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Simulation of Wheat Cultivar Response to Irrigation Treatments using of CERES-Wheat Model

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Abstract: Problem statement: Crop models are used as tools for enhancing agricultural research through the identification of gaps in knowledge as well as by providing support for decision making in agricultural planning. **Approach:** In order to evaluation of CERES-Wheat model on five cultivars of winter wheat under Karaj weather condition in Full Irrigation (FI) and Terminal Irrigation at Flowering (TIF) an experiment conducted in form of split plot in based on randomize complete block design with four replicate in research field Islamic Azad university of Karaj branch in 2009. **Results:** Two irrigation levels located in main plot and cultivars as sub plot. In this study simulation of some traits such Grain Yield (GY), Leaf Dry Weight (LDW), Plant Height (PH), Biomass (B), Leaf Number per plant (LN) and Leaf Area Index (LAI) evaluated by use of CERES-Wheat model. According to simulation results, model was successful in simulation of traits whole under two irrigation treatments. Rate of R^2 was low in regression curve of measured versus simulated for traits of LAI and LDW. Model simulated GY with high vigor for both irrigation conditions. **Conclusion/Recommendations:** Variation dimension of R^2 in FI and SI obtained 80.89-80.91 and 80.88-81.01, respectively. The variation dimension of Wilmot coefficient (d) FI and TIF is 0.73-0.75 and 0.61-0.72, respectively. Simulation precise in TIF is lower than FI. We can after evaluation and calibration model by means of experimental replication and reduce of Root Mean Square Error (RMSE) as a result used for research objective management programming in Karaj zones. We proposed for increasing predicting precise by model must be determinate genetic coefficient correctly and soil data and weather data supplied in experimental filed.

Key words: Wheat, simulation, CERES-Wheat model, irrigation

INTRODUCTION

Drought stress is one of the limited factors crop yield in arid and semiarid zone in the world (Ozturk and Aydin, 2004). Iran with annual precipitation mean 240 mm was part of this zone (Andarsian *et al*., 2005). Environmental tension such salting (soil and water) and water deficit were main preventives in world crop production specially Iran (Bakhshandeh, 2006). According reports of Johnston and Fowler (1992) the most sensitive wheat development stage toward drought is flowering stage. The water stress after flowering, probably via damage to seed fertility process can be reduced seed number per year. Drought stress in flower component production to grain filling stage because of fertilize ear decrease and seed number per ear decrease cause grain yield loss (Emam *et al*., 2007). Access to identification and management of yield limitation factors, need to achievement continual expensive experiment in multiple years and location therefore is necessary finding a method for expensive decreasing (Goudriaan, 1977).

Today achieve of this important order using simulation of vegetative and reproductive growth

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processes was possible by computer software's in basis of mathematical equation and evaluate of much effective variable on grain yield (Wolfram, 1991). Simulation models were used, noticeable for improvement crop production management (Mahallati, 2000). In arid and semi-arid zones water deficit is one of main limitations in agriculture improvement therefore increasing of Water Use Efficiency (WUE) in this areas have been significant. The models that effects of water different content simulated in based its quantity was useful tools for irrigation management and WUE developed (Alizadeh *et al*., 2010). According to many report researchers by CERES-Wheat model designated quantity effect in different climate, environment and management parameters on wheat production in base on different strategy such evaluate of different variety production, different planting date, study of nitrogen consume content and time and also simulated this factors with long time weather data on wheat growth and development at zonal and international levels (Bouman *et al*., 1996; Boote *et al*., 2001). In other hand, in basis of extension applied CERES-Wheat model in different production condition especially water and salt stress that is prevalent in my crop production system and also economical limitation in agriculture researches in my country using of this model have significant duties (Kiani, 2002). Ghaffari *et al*. (2001) explained to help of CERES-Wheat model that grain yield to variation 6.9-7.8 ton/ha as different off between simulated and actual data was 0.24 ton/ha (less of mean 10%) in Kent, England. Also by using of this model grain yield potential simulated in six zones as its variation dimension calculated to 8995-9894 kg/ha at different years. Hundale and Kaor (1997) in order to predicting of wheat grain yield in aqua plains of Panjab, India by use of CERES-Wheat model and climate weather five years data, simulated traits such grain yield, total dry matter, phonological stages flowering and maturity. In order calibration and evaluation of CERES-Wheat model under Ahvaz weather condition, two experiments carry out in two years continual. According to their results, RMSE rate in all of treatments was less than mean 10%. This result showed that model has high capability in simulation of wheat grain yield and phonological stage in this area. The CERES-Wheat model was used for others study such nitrogen consume management on wheat yield (Sassendran *et al*., 2004), irrigation management and evaluation of drought on wheat yield (Lobell and Ortiz-Manasterio, 2006), interaction effects of humidity and nitrogen (Rinaldi, 2004), drought stress under climate change (Popova and Kercheva, 2005) in different points of world. All of the investigations declared that this model have high capability for wheat traits simulation in different treatments. This experiment conducted to object evaluate of CERES-Wheat model for simulation of growth, development and grain yield of five winter wheat cultivars under two irrigation treatment (normal and stop irrigation at flowering stage) under Karaj climate.

MATERIALS AND METHODS

In order to calibration and evaluation of CERES-Wheat model on five winter wheat cultivar planted under Karaj weather condition under full irrigation and Terminal Irrigation at Flowering (TIF) an experiment carry out in form of split plot in based on randomize complete block design with four replicate in research field Islamic Azad university of Karaj branch in 2009 (35°43′N, 50°49′E, altitude 1174 Meter Sea Level (MSL). Experimental treatments including of irrigation in two levels, full irrigation and TIF as main plot and five wheat cultivars Alamut, Shahryar, MV17, Back cross Roshan and Kaskogen. After ground preparing include of plowing, disc and level in based on soil test, nitrogen manure was consumed to rate of 400 kg/ha (Urea) as 0.33% simultaneously to planting and 0.73% at first of stem elongate. For every plot considered 8 sowing line, inter and intra equal to 15 and 4 cm, respectively. Between main plot and sub plot considered 3 and 0.5 m distance. Seed planting implement achieved at November 8th (2009) and first irrigation after planting. For CERES-Wheat run model required two data class:

- Measured field data (actual data)
- Predicted model data (by using of input data)

Model evaluated in based on comparison between measured and predicted data in basis of statistic parameters. Experimental field data include of plant height (PH), Leaf Number PER Plant (LNP), Leaf Area Index (LAI) and Leaf Dry Weight (LDW) in six stages with 10 interval days. For identification of cultivars genetic coefficient used GENCALC software. Field experimental data include of plot characteristics, planting pattern, planting depth, seed and planting density, treatments, genetic coefficient, irrigation method and time, planting and harvesting date, chemical and physical soil characters. Soil date information in three layer of soil shallow, average and deep include of color, texture, density, organic percentage, nitrogen, phosphor, potassium available, pH, electrical conductivity. Plant data include of six sampling stage in growth duration and harvest time. Weather important data considered Maximum and minimum daily temperature (Celsius) rain daily (mm) and daily sunny hours (or sunny radiation).

Stop irrigation treatment carry out at May 9 th 2010 after 50% anthesis. Final harvesting at June 6th by three interior line of every plot after omission 0.5 m edge with 3 m long. For statistic calculation and curves design used SAS and Excel software. Simulated and measured data compared for evaluation of model. Index evaluation include of Wilmot agreement index (d) (Willmott, 1982) and R^2 creation of linear regression analysis (1:1 line). When d obtained by model was near to 1, showed that model had simulated trait successfully as variation among observed and predicted was low. According to some reported modelers, d rate upper to 0.60 for 8 sample acceptable for simulation. Every time R^2 obtained regression analysis of function linear by model near to 1 showed that model description was suitable for trait simulation. In evaluation of model ability for R^2 predicting in based of sample number in basis of statically source (8 sample) rate of 0.66 at 5% level and upper to 0.79 at 1% level is significant (Soltani *et al*., 2005; Ehdaee, 1994).

RESULTS

Grain yield simulation: Regression relation (Table 1) of measured and predicted (line 1:1) of grain yield in wheat cultivars in full irrigation (FI) and terminal irrigation at flowering (TIF) showed that, model have been high ability for grain yield simulation in Karaj zone. R^2 line (1:1) of grain yield in wheat cultivars in FI and, TIF was equal to 80.89-80.91 and 80.88-81.01, respectively, showing that fit model for both irrigation conditions. According to variation process simulated and measured GY in wheat cultivars in this area (Fig. 1), variation dimension of d in all of the cultivars under FI and TIF conditions equal to 0.73-0.75 and 0.61-0.72, respectively. This result showed that model in predicting of GY variation in both irrigation was successfully.

According to Fig. 1, drought stress comparison to normal irrigation in all of the cultivars occurred grain yield decreasing and model could simulate yield loss. In this research because of unsuitable many environmental factor and also GY loss to reason time harvest shattering as GY simulated was higher measured.

Table 1: comparison of simulation and measured grain yield (line 1:1)

Full irrigation			Terminal irrigation at flowering	
Cultivars	Y = X	R^2	Y = X	R^2
Back cross winter				
Roshan	Y = 0.9271X	0.8089	Y = 0.8709X	0.8088
Kaskogen	Y = 0.9790X	0.8089	Y = 0.6269X	0.8089
Alamut	Y = 1.0312X	0.8089	Y = 0.6416X	0.8094
Shahryar	Y = 0.9084X	0.8089	Y = 0.6905X	0.8101
MV17	Y = 0.9651X	0.8091	Y = 0.8144X	0.8089

Table 2: comparison of simulation and measured biomass (line 1:1)

Full irrigation			Terminal irrigation at flowering	
Cultivars	Y = X	R^2	Y = X	R^2
Back cross winter				
Roshan	Y = 1.0633X	0.9374	Y = 0.9532X	0.9191
Kaskogen	Y = 1.1026X	0.9051	Y = 1.0327X	0.9312
Alamut	Y = 1.1545X	0.8934	Y = 0.9859X	0.9147
Shahryar	Y = 1.0704X	0.9047	Y = 0.8949X	0.8948
MV17	Y = 1.0438X	0.9177	Y = 0.8455X	0.8501

Acceptable predicting exhibited using CERES-Wheat for wheat in different environment condition by McMaster *et al*. (1992).

Biomass simulation: According to biomass regression curve (line 1:1) in both irrigation condition exhibited high ability model for trait simulation (Table 2). R^2 dimension in line 1:1 of biomass wheat cultivars in two FI and SI condition calculated 0.89-0.93 and 0.85-0.93, respectively. Indeed description model for this trait was suitable both irrigation condition (Table 2). In based on variation process of biomass simulation in FI and SI condition, variation dimension d calculated 0.91-0.94 and 0.94-0.96, respectively. This result showed that model acted successfully (Fig. 2).

According to Fig. 2 biomass variation process both irrigation condition was suitable as in all of cultivars, biomass simulated the more than measured. Kiani (2002) experiment, biomass simulated using CERES-Wheat model in wheat cultivars under Birjand climate upper than measured data. This researcher declared major factor for this result, equation incoherence used model toward biomass measured.

LAI simulation: According to Table 2, model was successful in simulation of LAI. Variation of R^2 (line 1:1) to rate of 0.68-0.85 exhibited model was suitable for LAI simulate in FI condition. Variation dimension of R^2 was significant at 5 and 1% levels, respectively.

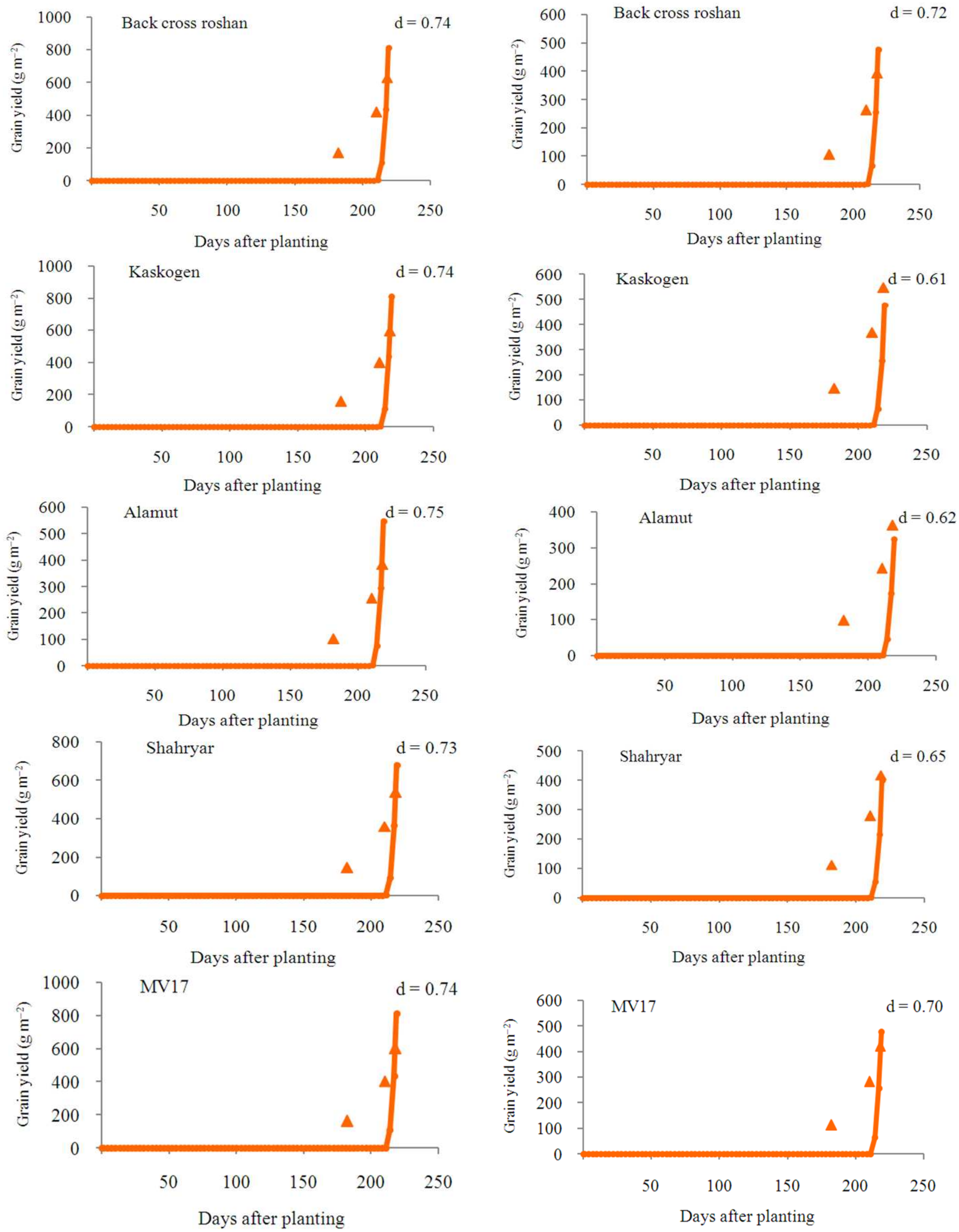

Fig. 1: Grain filling process (g/m2). Line (simulated) and Δ (measured)

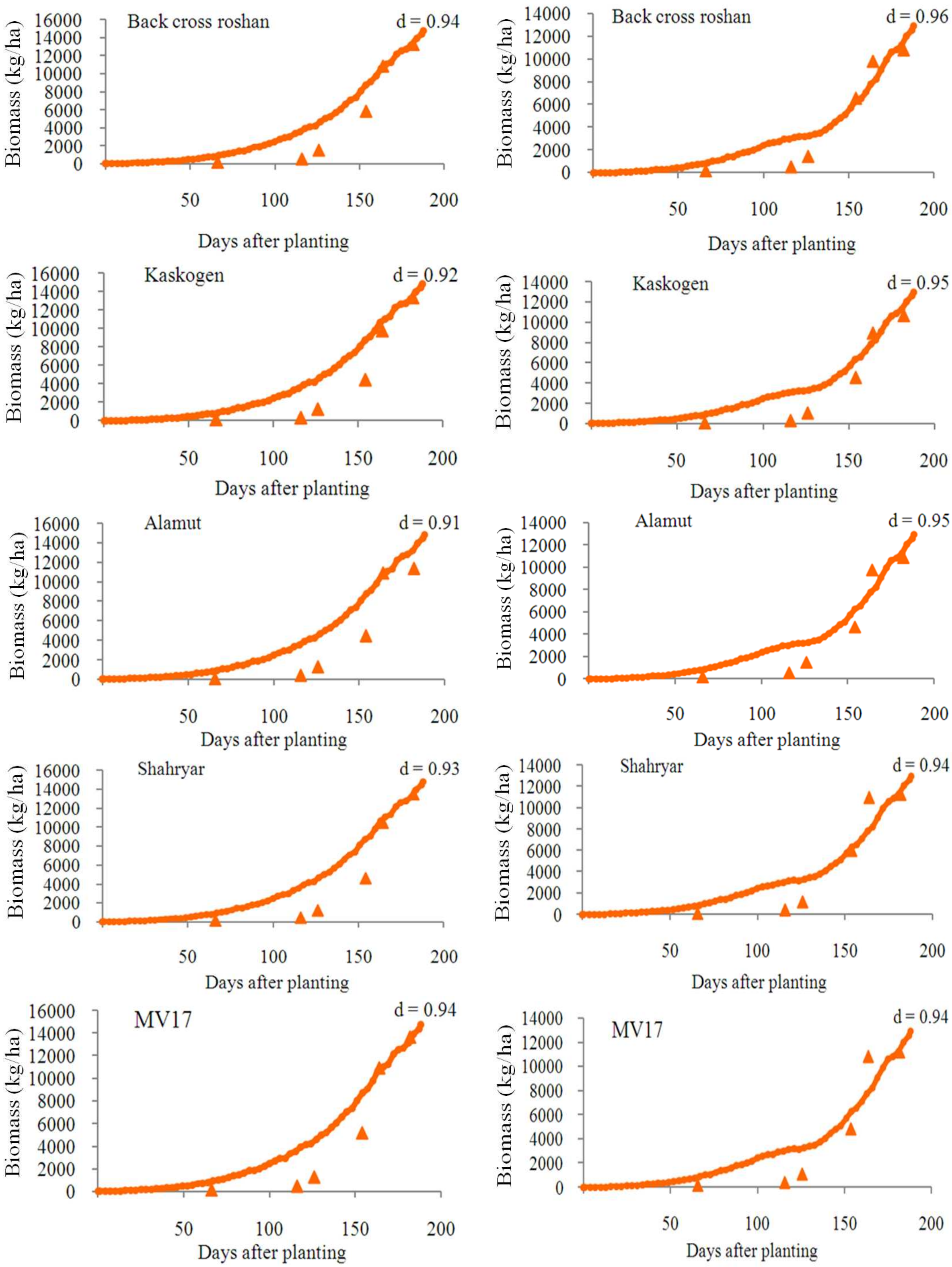

Fig. 2: Biomass process (kg/ha) (simulated) and Δ (measured) (line 1:1)

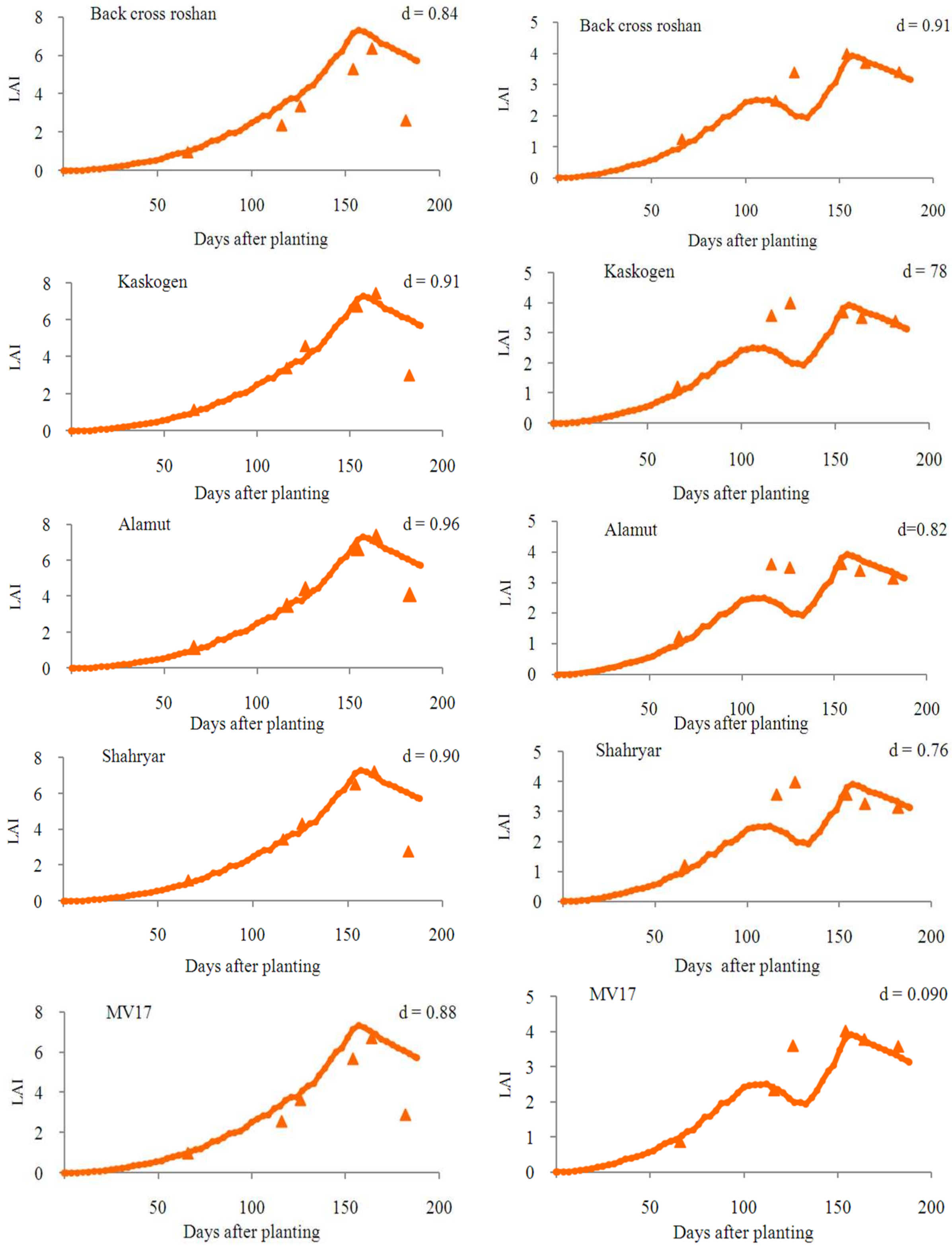

Fig. 3: LAI process (kg/ha) (simulated) and Δ (measured) (line 1:1)

Table 3: comparison of simulation and measured LAI (line 1:1)

	Full irrigation		Terminal irrigation at flowering	
Cultivars	Y = X	R^2	Y = X	R^2
Back cross winter				
Roshan	Y = 1.3051X	0.7486	Y = 0.9019X	0.7546
Kaskogen	Y = 1.0404X	0.7065	Y = 0.8344X	0.4194
Alamut	Y = 1.0432X	0.8599	Y = 0.882X	0.7937
Shahryar	Y = 1.0793X	0.6811	Y = 0.8542X	0.3219
MV17	Y = 1.22X	0.7687	Y = 0.8827X	0.7050

For Shahryar cv. R^2 was low although trait variation process was suitable (Table 3). Variation rate of R^2 line 1:1 in cultivars under SI condition was 0.32-0.75, indeed model description for LAI in two cultivars such back cross Roshan cv. and MV17 cv. was successful (Fig. 3). Perhaps this subject in reason to extreme increasing of daily temperature in growth duration and leaves lose or because of errors in sampling stages so almost leaf area measurement have been higher error comparison to other traits. Figure 3 showed that simulation of LAI variation process in both irrigation and all of cultivars have d range 0.84-0.96 and 0.76-0.91, respectively. Indeed model was successful for simulation of LAI variation under both irrigation.

Model in LAI simulation under FI the more successful in comparison to SI (after flowering). According to many reports that almost models acted under potential growth better than limited growth. Perhaps input data (weather, soil and plant) that introduced to model have been high error.

DISCUSSION

According to result (Table 1) all of the experimental cultivars have been suitable description and significant on grain yield. In fact, model could be predicted well grain yield. This result agrees with Ghffari *et al*., (2001) reports. Grain yield varied under affect of many different factors and this is problem for obtaining optimum prediction. Optimum predicting of grain yield in respect of traditional management have been so much important (Otter-Nacke *et al*., 1986). The precise identification of phonological stages and using precise and correct genetic coefficient for each cultivar for suitable simulation of grain yield is very important (Xue *et al*., 2004; Alizadeh *et al*., 2010). We must consider even small variation among cultivars in respect of requirement parameters affected on growth process (Andarsian *et al*., 2005). Model predicted total dry weight more precise compared to grain yield. This result agrees with many reports (Johnston and Fowler, 1992; Hundale and Kaur, 1997). Suitable simulation of biomass by model affected positively on grain yield simulation. According to further modeler reports (Johnston and Fowler, 1992; Otter-Nacke *et al*., 1986; Andarsian *et al*., 2005) optimum prediction of biomass for every plant is primary and important ways for successfully simulation in compared to other plant details. In fact optimum predicting of total dry matter showing that model in all of the cultivars under normal and stress irrigation could be predicted successfully in basis of daily time. Therefore we can use this model for dry matter production programming in wheat planting. In basis of statistic parameters obtaining in this experiment, model described LAI with precision lower than biomass and grain yield. Many modelers believed that predicting LAI compared to other traits is very more difficult. Precise simulation LAI can be increase grain yield and biomass simulation precision. Perhaps we must measured LAI with higher precision as result that errors rates will reduce for predicting grain yield and biomass and also weed control achieved, precisely in all of plant growth stage.

CONCLUSION

Results of CERES-Wheat model evaluation in this study showed that model simulation in all of cultivars under FI and SI for traits includes biomass, grain yield have been successful but for LAI absolute under FI irrigation simulated well. Rate of high R^2 in regression curve among measured and predicted data (line 1:1) introduced model description precise. Therefore we can apply after the more experiment replicate and with higher precise, investigation of model accuracy, for researches objective and management programming in biomass and grain yield of wheat under Karaj climate. Also for LAI by means of reduction error creation factors pay to model calibration for this trait.

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