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OILCROP-SUN MODEL APPLICATION FOR AGRONOMIC STRATEGIES OF SUNFLOWER CROP

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Abstract

The experiments were carried out to evaluate the performance of DSSAT (OILCROP-SUN) model to simulate growth and development of sunflower hybrids under irrigated conditions in semi arid environment of Sargodha and to determine the impact of varying planting densities and nitrogen levels on achene yield and economic return. The model was evaluated with experimental data collected in trial conducted during spring season in 2010 and 2011. Split split plot design was used in layout of experiment with three replications. The treatments comprised of two hybrids (Hysun-33 and S-278), three planting densities (83,333, 66,666 and 55,555 plants ha^{-1}), with three levels of nitrogen (100, 125 and 150 kg ha^{-1}). The results showed that the model was able to simulate growth and yield of sunflower, with MPD (mean percentage difference) of 5.94% between observed and simulated achene yield. The management strategy consisted of 8.33 plants m^{-2} along with 150 kg N ha^{-1} was the best for high yield and monitory return of sunflower hybrids as simulated by model.

Key words*: crop management, decision support system for agro-technology transfer, planting densities, nitrogen, achene yield, simulate.*

INTRODUCTION

Per acre achene yield of sunflower in Pakistan is very low and possible reason for it is the non-adoption of new developed short stature hybrids with high fertilizer requirements.

During the last decade, a rising number of researchers throughout the world have invested in plants growth modeling and applications (Fourcaud and Zhang, 2008; Li et al., 2010). Evaluation of a crop simulation model involves establishing confidence in its capability to predict outcomes experienced in the real world. A frequently used method for evaluation of models involves comparing observed values with simulated results in a scatter diagram. Normally a linear regression is used to fit a straight line between observed and simulated values (Smith and Rose, 1995).

The objectives of this study therefore, were, to evaluate the performance of OILCROP-SUN model for management of agronomic practices (planting density and nitrogen) performed under irrigated conditions in semi arid environment of Sargodha and to determine the best management option to increase sunflower productivity.

MATERIALS AND METHODS

The Experiments were conducted at the Research Area of University College of Agriculture, Sargodha (32.05^{o}N, 72.67^{o}E, and 188 m altitude) during the spring seasons of 2010 and 2011.

The experiment was laid out in split split plot design. Sunflower hybrids (Hysun-33, S-278) were kept in main plots, planting densities (83,333, 66,666 and 55,555 plants ha^{-1} by maintaining plant to plant distance 20, 25 and 30cm, respectively) randomized in sub plots and nitrogen rates (100, 125 (standard), 150 kg ha^{-1}) in sub sub plots. 1/3rd dose of nitrogen and all of P and K fertilizer was applied at the time of sowing and remaining 2/3 rd of N was applied in two splits, at first irrigation and flowering stage. All other cultural practices such as hoeing, irrigation and plant protection measures were kept normal for the crop.

Plant sampling and measurements

Phenology and development were recorded during both the vegetative and reproductive phases in both years. An area meter (JVC Model TK-S310EG) was used for the measurement of leaf area and dry weights, leaf area index and total dry matter (gm^{-2}) were recorded at each harvest as explained by Cantagallo et al. (2002), and Hunt et al., (2002).

At final harvest, three rows with a length of 6 m for each plot were harvested. All the head were threshed mechanically to determine achene yield of entire plot and converted into kg ha^{-1}. All weather data was obtained from measurements made at the crop physiology meteorological observatories site.

Weather station provided daily maximum and minimum air temperature (ºC) i.e mean temperature, total rainfall (mm) and mean relative humidity.

Calibration and evaluation of OILCROP-SUN

Data collected during 2010 and 2011 was used as input data for calibration and evaluation of the crop-model.

The model simulation was performed under optimum growth conditions. The comparison of model simulations with the observations assesses accuracy of the model (Hoogenboom et al., 2004).

Standard meteorological, soil, plant characteristics and crop management data was obtained from each site and used as input data for the model (Pereya-Irujo, 2007; Pereya-Irujo et al., 2009). Crop genetic inputs i.e. genetic coefficients was calculated by decision support system for agro-technology transfer (DSSAT V 4.5), by using observed data of two years trial (Tyagi et al., 2000).

he model simulation was performed under optimum growth conditions. The comparison of model simulations with the observations will assess accuracy of the OILCROP-SUN Model (Rinaldi et al., 2003; Hoogenboom et al., 2004).

The experimental files that were used as inputs files includes, weather data file for the experimental period (WeatherMan), soil data of respective experiment (SBuild), crop management data file (XBuild) and crop cultivar coefficients filed (Diodato and Bellocchi, 2007; Trnka et al., 2007). As a part of calibration and evaluation process the simulated data for anthesis date, maturity date, achene yield, and total biomass were compared with the observed values.

Statistical indices

Simulation performance was evaluated by calculating different statistic indices like root mean square error (RMSE), mean percentage difference (MPD), error % and index of agreement (Wallach and Goffinet, 1989). The Index of Agreement (*d*) as described by Willmott et al. (1985) that if the *d*-statistic value is closer to one, then there is good agreement between the two variables that are being compared and vice versa, so it is very important that if value is varies from value of one then there will be weak agreement of the variable that we are being compared with each other.

RESULTS AND DISCUSSIONS

Model calibration

The OILCROP-SUN model was calibrated with experimental data collected during 2010 sunflower crop season.

The cultivar coefficients of Hysun-33 and S-278 were estimated through trial and error and comparison of simulated and observed data. The final values for the two cultivar coefficients that determine vegetative and reproductive growth and development are presented in Table 1.

A close agreement was obtained between simulated and observed values for sunflower phenology.

The model predicted the dates for days to anthesis and physiological maturity with a slight difference between observed and simulated dates for Hysun-33 and S-278 hybrids, respectively.

The simulated and observed values were in good agreement for Leaf area index and above ground biomass at different phonological stages for different combinations of plant density and nitrogen levels (Figures 1 and 2).

The lower values for RMSE and higher d-values close to one reflected that model predicted LAI and above ground biomass quite well.

Table 1. Cultivar coefficients used with OILCROP- SUN Model for sunflower hybrids

Genotype	P_1 (^{0}Cdays)	P_2 (days)	P_5 (^{0}Cdays)	G_2 (Nr)	G_3 (mg day^{-1})	O_1 (%)
Hysun-33	275.0	2.65	580	20	2.99	7
S-278	250.0	2.50	565	75	3.87	0

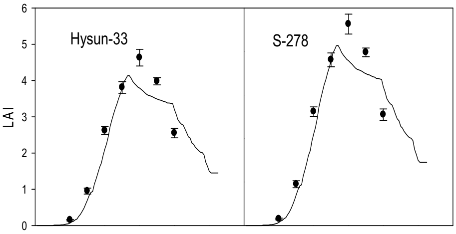

Figure 1. Comparison of simulated and observed values of LAI for sunflower hybrids during modelling calibration against 20 cm plant spacing and 150 kg N ha^{-1} under Sargodha conditions during the year, 2010

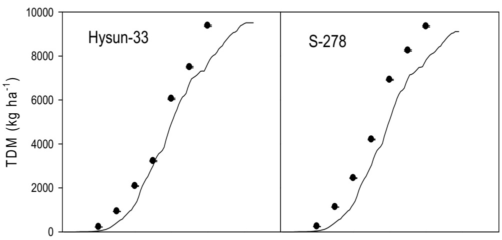

Figure 2. Comparison of simulated and observed values of TDM for sunflower hybrids during modeling calibration against 20 cm plant spacing and 150 kg N ha^{-1} during the year, 2010

Model evaluation

The OILCROP-SUN model was evaluated with experimental data collected during 2011 sunflower crop season. The model predicted the dates for anthesis with RMSE values from 1.65 and 2.20 days for sunflower hybrids Hysun-33 and S-278, respectively with average RMSE value of 1.89 days. Similarly, Mean Percentage Difference (MPD) values were 2.03 and 3.17 for sunflower hybrids Hysun-33 and S-278, respectively with average MPD value of 2.60 (Table 2). The model predicted the dates for physiological maturity with RMSE values from 1.74 and 3.45 days for sunflower hybrids Hysun-33 and S-278, respectively with average RMSE value of 2.60 days. Similarly, Mean Percentage Difference (MPD) values were 1.34 and 2.66 for sunflower hybrids Hysun-33 and S-278, respectively with average MPD value of 2.00 (Table 3). The predicted and observed values for LAI and total above- ground biomass at different phonological stages for different combinations of planting density and nitrogen levels were in a good agreement (Fig 3 and 4). The value for the d-value for LAI and above-ground biomass were ranged from 0.95 and 0.99 (Table 5). The lower values for RMSE and higher d-values close to one revealed that model predicted LAI and above ground biomass quite well. However, the RMSE values for achene yield at final harvest were 194.30 to 214.10 kg ha^{-1} for Hysun-33 and S-278 hybrids, respectively with average RMSE value of 204.20 kg ha^{-1}. Similarly, Mean Percentage Difference (MPD) values were 5.83 and 6.04 for sunflower hybrids Hysun-33 and S-278, respectively with average MPD value of 5.94 (Table 4). In general, the results for model evaluation with the observed data sets indicated the OILCROP-SUN model was able to simulate yield accurately for sunflower hybrids for treatment combinations of plant density and N rates under irrigated conditions for a semi arid environment in Sargodha, Pakistan.

Model application

An analysis for identifying the best agronomic practices (optimum combination of plant density and N levels) for sunflower production was done. The OILCROP-SUN model was used to simulate achene yield for sunflower.

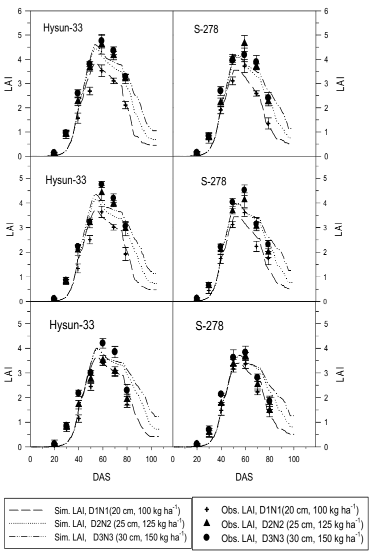

Figure 3. Comparison of simulated and observed values of leaf area index of different sunflower hybrids at varying planting densities and nitrogen rates during 2011

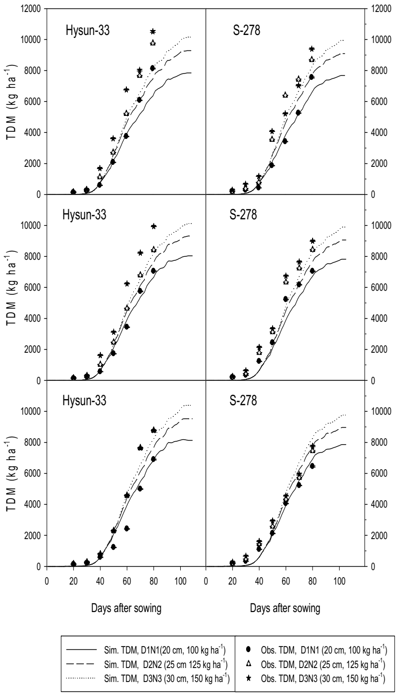

Figure 4. Comparison of simulated and observed values of total dry matter of different sunflower hybrids at varying planting densities and nitrogen rates during the year, 2011

Table 5. d-statistics of time course simulation of LAI and TDM at varying planting densities and nitrogen rates of sunflower hybrids at Sargodha during 2011

Treatments	**d-statistics value (LAI & TDM for Hysun-33)**		**d-statistics value (LAI &TDM for S-278)**	
	LAI	TDM	LAI	TDM
D1N1	0.96	0.98	0.98	0.99
D1N2	0.98	0.98	0.98	0.99
D1N3	0.98	0.98	0.98	0.99
D2N1	0.96	0.98	0.98	0.99
D2N2	0.97	0.99	0.99	0.99
D2N3	0.97	0.99	0.99	0.99
D3N1	0.95	0.95	0.95	0.99
D3N2	0.95	0.95	0.98	0.98
D3N3	0.97	0.99	0.99	0.99

Table 2. Comparison of simulated and observed days to anthesis at different planting densities and nitrogen levels during year, 2011

Location	**Spacing**	**N rates**	**Hysun-33**			**S-278**			**Average**		
	(cm)	**(Kg ha^{-1})**	**Sim**	**Obs.**	**Error (%)**	**Sim**	**Obs**	**Error (%)**	**Sim**	**Obs**	**Error (%)**
Sargodha	**20**	**100**	65	64	1.56	62	60	3.33	64	62	2.45
		125	65	66	-1.52	62	61	1.64	64	64	0.06
		150	65	67	-2.99	62	61	1.64	64	64	0
	25	**100**	65	66	-1.52	62	60	3.33	64	63	0.91
		125	65	66	-1.52	62	61	1.64	64	64	0.06
		150	65	68	-4.41	62	61	1.64	64	65	-1.39
	30	**100**	65	63	3.17	62	58	6.9	64	61	5.04
		125	65	64	-1.56	62	59	5.08	64	62	3.32
		150	65	65	0	62	60	3.33	64	63	1.67
RMSE (days)				1.65			2.2			1.89	
MPD				2.03			3.17			2.6	

Table 3. Comparison of simulated and observed days to anthesis at different planting densities and nitrogen Levels during year, 2011

Location	Spacing	N rates	Hysun-33			S-278			Average		
	(cm)	(Kg ha^{-1})	Sim	Obs.	Error (%)	Sim	Obs.	Error (%)	Sim	Obs.	Error (%)
Sargodha	20	100	106	107	-0.93	100	97	3.09	103	102	1.08
		125	106	108	-1.85	100	100	0	103	104	-0.93
		150	106	109	-2.75	100	100	0	103	105	-1.38
	25	100	106	106	0	100	98	2.04	103	102	1.02
		125	106	108	-1.85	100	98	2.04	103	103	0.09
		150	106	109	-2.75	100	101	0	103	105	-1.87
	30	100	106	105	0.95	100	94	6.38	103	100	3.67
		125	106	106	0	100	95	5.26	103	101	2.63
		150	106	107	-0.93	100	96	4.17	103	102	1.62
RMSE (days)				1.74			3.45			2.6	
MPD				1.34			2.66			2	

Table 4. Comparison of simulated and observed achene yield kg ha^{-1} at different planting densities and nitrogen levels during year, 2011

Location	Spacing	N rates	Hysun-33			S-278			Average		
	(cm)	(kg ha^{-1})	Sim	Obs.	Error (%)	Sim	Obs.	Error (%)	Sim	Obs.	Error (%)
Sargodha	20	100	2542	2569	-1.05	2803	2794	0.32	2673	2682	-0.36
		125	3168	2981	6.27	3448	3424	0.7	3308	3203	3.49
		150	3511	3319	5.78	3740	3610	3.6	3626	3465	4.69
	25	100	2446	2438	0.33	2740	2589	5.83	2593	2514	3.08
		125	3091	2889	6.99	3378	3182	6.16	3235	3036	6.58
		150	3384	3195	5.92	3601	3395	6.07	3493	3295	5.99
	30	100	2389	2275	5.01	2692	2463	9.3	2541	2369	7.15
		125	3017	2690	12.16	3305	2989	10.7	3161	2840	11.36
		150	3224	2958	8.99	3530	3157	11.2	3377	3058	10.4
RMSE (kg ha^{-1})				194.3			214.1			204.2	
MPD				5.83			6.04			5.94	

CONCLUSIONS

OILCROP-SUN model did well to serve as a tool for determining agronomic practices (the best combination of plant density and nitrogen rates for sunflower cultivation under irrigated semi-arid environment. This study illustrates the potential for using crop simulations models as an information technology for determining suitable management strategies for sunflower production in Sargodha, Punjab, Pakistan. Therefore, we can conclude that the OILCROP-SUN model could potentially assist resource-poor farmers in providing them with alternate management options. However, we suggest that a few years of actual field experiments should be conducted for model evaluation in order to be able to identify the optimum management practices for a specific region and for a specific crop.

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