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CONTENTS

Testing of InfoCrop model to optimize farm resources for mustard crop under *tarai* region of Uttarakhand

MANISHA TAMTA[1], RAVI KIRAN[2], ANIL SHUKLA[2], A. S. NAIN[2] and RAJEEV RANJAN[2]

[1]*ICAR- Research Complex for Eastern Region, Patna (Bihar)-800014,* [2]*College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar-263145 (U.S. Nagar, Uttarakhand)*

ABSTRACT: Field experiment was conducted at G. B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand) during the *rabi* season of the year 2014-15 for -three dates of sowing and five planting geometries of mustard crop to test the truthfulness and usefulness of InfoCrop model; and subsequently to optimize the farm resources and decision making. In this study InfoCrop v 2.1 model was used to derive genetic coefficients of the Indian mustard var. RGN - 73 followed by its validation. After successful calibration of the model, simulated and observed values of the experiment were found to be in a good agreement for seed and biological yield while model underestimated the -LAI. Results showed a reduction of seed yield from 1780.5 kg/ha to 1556.5 kg/ha for the delay in sowing from 22nd October to 11th November under field conditions and a similar trend of decrease in yield was also simulated-. Probability analysis was carried to optimize date of sowing at three levels e.g., 90%, 75%, and 60% for the past five years (2010 -2014). The results showed that optimum sowing window for mustard under Pantnagar region lies in the month of October (22nd -28th October) giving a potential yield of up to 2091.7 kg/ha. The planting geometry of 30 × 10 cm and, 30 × 20 cm and 30 × 30 cm was found favorable to get maximum yield under late and timely sown conditions, respectively.

Key words: Date of Sowing, Indian mustard, InfoCrop, planting geometry

At present, India is one of the top vegetable oil economies in the world. Oilseeds are important component of the agricultural economy, next to food grains, in terms of area, production and value. Rapeseed-mustard (*Brassica* spp.) is a major group of oilseed crops and India is the third largest producer (9.34 mt) of this crop after Canada and China. Rajasthan contributes maximum to the production of rapeseed-mustard (4.08 mt) in the country followed by Haryana (1.25 mt) and Uttar Pradesh (1.12 mt) for year 2018-19 (DES, 2021). In India, mustard is mostly grown in northern and north-western parts of the country as *rabi* crop after harvest of *kharif* crop primarily in marginal lands with limited irrigation or on residual soil moisture. Being highly sensitive to the changes in temperature, its development and productivity depends significantly on the time of sowing. The average sowing time in major mustard growing states starts from the first week of October and lasts up to the first week of November. Instead of this optimal sowing window, sowing of mustard is generally delayed due to late harvesting of *kharif* crops and non-suitability of soil moisture for seed germination. Growth and development of individual plants are modified with the space available to plants. Therefore, planting geometry is an important management factor that influences the seed yield of crops. Seed yield per unit area responds to plant density in a curvilinear fashion, with maximum yield occurring at the optimum plant density which depends upon crop species, environmental conditions and agronomic factors (Hassan and Arif, 2012). As the plant densities decline, reduction in the number of plants per unit area is partially compensated by an accompanying increase in the productivity of each plant.

Crop growth simulation model (CGSM) is a very useful and effective tool to predict the growth and yield of a crop (Banerjee *et al.,* 2016) and to assess the impact of environment, genetics and breeding strategies, crop management, as well as climate change and variability on growth and yield. Specifically, a crop model can be described as a quantitative scheme for predicting the growth, development- and yield of a crop, given a set of genetic features and relevant environmental variables (Challinor *et al.,* 2003). Models also provide a means to quantify the effects of climate, soil and management on crop growth and sustainability of agriculture production (Timsina *et al.*, 2004). Crop models can help researchers, policymakers and farmers to make appropriate decisions on crop management practices, marketing strategies and food security of a country. The InfoCrop model used in this study is a decision support system, developed by scientists at Indian Agricultural Research Institute, New Delhi to simulate the effects of weather, soils, agronomic management (including planting, nitrogen, residues and irrigation) and major pests on crop yield and its associated environmental impacts. Sub-models for rice, wheat, maize, sorghum, pearl millet, potato, sugarcane, cotton, pigeonpea, chickpea, groundnut, mustard and soybean are available in InfoCrop. The model considers the key processes related to crop growth, effects of water deficit, flooding, nitrogen management, temperature and frost stresses, crop–pest interactions, soil water and nitrogen balance, and soil organic carbon dynamics (Aggarwal *et al.,* 1994). Therefore, keeping in view the wide usability of simulation models a study was conducted to test the performance of InfoCrop model under localized conditions of Uttarakhand state to simulate the growth and development of Indian mustard crop, which can later be used in farm level decision making for managing farm resources in a better way.

MATERIALS AND METHODS

The field experiment was conducted at Norman E. Borlaug Crop Research Centre (CRC) of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand) during the *rabi* season of the year 2014-15. Geographically this centre is situated at 29°N latitude and 79.3°E longitude with an elevation of 243.8 meter from mean sea level. This region comes under sub-humid and sub-tropical climate with four distinct seasons and an average rainfall of about 1434.4 mm annually. The experiment was laid out in Split Plot Design with three replications having three planting dates at an interval of 10 days (22^{nd} October, 1^{st} November and 11^{th} November) as main plot treatment and five planting geometries (30 × 10 cm, 30 × 20 cm, 30 × 30 cm, 45 × 15 cm, 45 × 30 cm) as sub-plot treatment. The crop was sown with the help of dibbler at 3-4 cm depth. Soil of the experimental site was silty clay loam in texture. Fertilizers were applied as per the recommended dose of 120 kg N, 40 kg P_2O_5 and 20 kg K_2O per ha. In the present study InfoCrop v 2.1 was used to calibrate the genetic coefficients of the Indian mustard (*Brassica juncea*) var. RGN-73, to validate the model for its truthfulness and subsequently using it to optimize the farm resources and in decision making. If a model does not behave according to the expectations then, some corrections of the functional relationship may be necessary, or coefficients may need to be corrected, this is called model calibration and is an elementary aspect of verification. All the input (weather, soil and crop) files were created and model was run to predict the output *viz.,* leaf area index, biomass, yield, etc. Subsequently, the predicted outputs were compared with the observed values of the experimental plot. Model was run several times to get the output close to the field values by making slight changes in a particular factor at a time. Validation of the calibrated model was carried out by comparing the values of model output for seed yield, biological yield and LAI with the observed values of field experiment. InfoCrop model was calibrated using the field data of two dates of sowing (D1 and D2). The genetic coefficients were determined by running the model for each parameter until, a close agreement between the simulated and the observed value is reached following Ebrayi *et al.* (2007) and Venugopalan *et al.* (2014).

The optimum dates of sowing for Indian Mustard under *tarai* region was worked out using meteorological data of five years (2010-2014) and package of practices given by the scientists of GBPUA&T, for the region. Successfully calibrated and validated InfoCrop model was run at an interval of one week to find out the week with maximum productivity of the mustard crop. Apart from the optimum week, sowing of two additional weeks *viz.,* the previous and succeeding one to the optimum week were also considered to find out the optimum dates of sowing, Thereafter, model was used at an interval of one day (for the week with maximum productivity) to find out the optimum dates of sowing (Pareek, 2014). At last probability analysis was carried out by using 'Ranking order method' suggested by Doorenbos and Pruitt (1984). For this, optimum dates of sowing as simulated by model for five years were arranged in descending order on the basis of amount of yield. A number was assigned to each record, that is called ranking number (m), then the probability number Fa(m) was assigned to these ranking numbers as follows:

$$Fa\ (m) = \frac{100m}{n+1}$$

Where:

n = number of records
m = rank number

Recommended planting geometry for the mustard is 30 × 15 cm which utilizes 5 kg/ha seed rate under normal conditions. Using a particular planting geometry for different growing conditions decides the cost of production, which is the main concern for the plant growers as it directly relates to the amount of seed to be used at the time of sowing. Maximization of seed yield and minimization of production cost have remained a matter of prime importance for all the scientists and policy makers for the last few decades. Therefore, to optimize the planting geometry five different geometries 30 × 10 cm, 30 × 20 cm, 30 × 30 cm, 45 × 15 cm and 45 × 30 cm other than 30 × 15 cm were used in the present investigation. For the optimization of planting geometry, the InfoCrop model was run for five different times under three dates of sowing. At first, all the geometries were converted into the seed rates and then the model was simulated for the seed and biological yields. Then a comparative analysis was conducted between the observed and simulated outputs, as earlier reported by Srinivas and Akula (2014) for optimization of date of sowing and spacing using InfoCrop model.

Statistical analysis used to test the results involves Coefficient of Determination (R^2) and Root Mean Square Error (RMSE). The R^2 was used to find out the relationships between two different variables *i.e.,* dependent and independent variables. Its value ranges from 0 to 1. For the present investigation simulated yield and observed yield were considered as dependent variable and independent variables respectively. Coefficient of determination was calculated between two variables. The RMSE describes mean absolute deviation between simulated and observed, where the accuracy of simulation is characterized by lower value of RMSE. It ranges from zero to positive infinity, with the former indicating good and the latter poor model performance. It was calculated by following the given formula:

$$RMSE = \sqrt{\frac{1}{n}\Sigma\ (S\text{-}O)^2}$$

Where,

S = simulated value
O = Observed value
n = Number of observations

RESULTS AND DISCUSSION

The phenological and all other genetic coefficients of the variety RGN-73 derived by the model are listed in the Table 1. The base temperature at different phenological stages of mustard was found to be 5°C as also been reported by Adak *et al.* (2009), Singh *et al.* (2014) and Tamta *et al.* (2018). Whereas the optimum and maximum temperature for crop development were reported to be 24°C and 40°C, respectively. Model was validated for seed yield, biological yield and leaf area index with the corresponding data of different treatments. Observed and simulated above ground dry weight showed decrease in biological yield with delayed sowing. Simulated above ground dry weight (5756.8 kg/ha) was very close to the observed (5602.3 kg/ha) in different sowing conditions, as depicted in Table 2. The seed yield ranged between 1556.5 to 1780.5 kg/ha and 1444.9 to 1565.1 kg/ha for observed and simulated, respectively with a relatively good RMSE of 140.49 kg/ha (8.59 %). Leaf area index ranged between 0.3 to 1.1 and 0.37 to 0.51 at 30 days, 2.8 to 3.0 and 1.02 to 1.81 at 60 days, 2.7 to 3.3 and 0.64 to 0.71 at 90 days for observed and simulated data, respectively. It is clearly evident that model underestimated the LAI. Similar results have been reported by Choudhary *et al.* (2014).

It is evident from the Table 3 and Table 4, for most of the times, the optimum week of sowing lies in the

Table 1: Genetic coefficients derived by model for Indian Mustard var. RGN-73

Phenology parameters	Value	Growth parameters	Value	Source: Sink balance parameters	Value
Base temperature for sowing to germination (°C)	5	Relative growth rate of leaf area (°C/d)	0.008	Slope of storage organs number/m^2 dry matter during storage organ formation (storage organ/kg/day)	600000
Thermal time for sowing to germination (°C days)	160	Specific leaf area (dm^2/mg)	0.0022	Potential weight of the storage organs (mg/seed)	4.8
Base temperature for germination to 50% flowering (°C)	5	Index of greenness of leaves (scale)	1	Nitrogen content of storage organs (fraction)	0.039
Thermal time for germination to 50% flowering (°C days) (ha soil/ha of leaf fraction)	606	Extinction coefficient of leaves at flowering	0.6	Sensitivity of storage organs setting to low temperatures (scale)	1
Base temperature for 50% flowering to physiological maturity (°C)	5	Radiation use efficiency (g/MJ/day)	2.3	Sensitivity of storage organs setting to high temperatures (scale)	1
Thermal time for 50% flowering to maturity (°C days)	808	Root extension growth rate (mm/day)	35	-	-
Optimal temperature for development (°C)	24	Sensitivity of crop to flooding (scale)	1	-	-
Maximum temperature for development (°C)	40	Index of N fixation (scale)	1	-	-
Sensitivity to photoperiod (scale)	1	-	-	-	-

month of October. For the two consecutive years the optimum week of sowing as simulated by the model was 22 October to 28 October, which is, itself in the range of the average sowing dates, recommended by the scientists for the region. After critically analyzing the data presented in Table 5, it was found that, there were 90% chances (at 90% level of probability) of getting 867.2 kg /ha seed yield, had the crop been sown on 8th October for the year 2010. Similarly, there were 90 % chances of getting 1187.6 kg seed yield on per hectare basis for the year 2014. This probably level, signifies that there are 90 % or 75 % or 60 % cases of getting optimum yield, if the sowing can be done on the recommended dates as listed on the table for different years.

Comparison between simulated and observed seed yield (kg/ha) of variety RGN-73 under different dates of sowing and planting geometry has been reported in Table 6. For all the five geometries the model predicted a similar trend of decrease in seed yield with delayed sowing as is case of the observed ones. The geometry of 30 × 10 cm showed the minimum value of RMSE (140.50 kg/ha) with an error Per centage of 8.59 % as compared to that of the other four geometries. So, it can be inferred that, on an average, a closer geometry (30 × 10 cm) results into more seed yield under late sown conditions as simulated by model and observed in field. Whereas, under timely sown conditions 30 × 20 cm and 30 × 30 cm results into better seed yield as compared to wider geometries as reported under field condition. Similar results have also been reported by Srinivas and Akula (2014).

CONCLUSION

In totality, genetic coefficients for the variety RGN -73 were successfully derived from the model by iterative run with the help of experimental data and extensive literature search.

Table 3: Optimum sowing week for past 5 years as simulated by model

Year	Optimum week	Biological yield (kg/ha)	Seed yield (kg/ha)
2010-11	15 October – 21 October	4194.0	1147.0
2011-12	29 October – 4 November	6105.9	1720.9
2012-13	08 October – 14 October	5279.2	1952.0
2013-14	22 October – 28 October	6250.9	2091.7
2014-15	22 October – 28 October	5502.2	1413.0

Table 2: Comparison of simulated and observed values of total above ground dry weight (kg/ha), seed yield (kg/ha) and Leaf area index (LAI)

Date of sowing	Total above ground dry weight (kg/ha)		Seed yield (kg/ha)		Leaf area index (LAI)					
					30 DAS		60 DAS		90 DAS	
	O	S	O	S	O	S	O	S	O	S
22 October	7016.7	6016.2	1780.5	1565.1	1.1	0.51	3.0	1.81	3.3	0.71
01 November	5602.3	5756.8	1568.8	1549.7	0.6	0.46	3.0	1.52	2.8	0.69
11 November	5100.5	4771.3	1556.5	1444.9	0.3	0.37	2.8	1.02	2.7	0.64
RMSE	614.61		140.49		0.35		1.50		2.27	
% RMSE	10.41		8.59		51.86		51.23		77.25	

(Where, O - Observed and S - Simulated)

Table 4: Simulated yield of mustard for optimum, previous and succeeding weeks for different years from 2010-11 to 2014-15

Year/Week	2010-11		2011-12		2012-13		2013-14		2014-15	
	Optimum days	Seed yield (kg/ha)	Optimum days	Seed yield (kg/ha)	Optimum days	Seed yield (kg/ha)	Optimum days	Seed yield (kg/ha)	Optimum days	Seed yield (kg/ha)
Previous week	8 Oct	867.2	22 Oct	1161.9	1 Oct	1953.2	15 Oct	1629.4	15 Oct	1324.3
	9 Oct	1018.9	23 Oct	1321.8	2 Oct	1133.6	16 Oct	1742.1	16 Oct	1411.5
	10 Oct	1070.8	24 Oct	1329.4	3 Oct	1219.8	17 Oct	1965.0	17 Oct	1469.1
	11 Oct	801.0	25 Oct	1309.8	4 Oct	1384.9	18 Oct	2096.2	18 Oct	1469.3
	12 Oct	938.9	26 Oct	1455.2	5 Oct	1415.6	19 Oct	2382.8	19 Oct	1406.8
	13 Oct	988.0	27 Oct	1509.5	6 Oct	1703.1	20 Oct	2206.0	20 Oct	1571.9
	14 Oct	1070.5	28 Oct	1589.4	7 Oct	1995.5	21 Oct	2196.7	21 Oct	1604.7
Optimum week	15 Oct	1147.0	29 Oct	1720.9	8 Oct	1952.0	22 Oct	2091.7	22 Oct	1530.3
	16 Oct	1129.8	30 Oct	1765.1	9 Oct	2113.3	23 Oct	1993.0	23 Oct	1253.7
	17 Oct	1147.2	31 Oct	1823.0	10 Oct	2116.4	24 Oct	1885.3	24 Oct	1187.6
	18 Oct	1100.7	1 Nov	1753.0	11 Oct	2109.2	25 Oct	1831.7	25 Oct	1174.6
	19 Oct	1147.7	2 Nov	1672.2	12 Oct	1982.5	26 Oct	1828.8	26 Oct	1316.5
	20 Oct	1117.8	3 Nov	1525.0	13 Oct	2000.2	27 Oct	1528.8	27 Oct	1410.2
	21 Oct	954.9	4 Nov	1532.4	14 Oct	1928.0	28 Oct	1368.8	28 Oct	1349.5
Succeeding week	22 Oct	951.4	5 Nov	1414.4	15 Oct	1921.9	29 Oct	1418.5	29 Oct	1261.4
	23 Oct	958.2	6 Nov	1406.9	16 Oct	2136.4	30 Oct	1422.5	30 Oct	1329.2
	24 Oct	8734	7 Nov	1563.2	17 Oct	1894.1	31 Oct	1560.6	31 Oct	1471.8
	25 Oct	922.8	8 Nov	1454.5	18 Oct	1995.6	1 Oct	1414.2	1 Oct	1371.8
	26 Oct	998.7	9 Nov	1486.9	19 Oct	1816.1	2 Oct	1542.6	2 Oct	1473.8
	27 Oct	971.9	10 Nov	1275.7	20 Oct	1655.0	3 Oct	1563.5	3 Oct	1504.7
	28 Oct	992.8	11 Nov	1130.9	21 Oct	1411.2	4 Oct	1549.7	4 Oct	1457.4

Table 5: Different levels of probability for optimum date of sowing

Year	Different levels of probability		
	90 %	75 %	60%
2010	8 – October(867.2 kg/ha)	12 – October(938.9 kg/ha)	27 – October(971.9 kg/ha)
2011	22 – October(1161.9 kg/ha)	24 – October(1329.4 kg/ha)	26 – October(1455.20 kg/ha)
2012	03 – October(1219.6 kg/ha)	05 – October(1415.6 kg/ha)	17 – October(1894.1 kg/ha)
2013	01 – November(1414.2 kg/ha)	27 – October(1528.8 kg/ha)	03 – November(1563.5 kg/ha)
2014	24 – October(1187.6 kg/ha)	26 – October(1316.5 kg/ha)	30 – October(1392.2 kg/ha)

The simulated above ground dry weight and seed yield of RGN-73 reported a good correlation with the observed values along with the acceptable error Per centage (10.41 % and 8.59). As a result of the model run, the optimum week of sowing for the two consecutive years of 2013 and 2014 was 22 October – 28 October and the probability analysis has also revealed that, the sowing of mustard should be carried out within the month of October to get maximum seed yield under *tarai* conditions.

Table 6: Effect of planting geometry on seed yield (kg/ha)

PG/Date of Sowing	G1(30×10 cm)		G2(30×20 cm)		G3(30×30 cm)		G4(45×15 cm)		G5(45×30 cm)	
	O	S	O	S	O	S	O	S	O	S
22 October	1780.5	1565.1	1795.0	1287.9	1977.7	1123.0	1492.1	929.7	1281.2	695.5
01 November	1568.8	1549.7	1732.1	1300.6	1598.7	1105.2	1484.2	914.2	1179.9	600.4
11 November	1556.5	1444.9	1453.9	1351.6	1258.6	919.07	1097.3	700.6	960.6	418.3
RMSE	140.50		388.94		602.59		515.93		569.49	
% RMSE	8.59		23.43		37.39		38.00		49.93	
R^2	0.84		0.89		0.81		0.80		0.97	

(Where, PG-Planting Geometry, O-Observed and S-Simulated)

Simulated results of the model for different sowing dates exhibited a reduction in seed yield with wider spacing as was evident from the field experimentation. Therefore, it is concluded that to harvest the best produce the planting geometry of 30 × 30 cm followed by 30 × 20 cm and closer geometry of 30 × 10 cm may be opted under timely and late sown conditions, respectively as a decision-making strategy so as to optimize the use of farm resource.

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