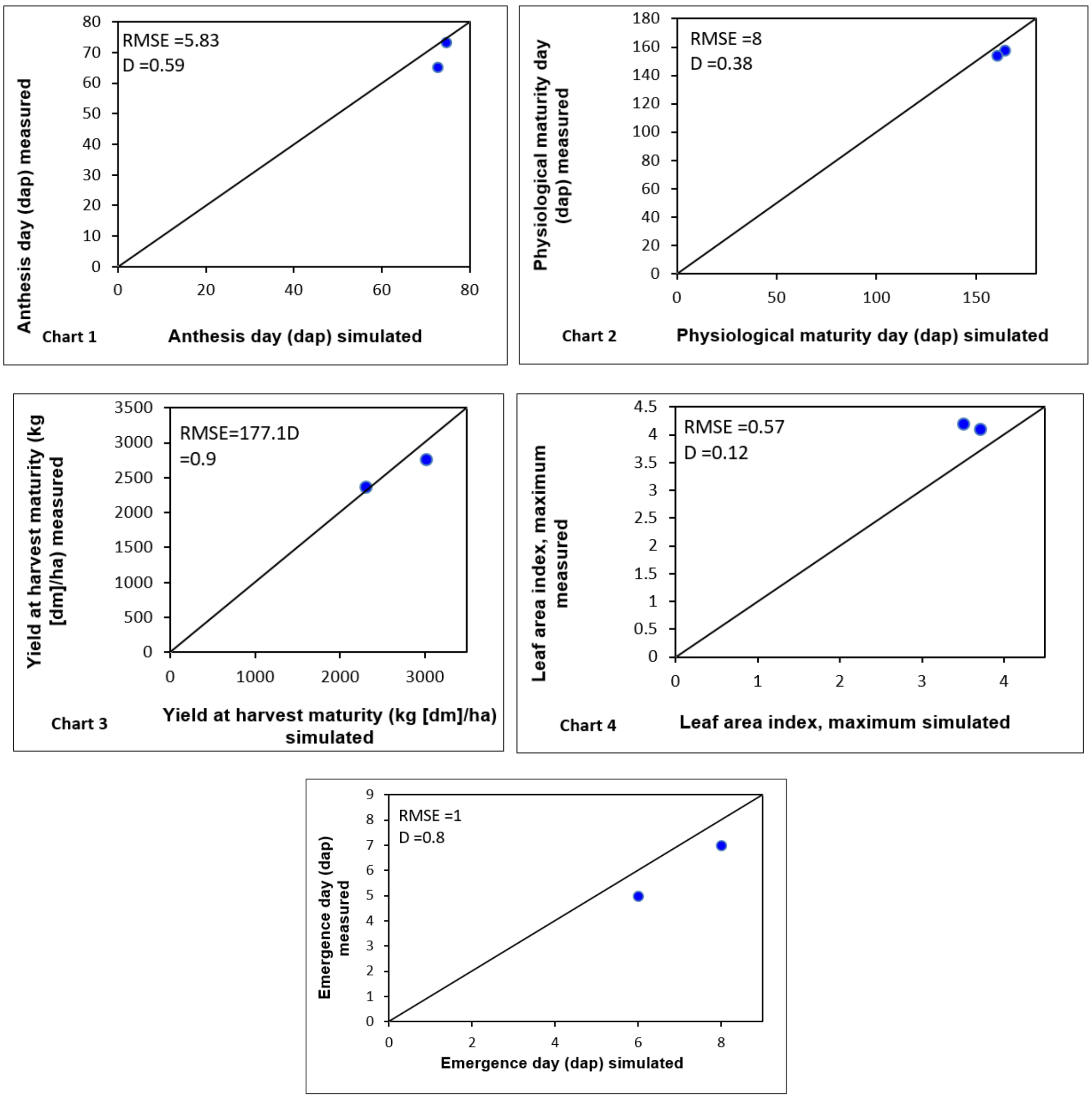

Figure 1: Performance of model for CIM-616 under temporal variations

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Table 8: Simulated and observed data for emergence, LAI, yield at maturity, yield of genotype FH-142 under evaluation of CROPGRO-Cotton model

Variable Name	Mean		RMSE	d-Stat.
	Observed	Simulated		
Anthesis day	63	67	4.47	0.6
Emergence	5	7	2	0.6
Yield (kg ha^{-1})	2276	2126	175.11	0.72
LAI maximum	4.1	4.47	0.48	0.12
Maturity day	151	151	1	0.88

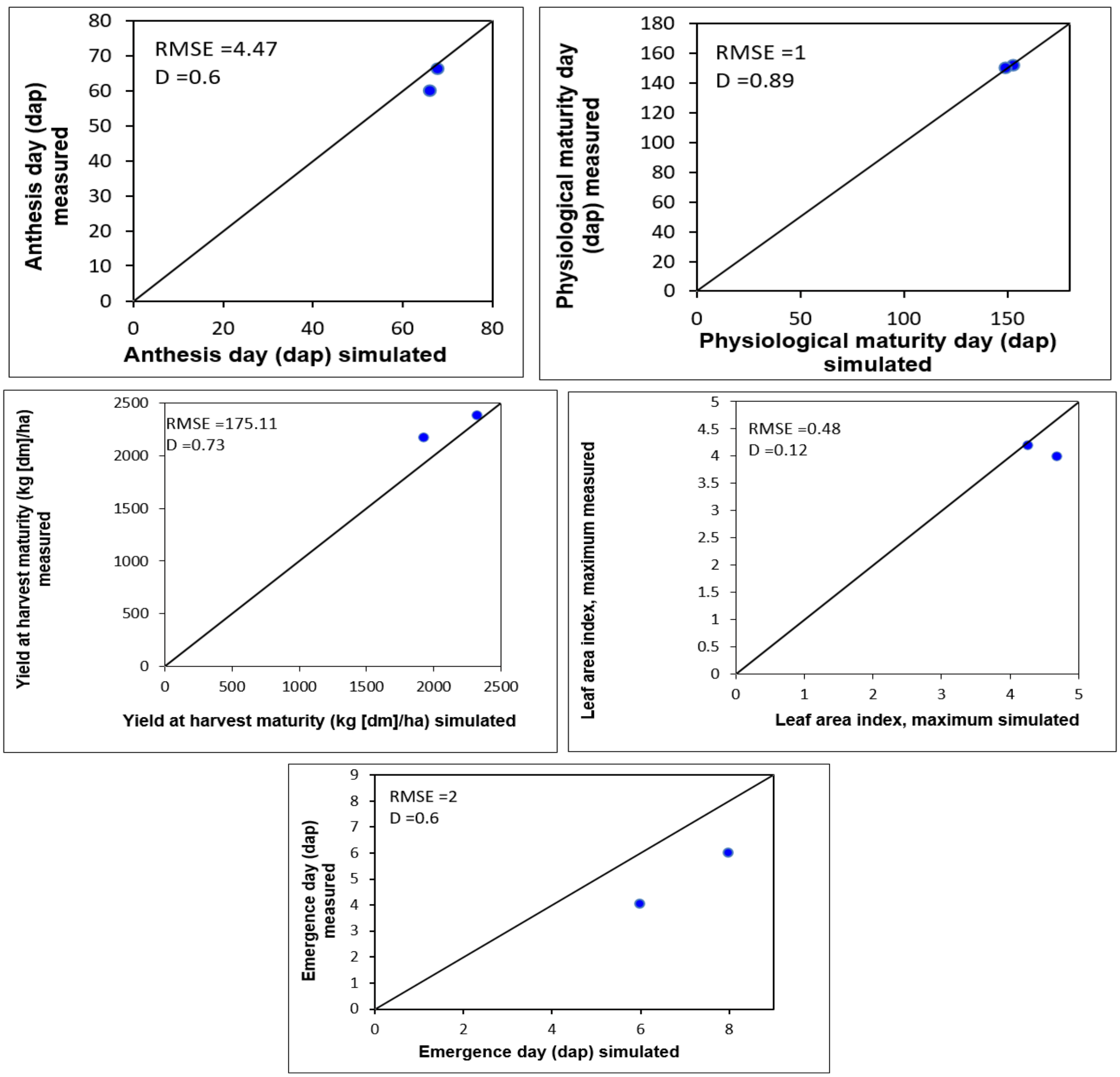

Figure 2: Performance of model for FH-142 under temporal variations

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4. DISCUSSION

Individual effect of planting times and cultivar shows highly significant results than their combinations. Similar findings were also observed by Wajid et al. (2014). Similar results noted by Arshad (2006) that LAD was significantly difference with different planting time and cotton cultivar. He also indicated that earlier planting has more LAD than late planting of cotton cultivar. Similar result was obtained by Iqbal (2011) that TDM significantly different with different planting time and genotype. Different in biomass production is due to the variation in day and night duration, temperature, longer day (more sunshine hours), shorter days (less sunshine hours), heat stroke and cold shock may affected the TDM (Sawan et al., 2002). Similar result was observed by Ali et al. (2009) and Iqbal (2011) that plant height is varietal character that greatly influenced by planting time. Different genotype gained different plant height at different planting time due to difference in their genetic makeup. At earlier planting, crop have more time to obtain maximum height before reaching at their maturity stage than late planting time. Similar findings were observed by Bozbek et al. (2006) and Wrather et al. (2008). They indicated that early planting produced more number of bolls because of suitable climate condition of the cotton crop than in late planting. Early planting have more number of opened bolls as compared to the late planting due to environmental fluctuation and this results was similar to the research conducted by Arshad et al. (2007). Our consequences were similar with that conclusion of Buttar and Singh (2006). Planting time significantly influences average bolls weight because of fluctuation in environmental circumstances of various planting time. Singh et al. (2007) reported that various genotype have various weight of 100-cotton seed (seed index), each cultivar have significantly different from each other and perform differently in various environmental conditions. Similar results were observed by Ali and Khan (2007). Iqbal (2011) reported that delayed planting was the only cause of reduction in seed cotton yield. It was also noted that cultivar CIM-616 gave the highest yield on different planting time compared to the cultivar FH-142. Rahman et al. (2017) reported that late planting reduced seed cotton yield in all cultivars due to short period of growing cycle, high temperature and lower total dry matter production is the cause of reduction in yield.

5. CONCLUSION

It was concluded that the early planting of cotton utilize the existing resources and promote the growth, development and yield characteristics than late sown crop. Genotypes also influence different growth and yield parameters significantly. Planting dates in combination with different cultivars can improve plant growth, development and yield attributes. CIM-616 in combination with early (01 April) planting performs best and gave higher crop yield as compared to FH-142. Thus, late sown crop reduces the usage of environment resources to obtain optimum growth and yield of cotton. It is significantly vital for farmers to know that yield of cotton is not being achieved due to genotypes and temporal variations.

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Conflict Of Interest

We declare that current article is original and has not been submitted for publication, in part or in whole, to any other national or international journal.

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