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OILCROP-SUN Model Relevance for Evaluation of Nitrogen Management of Sunflower Hybrids in Sargodha, Punjab

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ABSTRACT

The experiments were conducted to evaluate the performance of crop system (DSSAT) OILCROP-SUN model simulating growth & development and achene yield of sunflower hybrids in response to nitrogen under irrigated conditions in semi arid environment, Sargodha, Punjab. The model was evaluated with observed data collected in trials which were conducted during spring season in 2010 and 2011 in Sargodha, Punjab, Pakistan. Split plot design was used in layout of experiment with three replications. The hybrids (Hysun-33 & S-278) and N levels (0, 75, 150 and 225 kg·ha^{-1}) were allotted in main and sub plots, respectively. The OILCROP-SUN model showed that the model was able to simulate growth and yield of sunflower with an average of 10.44 error% between observed and simulated achene yield (AY). The results of simulation analysis indicated that nitrogen rate of 150 kg·N·ha^{-1} (N_3) produced the highest yield as compared to other treatments. Furthermore, the economic analysis through mean Gini Dominance also showed the dominance of this treatment compared to other treatment combinations. Thus management strategy consisting of treatment 150 kg·N·ha^{-1} was the best for high yield of sunflower hybrids.

Keywords: Decision Support System for Agro-Technology Transfer; Nitrogen; Achene Yield; Crop Modeling

1. Introduction

Oil seed sector, because of ever rising use of edible oil, has attained significant magnitude in the cost-cutting measure of Pakistan. Pakistan is a net importer of edible oil and is spending millions of dollars on its import every year. Sunflower crop, because of having high oil and protein contents, has the potential to overpass this gap that exists between the domestic demands and supply [1]. Sunflower production is very low, and the possible reason is the non-adoption of newly developed hybrids with higher nutrition requirements. The growers are applying less nitrogen per hectare, hence, the sowing of hybrids of high yield potential with optimum nitrogen dose is considered as a hopeful approach to increase edible oil production as well as to reduce the import bills [2]. Choices of hybrid play a great role in increasing sunflower production. [3] worked on performance of various sunflower hybrids and found a significant difference in yield and yield components of various hybrids. He suggested that hybrids should be selected according to agroclimatic conditions of a particular region to obtain higher return. [4] concluded in his experiments that cultivar adaptation is imperative for regions in term of obtaining highest yield. [5] worked on various sunflower hybrids and concluded that hybrids differ regarding to yield potential. Yield parameters were increased by nitrogen supply, whereas, harvest index and seed oil percentage were diminished by the N application [6]. Evaluations of a crop simulation model ascertained confidence in its competence to forecast outcomes veteran in the real world. Several simulation models are being used for the sunflower [7,8]. Crop growth simulations models are based on scientific knowledge which serves as a quantitative tool for evaluation of agronomic factors effects on yield. Crop simulation mo-

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dels greatly facilitate optimization of crop and its management strategies [9]. [10] implemented observed results obtained from his experiments conducted into DSSAT (CSM-CERES-Rice model) to appraise the impact of plant population and nitrogen levels on leaf area index and total dry matter as well as yield and yield parameters. The evaluation of DSSAT (CSM-CERES-Rice) showed that the model was able to simulate growth and yield of rice grown in semi arid environment, with an average error of 11% between predicted and observed grain yield. This approach was described as a useful way to optimize the crop management for higher production per unit area as well as monetary return. Plants growth modeling and its applications have been investigated by a large number of researchers during the last decade [11,12].

The objectives of this study, therefore, were to evaluate the performance of OILCROP-SUN model for nitrogen management under irrigated conditions in semi arid environment and to determine the best management option to increase sunflower productivity for local environment of Punjab.

2. Materials and Methods

The experiment was carried out at the Research Area of University College of Agriculture Sargodha (32˚05''N, 72˚67''E), Pakistan, under irrigated semi arid conditions during the spring seasons of 2010 and 2011. The experiment was laid out in a Split plot arrangement under RCBD having three replications, keeping net plot size 4.20 × 8 m. Sunflower hybrids (Hysun-33, S-278) were kept in main plots and N levels (0, 75, 150 and 225 kg·ha^{-1}) in sub plots. The crop was sown by dibbler method on 70 cm spaced ridges and at 22.5 cm plant spacing using a recommended seed rate of 7 kg·ha^{-1}. Phosphorus and potash was applied at the rate of 100 - 50 kg·ha^{-1}, respectively. Nitrogen, P and K were given in the form of urea, single super phosphate and sulfate of potash, respectively. Full dose of P and K and 1/3 of N was applied at the time of sowing and remaining 2/3 of N was applied in two equal splits, at first irrigation and R3 stage (immature bud elongates). All other cultural practices such as weeding, water application and plant protection measures were kept normal for the crop.

2.1. Plant Sampling and Measurements

Phenology, as well as growth and development were recorded during both the vegetative and reproductive phases in both years. Five plants were selected at random and tagged in each plot; anthesis (flowering), and physiological maturity dates were noted. First growth sampling was conducted after 20 days of sowing, then each sampling every 10 days interval. The leaf area was measured from 10 g fresh leaves from harvested material from each fifteen days interval. An area meter (JVC Model TK-S310EG) was used for the measurement of leaf area and dry weights, LAI and TDM (gm^{-2}) were recorded at each harvest as explained by [13]. At final harvest, three rows with a length of 8 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} and final yield was corrected to 0% moisture. All weather data was obtained from measurements made at the nearest meteorological observatories around the experimental site. Weather station provided daily maximum and minimum air temperature (˚C) *i.e.* mean temperature, total rainfall (mm) and mean relative humidity (**Table 1**).

2.2. Calibration and Evaluation of OILCROP-SUN

Data obtained from experiments conducted during the years, 2010 and 2011 was used as input file for calibration and evaluation of the crop-model. The model simulation was performed under optimum growth conditions. The comparison of model simulated outcome with observed data assesses accuracy of the model [14]. Meteorological data of the location, soil as well as plant characteristics and crop management practices data was obtained from each site and used as input data for the model [15], Genetic coefficients of hybrids sown was calculated by decision support system for agro-technology transfer (DSSAT V 4.5), by using observed data of two years experimentation [16]. 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 file [17]. As a part of calibration and evaluation process the simulated data for different phonological developmental stages (anthesis and maturity date), AY, and TDM were compared with the observed values.

Table 1. Mean monthly weather data for sunflower growing season March-June in 2010 and 2011.

Months	Mean temperature		Total rainfall		Mean relative humidity	
	2010	2011	2010	2011	2010	2011
	˚C		mm		%	
March	22.5	21.3	9.2	7.11	58.5	59.4
April	30.2	25.6	4.06	35.06	44.2	46.3
May	32.7	33.8	2.04	8.89	44.9	38.5
June	33.5	33.7	14.74	126.25	44.6	51.0

2.3. 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 [18] with the help of following equations:

$$\text{RMSE} = \left[\sum_{i=1}^{n}\left(p_i - o_i\right)^2 / n\right]^{0.5}$$

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

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

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

where P_i and O_i are predicted and observed values respectively, O is the observed mean value. The Index of Agreement (d) as described by [19] 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.

3. Results and Discussion

3.1. 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 2**. A close agreement was obtained between simulated and observed values for sunflower phenology. The model predicted the dates for days to anthesis with a difference of one and 2 days between observed and simulated dates for Hysun-33 and S-278 hybrids, respectively. Similarly, the model predicted the dates for days to physiological maturity with a difference of 2 and 1 day 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. The lower values for RMSE and higher d-values close to one reflected that model predicted LAI and above ground biomass quite well. The d statistics values were (0.94, 0.96) and (0.96, 0.95) along with RMSE values of and (0.67, 0.47) & (1040, 1132 $kg \cdot ha^{-1}$) for LAI and TDM for Hysun-33 and S-278 hybrids, respectively.

3.2. Model Evaluation

The OILCROP-SUN model was calibrated with experimental data collected during 2011 sunflower crop season. The model predicted the dates for anthesis with RMSE values from 2.60 and 4.69 days for sunflower hybrids Hysun-33 and S-278, respectively with average RMSE value of 3.64 days. Similarly, Mean Percentage Difference (MPD) values were 3.12 and 6.37 for sunflower hybrids Hysun-33 and S-278, respectively with average MPD value of 4.74 (**Table 3**). The model predicted the dates for physiological maturity with RMSE values from 5.17 and 4.18 days for sunflower hybrids Hysun-33 and S-278, respectively with average RMSE value of 4.67 days. Similarly, Mean Percentage Difference (MPD) values were 3.88 and 3.63 for sunflower hybrids Hysun-33 and S-278, respectively with average MPD value of 3.75 (**Table 4**). The simulated and observed values for LAI and TDM at different phonological stages for different nitrogen levels were in a good agreement. The value for the d-value for LAI ranged from 0.87 and 0.97, while the RMSE ranged from 0.42 to 0.53. The d-value for above-ground biomass ranged from 0.85 to 0.99 while the RMSE ranged from 867 to 1043 $kg \cdot ha^{-1}$. The lower values for RMSE and higher d-values close to one revealed that model predicted LAI and TDM quite well. However, the RMSE values for achene yield at final harvest were 347.49 to 346.43 $kg \cdot ha^{-1}$ for Hysun-33 and S-278 hybrids, respectively with average RMSE value of 346.96 $kg \cdot ha^{-1}$. Similarly, Mean Percentage Difference (MPD) values were 10.01 and 10.88 for sunflower hybrids Hysun-33 and S-278, respectively with average MPD value of 10.44 (**Table 5**). In general, the results for model evaluation with the observed data sets indicated the OILCROP-SUN model was able to simulate yield

Table 2. Cultivar coefficients used with OILCROP-SUN Model for sunflower hybrids.

Genotype	P_1	P_2	P_5	G_2	G_3	O_1
	(˚C days)	(days)	(˚C days)	(Nr)	($mg \cdot day^{-1}$)	(%)
Hysun-33	280	2.55	560	746	2.43	53
S-278	255	3.25	545	915	3.22	65

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

N rates	Hysun-33			S-278			Average		
(kg·ha^{-1})	Sim	Obs.	Error (%)	Sim	Obs	Error (%)	Sim	Obs	Error (%)
0	75	71	5.63	68	60	13.33	72	66	9.48
75	75	72	4.17	68	64	6.25	72	68	5.21
150	75	74	1.35	68	66	3.03	72	70	2.19
225	75	76	−1.32	68	70	−2.86	72	73	−2.09
RMSE		2.60			4.69			3.64	
MPD		3.12			6.37			4.74	

Table 4. Comparison of simulated and observed physiological maturity at different planting densities and nitrogen rates during year, 2011.

N rates	Hysun-33			S-278			Average		
(kg·ha^{-1})	Sim	Obs.	Error (%)	Sim	Obs	Error (%)	Sim	Obs	Error (%)
0	116	107	8.41	101	94	7.45	109	101	7.95
75	116	112	3.57	101	97	4.12	109	105	3.85
150	116	113	2.65	101	100	1.00	109	107	1.83
225	116	115	0.87	101	103	−1.94	109	109	−0.54
RMSE		5.17			4.18			4.67	
MPD		3.88			3.63			3.75	

Table 5. Comparison of simulated and observed achene yield (AY) kg·ha^{-1} at different planting densities and nitrogen rates during year, 2011.

N rates	Hysun-33			S-278			Average		
(kg·ha^{-1})	Sim	Obs.	Error (%)	Sim	Obs	Error (%)	Sim	Obs	Error (%)
0	2730	2120	24.06	2851	2280	25.04	2791	2200	24.55
75	3192	3023	5.59	3258	2979	9.37	3225	3001	7.48
150	3486	3404	2.41	3870	3790	2.11	3678	3597	2.26
225	3720	3445	7.98	4078	3811	7.01	3899	3628	7.50
RMSE		347.49			346.43			346.96	
MPD		10.01			10.88			10.44	

accurately for sunflower hybrids for treatment of nitrogen rates under irrigated conditions for a semi arid environment in Sargodha, Pakistan.

4. Conclusion

In Model application, the results for model calibration and evaluation showed that model simulated values were close to observed values for phenology, and the growth and yield of sunflower. This study also showed the OILCROP-SUN model served as a tool for determining the best nitrogen levels for growing sunflower under irrigated conditions in semi-arid environment in Pakistan. This study illustrates the potential for using crop simulations models as 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 Pakistan and provide them with alternate management options. However, we suggest that in order to be able to identify the optimum management practices for a specific region and a specific crop, a few years of actual field experiments should be conducted for model evaluation.

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