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APPLICATION OF CSM-CERES-SWEET CORN $V_{4.5}$ MODEL FOR FORECASTING THE MOISTURE OF SOIL BY SPRINKLER AND FURROW IRRIGATION METHODS

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ABSTRACT
Two field experiments were developed on Golden Seed Sweet Corn varieties (SC403) in the Research Center of Agricultural and Natural Resources of Gorgan, in order to predict the soil moisture in different layers in 2007 and 2008. The Completely randomized block design was implemented in 3 replications on two fields with dimensions of 100 meters in 80 meters. Sprinkler irrigation method applied for first section and furrow irrigation method for second one. Fertilizer watering treatments applied two times (200 and 300 kg/ha N) for both sections. The soil moisture during the growing period in two depths of 0-30 and 30-60 cm was measured by weight. The CSM-CERES-Sweet corn $v_{4.5}$ model from the DSSAT$v_{4.5}$ set had been used during the 2 years of experiment with field data as input. The accuracy and applicability of the model assessed using the RMSE and d statistic indices. The assessment revealed that the model is properly applicable for simulating the changes in the soil moisture during the growing period. Based on the results the best prediction of soil moisture at the depth of 0-30 cm observed in the N200 irrigation – fertilizer treatment. The poorest simulation of the moisture obtained in the N300 irrigation – fertilizer treatment in the depth of 0-30 cm. Generally, the results of prediction in furrow irrigation – fertilizer treatments were more acceptable than those of the sprinkler irrigation – fertilizer treatments, and the model predicts the soil moisture of the deeper layers better than that of the surface layers.

KEYWORDS: CSM-CERES-Sweet corn $v_{4.5}$ Model, irrigation fertilizer, weighted moisture.

INTRODUCTION
In a dry weather, soil moisture deficiency in young sweet corn (zea mays var saccharata) plants with no nitrogen shortage, makes their leaves tubular, while drought in old plants, even with enough nitrogen, emerges the shortage signs (Mokhtarpoor and Mosavat, 2001). Irrigation water management requires timely application of appropriate amount of plant's water demand. Competition for water, high pumping costs and environmental concerns increased the importance of proper management of irrigation water according to the water demand. Consequently, determination and prediction of exact amount of soil moisture is of great importance for plant growth. In this way, soil moisture simulation models could be very useful (Mokhtarpoor *et al*., 2001).

Different simulating models are used for different applications all around the world. Decision support system for agriculture technology transfer (DSSAT) is a comprehensive system including cultivation systems such as CSM-CERES-Sweet corn $v_{4.5}$, predicting the sweet corn development in daily time intervals from cultivation to maturity stages. Physiological processes are the basis for showing the plant reaction to local changes of soil, water and weather (Lizaso *et al*., 2007). Input data needed to run the DSSAT models include daily meteorological information (minimum and maximum temperatures, precipitation and solar radiation), soil characteristics (morphological, chemical and physical characteristics of each layer). Collection of Cultivar coefficients showing the specific Cultivar type in the form of coefficients dependant to plant development and amount of seed production and biomass, are crop management information like cultivation density, row spacing, planting depth and application of irrigation and fertilization. This model stimulates the soil water balance to assess the product reduction potential caused by shortage water amount of soil below the field capacity. Soil water changes are determined daily as a function of sprinkler, irrigation, evapotranspiration, runoff and drainage from the lower layers of soil profile (Ritchie *et al*., 1989; 1998). The purpose of current study is prediction and simulation of the moisture of different layers of soil during the growing period of sweet corn.

MATERIALS AND METHODS
1- Experiment site
The present study includes two years of field experiment done in 2007 and 2008 in the Gorgan agricultural research station of Gorgan Agricultural and natural resources research center, located in 54^{o}, 25' longitude and 36^{o}, 54' latitude with elevation of 5 meters above sea level.

2- Soil condition and characteristics of experiment site

Soil samples had been collected by drill from depths of 0-20, 20-40, 40-60, 60-80, 80-100 cm of the study area and sent to laboratory. According to physical characteristics table, the soil texture of the study area is silt clay loam. Other physical and chemical characteristics like acidity, salinity, CEC, PWP and FC coefficients, anions and cations, organic materials percentage and so on in various depths had been measured and shown in tables 1 and 2.

Table 1- physical characteristics of experiment site soil

Bulk Density (gr/cm^3)	Saturation percentage	Permanent wilting point (percentage)	Field Capacity (percentage)	texture	Percentage of soil particles			Depth (cm)
					gravel	loam	clay	
1/44	49/9	13/1	27/7	silt clay loam	18	50	32	**20-0**
1/41	52/2	12/3	27	silt clay loam	18	48	34	**40-20**
1/40	51/9	9/8	27/6	silt clay loam	18	48	44	**60-40**
1/44	47/4	8/9	27	silt clay loam	20	48	32	**80-60**
1/39	**46**	**11/1**	**27**	**silt loam**	**22**	**50**	**28**	**-80 100**

Table 2- chemical characteristics of experiment site soil

Absorbable potassium and phosphorus		Exchangeable cations percentage Me/100g	EC Ds/m	PH	Total nitrogen (%)	Organic material (%)	Organic carbon (%)	depth (cm)
K	P							
393	11/3	20	1/96	7/1	0/16	2/24	1/30	**20-0**
393	11/8	13/5	2/13	7/3	0/17	2/13	1/24	**40-20**
287	5/9	9	1/29	7/5	0/12	1/17	0/68	**60-40**
190	2/3	8/5	1/20	7/6	0/15	1/07	0/62	**80-60**
141	**1/8**	**7**	**1/16**	**7/5**	**0/05**	**0/62**	**0/36**	**100-80**

3-Product characteristics

Scientific researches about sweet corn have been started from 35 years ago in research center of forages and corn of institute of seed and sapling improvement and production research of Iran, department of seed and forages researches.

Fortunately, the researches resulted in introduction of hybrid variety named Golden Seed (SC403), being used in current study.

4-Characteristics of experimental plan

Completely randomized blokes statistical plan in three iterations applied in two fields of 100 in 80 meters including two irrigation method treatments (sprinkler irrigation and furrow irrigation); Each irrigation method had two level of nitrogen fertilizer (200 and 300 kg/ha nitrogen fertilizer). This means that, 6 plots are located in sprinkler irrigated field with 3 of them receiving 200 kg/N/ha of fertilizer watering and other 3 received 300 kg/N/ha of fertilizer watering, contributing. Two fertilizer watering systems used in furrow irrigated field as well.

CSM CERES-Sweet corn $v_{4.5}$ Model Assessment

CSM CERES-Sweet corn $v_{4.5}$ model calibrated by data of the year 2007 and assessed by data of the year 2008.

In order to calibrate the model p_1,p_2,p_5,G_2,G_3 and PHINT Cultivar coefficients had been used by using phonological development parameters including the time period from cultivation to anthesis date and the time period from cultivation to maturity date as well as plant growth parameters like seed yield, dry weight of produced material at harvest date. To calibrate and evaluate germination, flowering and maturity dates by model compared with observed ones in the fields. Statistical indices like RMSE (root of mean square normal errors) and d (statistical index, showing compatible amount observed and stimulated data) are used for comparison. They can be calculated by the following equations (Loague, and Green, 1991).

Equation No. 1

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - o_i)^2}{N}} \times \frac{100}{M}$$

In which P_i and o_i are stimulated and observed amounts of considered variables, respectively. For example number of days from cultivation to anthesis date, number of days from cultivation to maturity date, leaf area index, total production of dry material, yield and its component. Normal measured RMSE reveals the percentage of difference between measured and observed amounts. RMSE of quite perfect simulation is less than 10%, for a good simulation it is between 10%-20%, for almost good simulation RMSE is between 20%-30%, and if it is more than 30% the simulation is week (Jamieson *et al*., 1991).

Equation No. 2

$$d = 1 - \left[\frac{\sum_{i=1}^{n}(p_i - o_i)^2}{\sum_{i=1}^{n}\left(\left|p_i^{/}\right| + \left|o_i^{/}\right|\right)^2} \right]$$

In which n is number of observations, p_i the predicted variable, o_i the observed variable, $p_i^{/} = p_i - M$, $o_i^{/} = o_i - M$, and M are average of observed variables. Index d being close to 1, shows the better match between observed and simulated data (Willmott *et al.*, 1985).

RESULTS AND DISCUSSION

1- Assessment of CSM-CERES-Sweet corn $v_{4.5}$ Model

1-1- Determination of Cultivar Coefficients (plant type)

Table 3- Cultivar Coefficients used for CSM-CERES-Sweet corn $v_{4.5}$ Model

Genotype	P_1 (^{0}Cday)	P_2 (days)	P_5 (^{0}Cday)	G_2 (Nr)	G_3 (mgday^{-1})	PHINT (^{0}Cday)
SC403	180	0/35	650	850	5/59	50

P1: thermal time from seed growing to the end of youth period in which the plant does not react to photoperiodic changes (declared by degree day above basic temperature of 8 centigrade degrees).
P2: period of time, during which development is delayed for each hour of increase in photoperiod above the longest photoperiod, leading to the maximum development (it is considered about 12.5 hours).
P5: thermal time from anthesis date to physiological maturity (defined as degree day above basic temperature of 8 centigrade).
G2: maximum possible number of seeds in plant.
G3: rate of seed filling during the period of linear filling of seed under optimal condition (milligram per day).
PHINT: intervals of successive leaf top emerging: thermal time interval (degree day) between successive leaf top emerging [2].

CSM-CERES-Sweet corn $v_{4.5}$ Model includes 6 Cultivar Coefficients of p_1, p_2 ,p_5 ,G_2 ,G_3 and PHINT showing the phenology and plant growth. Table 3 shows the calculated coefficients for the variety used in this research.

2- Soil moisture simulation

The amount of water of soil in all treatment kept at field capacity level in the experiment of the year 2008, for the plant to have maximum water storage during the growing period without being exposed to water stress. The amount of soil moisture measured by weight during the growing period, and compared with model simulation results (figures 1 to 16). Results of comparing CSM CERES-Sweet corn $v_{4.0}$ model with 2008 data reveals that for all treatments, the observed and simulated amounts of soil moisture in two different depths match properly. According to results, the best simulation of soil moisture observed in depth of 0-30 cm in fertilizer watering treatment of sprinkler N200, with root mean square error (RMSE) equal to 23% and the weakest simulation was in fertilizer watering treatment of sprinkler N300 at the same depth (with RMSE = 28%). Generally, model simulating results reveal the same trend in sprinkler and furrow fertilizer watering treatment, and despite the little difference the root mean square error in furrow fertilizer watering treatment (RMSE=25.37%) and sprinkler fertilizer watering treatment (RMSE=25.25%) is almost the same, which shows the model's ability in simulating different field conditions. Besides, the model simulates changes of moisture in deeper layers of soil, which normally are less under influence of soil surface factors, better than surface layers, with a little difference (RMSE= 24.8% for the depth of 30-60 cm, and RMSE= 25.6% for the depth of 0-30 cm).

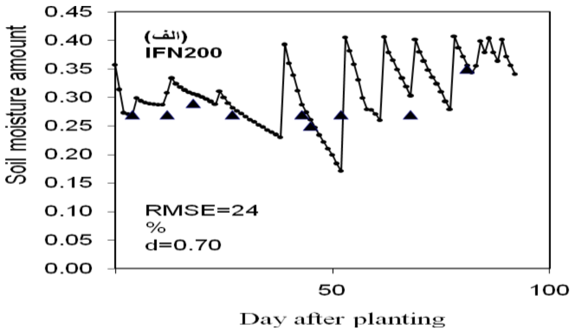

Figure 1- Changes of soil moisture during the growing season in the depth of 0-30 cm for fertilizer watering treatment of furrow irrigation with 200 kilograms per hectares of nitrogen fertilizer.

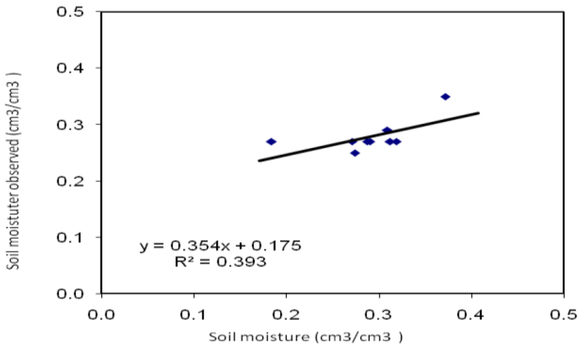

Figure 2- Comparison of observed and simulated changes of soil moisture in the depth of 0-30 cm for fertilizer watering treatment of furrow irrigation with 200 kilograms per hectares of nitrogen fertilizer.

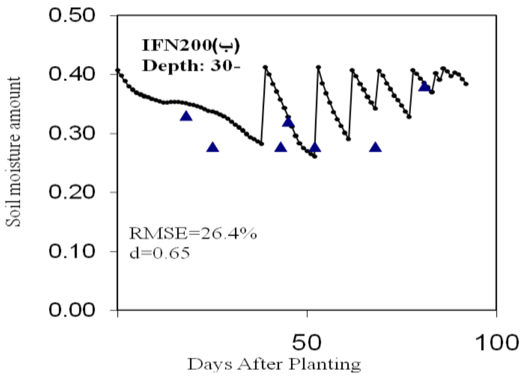

Figure 3- Changes of soil moisture during the growing season in the depth of 30-60 cm for fertilizer watering treatment of furrow irrigation with 200 kilograms per hectares of nitrogen fertilizer.

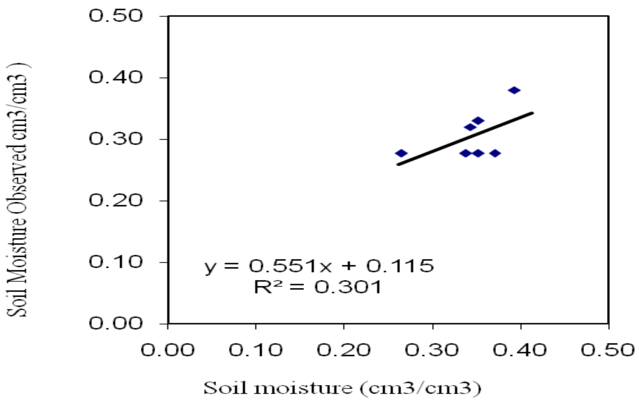

Figure 4- Comparison of observed and simulated changes of soil moisture in the depth of 30-60 cm for fertilizer watering treatment of furrow irrigation with 200 kilograms per hectares of nitrogen fertilizer.

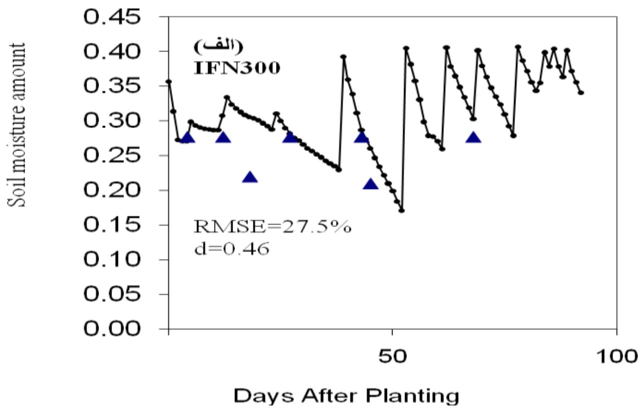

Figure 5- Changes of soil moisture during the growing season in the depth of 0-30 cm for fertilizer watering treatment of furrow irrigation with 300 kilograms per hectares of nitrogen fertilizer.

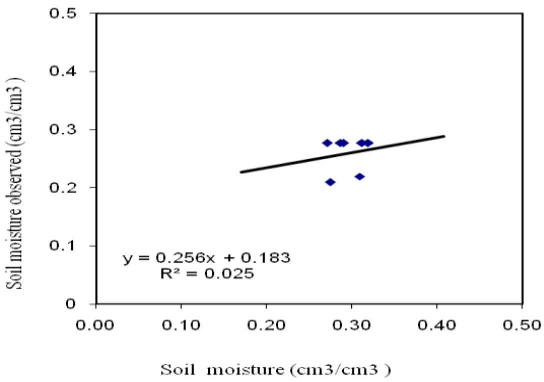

Figure 6- Comparison of observed and simulated changes of soil moisture in the depth of 0-30 cm for fertilizer watering treatment of furrow irrigation with 300 kilograms per hectares of nitrogen fertilizer.

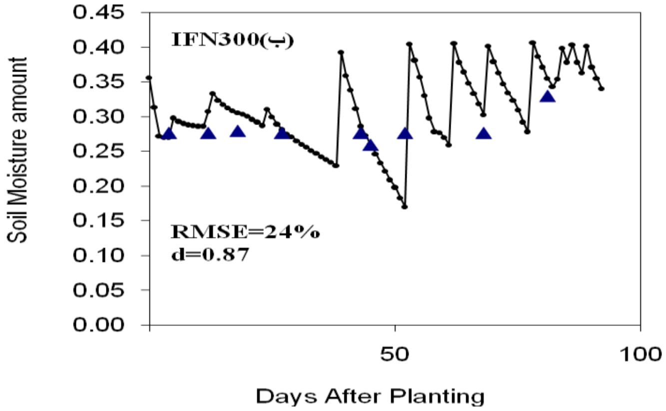

Figure 7- Changes of soil moisture during the growing season in the depth of 30-60 cm for fertilizer watering treatment of furrow irrigation with 300 kilograms per hectares of nitrogen fertilizer.

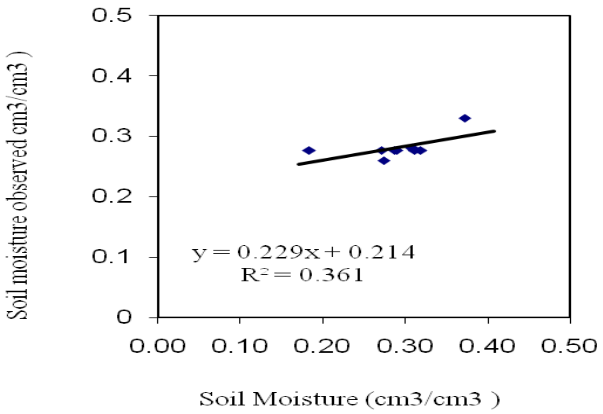

Figure 8- Comparison of observed and simulated changes of soil moisture in the depth of 30-60 cm for fertilizer watering treatment of furrow irrigation with 300 kilograms per hectares of nitrogen fertilizer.

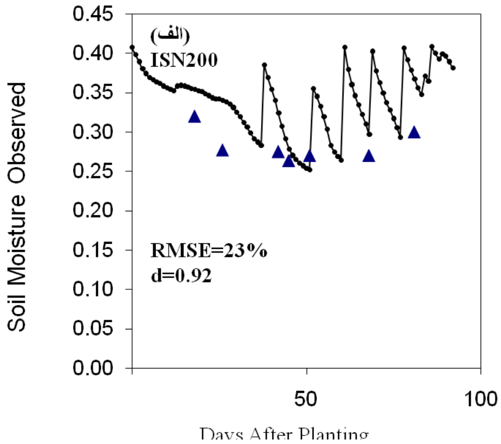

Figure 9- Changes of soil moisture during the growing season in the depth of 0-30 cm for fertilizer watering treatment of sprinkler irrigation with 200 kilograms per hectares of nitrogen fertilizer.

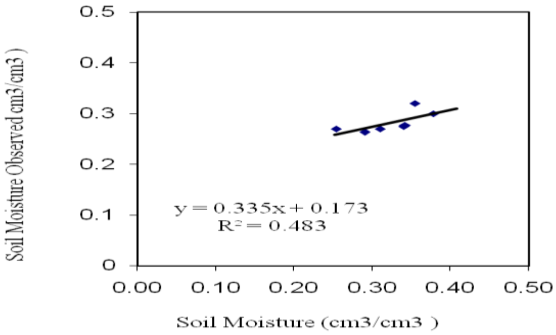

Figure 10- Comparison of observed and simulated changes of soil moisture in the depth of 0-30 cm for fertilizer watering treatment of sprinkler irrigation with 200 kilograms per hectares of nitrogen fertilizer.

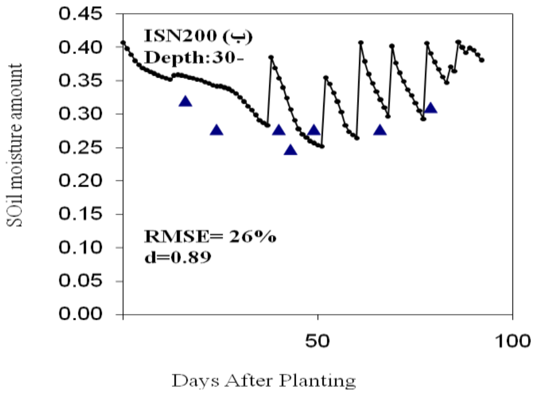

Figure 11- Changes of soil moisture during the growing season in the depth of 30-60 cm for fertilizer watering treatment of sprinkler irrigation with 200 kilograms per hectares of nitrogen fertilizer.

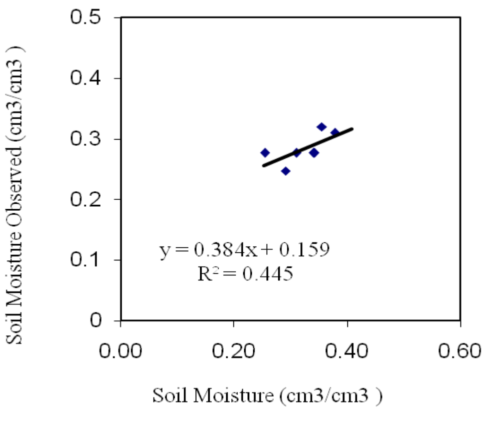

Figure 12- Comparison of observed and simulated changes of soil moisture in the depth of 30-60 cm for fertilizer watering treatment of sprinkler irrigation with 200 kilograms per hectares of nitrogen fertilizer.

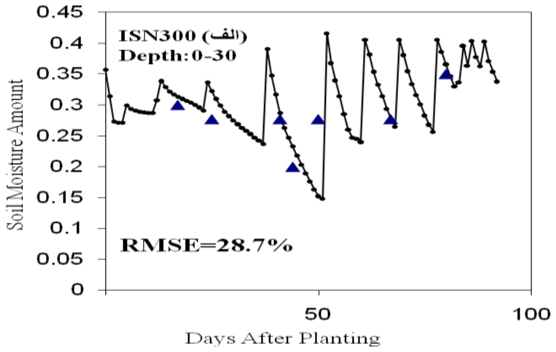

Figure 13- Changes of soil moisture during the growing season in the depth of 0-30 cm for fertilizer watering treatment of sprinkler irrigation with 300 kilograms per hectares of nitrogen fertilizer.

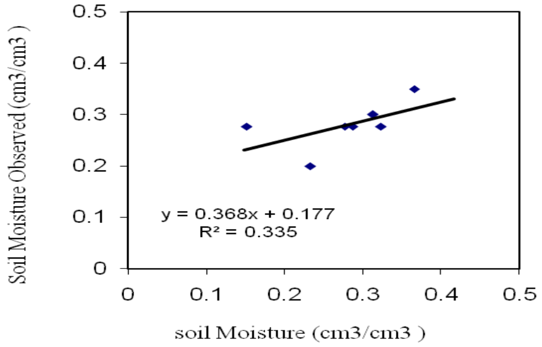

Figure 14- Comparison of observed and simulated changes of soil moisture in the depth of 0-30 cm for fertilizer watering treatment of sprinkler irrigation with 300 kilograms per hectares of nitrogen fertilizer.

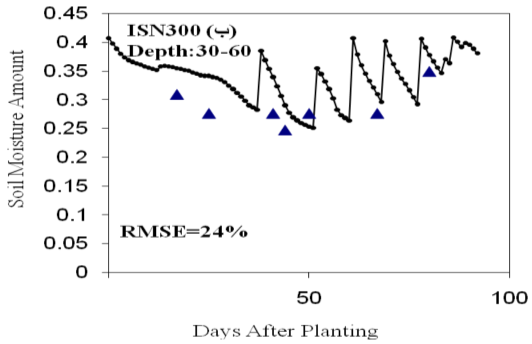

Figure 15- Changes of soil moisture during the growing season in the depth of 30-60 cm for fertilizer watering treatment of sprinkler irrigation with 300 kilograms per hectares of nitrogen fertilizer.

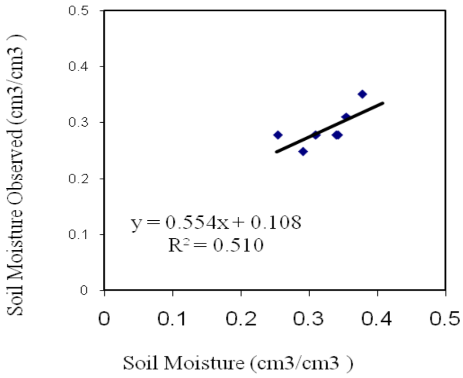

Figure 16- Comparison of observed and simulated changes of soil moisture in the depth of 30-60 cm for fertilizer watering treatment of sprinkler irrigation with 300 kilograms per hectares of nitrogen fertilizer.

CONCLUSION

The assessment results of soil moisture, using CSM CERES-Sweet corn $v_{4.0}$ model reveals that in two depth of soil (0-30 and 30-60 cm) for all the treatments, simulated and observed data match properly. Based on the experiment results, the best prediction of soil moisture was observed in the depth of 0-30 cm in the fertilizer watering treatment of sprinkler N200. The weakest simulation was in the fertilizer watering treatment of sprinkler N300 in the depth of 0-30 cm. Generally, the simulating results of the furrow fertilizer watering treatments were better than those of sprinkler fertilizer watering treatments. Besides, the model simulated the soil moisture changes of deeper layers (30-60 cm deep), which normally are less under influence of soil surface factors, better than surface layers (0-30 cm deep).

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