

Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 19(3), September-December, 2021]

Pantnagar Journal of Research

(Formerly International Journal of Basic and
Applied Agricultural Research ISSN : 2349-8765)



G.B. Pant University of Agriculture & Technology, Pantnagar



ADVISORYBOARD

Patron

Dr. Tej Partap, Vice-Chancellor, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Members

Dr. A. S. Nain, Ph.D., Director Research, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. A. K. Sharma, Ph.D., Director, Extension Education, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. S. K. Kashyap, Ph.D., Dean, College of Agriculture, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. N. S. Jadon, Ph.D., Dean, College of Veterinary & Animal Sciences, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. K. P. Raverkar, Ph.D., Dean, College of Post Graduate Studies, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Sandeep Arora, Ph.D., Dean, College of Basic Sciences & Humanities, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Alaknanda Ashok, Ph.D., Dean, College of Technology, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Alka Goel, Ph.D., Dean, College of Home Science, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. R. S. Chauhan, Ph.D., Dean, College of Fisheries, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. R. S. Jadaun, Ph.D., Dean, College of Agribusiness Management, G.B. Pant University of Agri. & Tech., Pantnagar, India

EDITORIALBOARD

Members

Prof. A. K. Misra, Ph.D., Chairman, Agricultural Scientists Recruitment Board, Krishi Anusandhan Bhavan I, New Delhi, India
Dr. Anand Shukla, Director, Reefberry Foodex Pvt. Ltd., Veraval, Gujarat, India
Dr. Anil Kumar, Ph.D., Director, Education, Rani Lakshmi Bai Central Agricultural University, Jhansi, India
Dr. Ashok K. Mishra, Ph.D., Kemper and Ethel Marley Foundation Chair, W P Carey Business School, Arizona State University, U.S.A
Dr. B. B. Singh, Ph.D., Visiting Professor and Senior Fellow, Dept. of Soil and Crop Sciences and Borlaug Institute for International Agriculture, Texas A&M University, U.S.A.
Prof. Binod Kumar Kanaujia, Ph.D., Professor, School of Computational and Integrative Sciences, Jawahar Lal Nehru University, New Delhi, India
Dr. D. Ratna Kumari, Ph.D., Associate Dean, College of Community / Home Science, PJTSAU, Hyderabad, India
Dr. Deepak Pant, Ph.D., Separation and Conversion Technology, Flemish Institute for Technological Research (VITO), Belgium
Dr. Desirazu N. Rao, Ph.D., Professor, Department of Biochemistry, Indian Institute of Science, Bangalore, India
Dr. G. K. Garg, Ph.D., Dean (Retired), College of Basic Sciences & Humanities, G.B. Pant University of Agric. & Tech., Pantnagar, India
Dr. Humnath Bhandari, Ph.D., IRRI Representative for Bangladesh, Agricultural Economist, Agrifood Policy Platform, Philippines
Dr. Indu S Sawant, Ph.D., Director, ICAR - National Research Centre for Grapes, Pune, India
Dr. Kuldeep Singh, Ph.D., Director, ICAR - National Bureau of Plant Genetic Resources, New Delhi, India
Dr. M. P. Pandey, Ph.D., Ex. Vice Chancellor, BAU, Ranchi & IGKV, Raipur and Director General, IAT, Allahabad, India
Dr. Martin Mortimer, Ph.D., Professor, The Centre of Excellence for Sustainable Food Systems, University of Liverpool, United Kingdom
Dr. Muneshwar Singh, Ph.D., Project Coordinator AICRP- LTFE, ICAR - Indian Institute of Soil Science, Bhopal, India
Prof. Omkar, Ph.D., Professor, Department of Zoology, University of Lucknow, India
Dr. P. C. Srivastav, Ph.D., Professor, Department of Soil Science, G.B. Pant University of Agriculture and Technology, Pantnagar, India
Dr. Prashant Srivastava, Ph.D., Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, University of South Australia, Australia
Dr. Puneet Srivastava, Ph.D., Director, Water Resources Center, Butler-Cunningham Eminent Scholar, Professor, Biosystems Engineering, Auburn University, U.S.A.
Dr. R. C. Chaudhary, Ph.D., Chairman, Participatory Rural Development Foundation, Gorakhpur, India
Dr. R. K. Singh, Ph.D., Director & Vice Chancellor, ICAR-Indian Veterinary Research Institute, Izatnagar, U.P., India
Prof. Ramesh Kanwar, Ph.D., Charles F. Curtiss Distinguished Professor of Water Resources Engineering, Iowa State University, U.S.A.
Dr. S. N. Maurya, Ph.D., Professor (Retired), Department of Gynecology & Obstetrics, G.B. Pant University of Agric. & Tech., Pantnagar, India
Dr. Sham S. Goyal, Ph.D., Professor (Retired), Faculty of Agriculture and Environmental Sciences, University of California, Davis, U.S.A.
Prof. Umesh Varshney, Ph.D., Professor, Department of Microbiology and Cell Biology, Indian Institute of Science, Bangalore, India
Prof. V. D. Sharma, Ph.D., Dean Academics, SAI Group of Institutions, Dehradun, India
Dr. V. K. Singh, Ph.D., Head, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi, India
Dr. Vijay P. Singh, Ph.D., Distinguished Professor, Caroline and William N. Lehrer Distinguished Chair in Water Engineering, Department of Biological Agricultural Engineering, Texas A&M University, U.S.A.
Dr. Vinay Mehrotra, Ph.D., President, Vinlax Canada Inc., Canada

Editor-in-Chief

Dr. Manoranjan Dutta, Head Crop Improvement Division (Retd.), National Bureau of Plant Genetic Resources, New Delhi, India

Managing Editor

Dr. S. N. Tiwari, Ph.D., Professor, Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Assistant Managing Editor

Dr. Jyotsna Yadav, Ph.D., Research Editor, Directorate of Research, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Technical Manager

Dr. S. D. Samantray, Ph.D., Professor, Department of Computer Science and Engineering, G.B. Pant University of Agriculture and Technology, Pantnagar, India

PANTNAGAR JOURNAL OF RESEARCH

Vol. 19(3)

September-December, 2021

CONTENTS

| | |
|--|-----|
| Unrevealing the role of epistasis through Triple Test Cross in Indian mustard NARENDER SINGH, USHA PANT, NEHA DAHIYA, SHARAD PANDEY, A. K. PANDEY and SAMEER CHATURVEDI | 330 |
| Testing of InfoCrop model to optimize farm resources for mustard crop under tarai region of Uttarakhand MANISHA TAMTA, RAVI KIRAN, ANIL SHUKLA, A. S. NAIN and RAJEEV RANJAN | 335 |
| <i>In vitro</i> evaluation of endophytes and consortium for their plant growth promoting activities on rice seeds DAS, J., DEVI, R.K.T. and BARUAH, J.J. | 342 |
| Effect of subsurface placement of vermicompost manure on growth and yield of wheat (<i>Triticum aestivum</i> L. Var. UP 2526) ABHISHEK KUMAR and JAYANT SINGH | 348 |
| Assessment of different nutrient management approaches for grain yield, gluten content and net income of common bread wheat (<i>Triticum aestivum</i> L.) in Western Himalayan region of Uttarakhand BHAWANA RANA and HIMANSHU VERMA | 359 |
| Suitability assessment of land resources for cassava (<i>Manihot esculenta</i> L.) and yam (<i>Dioscorea spp</i> L.) cultivation in Khana LGA, Rivers State, Southern Nigeria PETER, K.D., UMWENI, A.S. and BAKARE, A.O. | 367 |
| Biophysical and biochemical characters conferring resistance against pod borers in pigeonpea PARUL DOBHAR, R. P. MAURYA, PARUL SUYAL and S.K. VERMA | 375 |
| Population dynamics of major insect pest fauna and their natural enemies in Soybean SUDHA MATHPAL, NEETA GAUR, RASHMI JOSHI and KAMAL KISHOR | 385 |
| Fumigant toxicity of some essential oils and their combinations against <i>Rhizopertha dominica</i> (Fabricius) and <i>Sitophilus oryzae</i> (Linnaeus) NIDHI TEWARI and S. N. TIWARI | 389 |
| Long term efficacy of some essential oils against <i>Rhizopertha dominica</i> (Fabricius) and <i>Sitophilus oryzae</i> (Linnaeus) NIDHI TEWARI and S. N. TIWARI | 400 |
| Management strategies under chemicals, liquid organic amendments and plant extracts against black scurf of potato caused by <i>Rhizoctonia solani</i> Kühn in tarai regions of Uttarakhand SURAJ ADHIKARI, SHAILBALA SHARMA, R. P. SINGH, SUNITA T. PANDEY and VIVEK SINGH | 408 |
| Effective management strategies against ginger rhizome rot caused by <i>Fusarium solani</i> by the application of chemicals, bioagents and Herbal <i>Kunapajala</i> in mid hills of Uttarakhand SONAM BHATT, LAXMI RAWAT and T. S. BISHT | 417 |

| | |
|---|-----|
| Distribution and morphological characterisation of isolates of <i>Fusarium moniliforme</i> fsp. <i>subglutinans</i> causing Pokkah Boeng disease of sugarcane in different sugarcane growing areas of Udham Singh Nagar district of Uttarakhand HINA KAUSAR, BHAGYASHREE BHATT and GEETA SHARMA | 429 |
| Biointensive management of <i>Meloidogyne enterolobii</i> in tomato under glasshouse conditions SHUBHAM KUMAR, ROOPALI SHARMA, SATYA KUMAR and BHUPESH CHANDRA KABDWAL | 435 |
| Effect of pre-harvest application of eco-friendly chemicals and fruit bagging on yield and fruit quality of mango KIRAN KOTHIYAL, A. K. SINGH, K. P. SINGH and PRATIBHA | 447 |
| A valid and reliable nutrition knowledge questionnaire: an aid to assess the nutrition friendliness of schools of Dehradun, Uttarakhand EKTA BELWAL, ARCHANA KUSHWAHA, SARITA SRIVASTAVA, C.S. CHOPRA and ANIL KUMAR SHUKLA | 452 |
| Potential of common leaves of India as a source of Leaf Protein Concentrate RUSHDA ANAM MALIK, SHAYANI BOSE, ANURADHA DUTTA, DEEPA JOSHI, NIVEDITA, N.C. SHAHI, RAMAN MANOHARLAL and G.V.S. SAIPRASAD | 460 |
| Job strain and muscle fatigue in small scale unorganized agri enterprises DEEPA VINAY, SEEMA KWATRA, SUNEETA SHARMA and KANCHAN SHILLA | 466 |
| Drudgery reduction of farm women involved in weeding of soybean crop SHALINI CHAKRABORTY | 475 |
| Childhood obesity and its association with hypertension among school-going children of Dehradun, Uttarakhand EKTA BELWAL, K. UMA DEVI and APARNA KUNA | 482 |
| Spring water and its quality assessment for drinking purpose: A review SURABHI CHAND, H.J. PRASAD and JYOTHI PRASAD | 489 |
| Spatial distribution of water quality for Indo-Gangetic alluvial plain using Q-GIS SONALI KUMARA, VINOD KUMAR and ARVIND SINGH TOMAR | 497 |
| Application of geospatial techniques in morphometric analysis of sub-watersheds of Nanak Sagar Catchment AISHWARYA AWARI, DHEERAJ KUMAR, PANKAJ KUMAR, R. P. SINGH and YOGENDRA KUMAR | 505 |
| Evaluation of selected carbon sources in biofloc production and carps growth performance HAZIQ QAYOOM LONE, ASHUTOSH MISHRA, HEMA TEWARI, R.N. RAM and N.N. PANDEY | 516 |
| Calcium phosphate nanoparticles: a potential vaccine adjuvant YASHPAL SINGH and MUMTESH KUMAR SAXENA | 523 |
| Factors affecting some economic traits in Sahiwal Cattle DEVESH SINGH, C. B. SINGH, SHIVE KUMAR, B.N. SHAHI, BALVIR SINGH KHADDA, S. B. BHARDWAJ and SHIWANSHU TIWARI | 528 |
| The effect of probiotics and growth stimulants on growth performance of Murrah Buffalo SAMEER PANDEY, RAJ KUMAR, D.S. SAHU, SHIWANSHU TIWARI, PAWAN KUMAR, ATUL SHARMA and KARTIK TOMAR | 532 |

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

MANISHA TAMTA¹, RAVI KIRAN², ANIL SHUKLA², A. S. NAIN² and RAJEEV RANJAN²

¹ICAR- Research Complex for Eastern Region, Patna (Bihar)-800014, ²College 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 (22nd October, 1st November and 11th 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 P₂O₅ and 20 kg K₂O 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:

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

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 |
| Optimum week | 14 Oct | 1070.5 | 28 Oct | 1589.4 | 7 Oct | 1995.5 | 21 Oct | 2196.7 | 21 Oct | 1604.7 |
| | 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 |
| Succeeding week | 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 |
| | 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.

ACKNOWLEDGEMENTS

The corresponding author is grateful to AICRP on Rapeseed- Mustard at GBPUA&T, Pantnagar for providing facilities to conduct the trial and to the Department of Agrometeorology, GBPUA&T, Pantnagar for providing weather data.

REFERENCES

- Adak, T., Chakravarty, N. V. K. and Saxena, R. (2009). Growth and yield prediction in mustard using InfoCrop simulation model. *Journal of Agrometeorology*, 11(2): 156-161.
- Aggarwal, P. K., Kalra, N., Singh, A. K. and Sinha, S. K. (1994). Analyzing the limitations set by climatic factors, genotype, and water and nitrogen availability on productivity of wheat. I. The model documentation, parameterization and validation. *Field Crops Research*, 38: 73-91.
- Banerjee, S., Das, S., Mukherjee, A., Mukherjee, A. and Saikia, B. (2016). Adaptation strategies to combat climate change effect on rice and mustard in Eastern India. *Mitigation and Adaptation Strategies for Global Change*, 21: 249-261.
- Challinor, A. J., Slingo, J. M., Wheeler, T. R., Craufurd, P. Q. and Grimes, D. I. F. (2003). Toward a combined seasonal weather and crop productivity forecasting system: Determination of the working spatial scale. *Journal of Applied Meteorology and Climatology*, 42(2): 175-192.
- Choudhary, D., Patel, H. R. and Pandey, V. (2014). Calibration and validation of InfoCrop model v. 1.0 for yield and yield attributing characters of kharif maize in middle Gujarat region. *Biosciences*, 7(13): 1528-1530.
- DES. (2021). Pocket Book of AGRICULTURAL STATISTICS 2019, Directorate of Economics & Statistics, Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare, Government of India, New Delhi. <https://eands.dacnet.nic.in/> accessed on 02/04/2021.
- Doorenbos, J. and Pruitt, W. O. (1984). Crop Water requirements—Guidelines for predicting crop requirements. *FAO irrigation and drainage paper*, 24: 45-90.
- Ebrayi, K. N., Pathak, H., Kalra, N., Bhatia, A. and Jain, N. (2007). Simulation of nitrogen dynamics in soil using Infocrop model. *Environmental Monitoring and Assessment*, 131(1): 451-465.
- Hassan, F. U. and Arif, M. (2012). Response of white mustard (*Sinapis Alba* L) to spacing under rainfed conditions. *The Journal of Animal & Plant Sciences*, 22(1): 137-141.
- Pareek, N. (2014). Analyzing water requirement of wheat (*Triticum aestivum* L.) using Aquacrop

- model in Tarai region of Uttarakhand. Master's Thesis, G.B.P.U.A.&T., Pantnagar, U.S. Nagar, Uttarakhand.
- Singh, M.P., Lallu and Singh, N. B. (2014). Thermal requirement of indian mustard (*Brassica juncea*) at different phonological stages under late sown condition. *Indian Journal of Plant Physiology*, 19(3): 238–243.
- Srinivas, S. and Akula, B. (2014). Estimation of net returns in rice production using Infocrop model. *Progressive Agriculture*, 14(1): 17-21.
- Tamta, M., Kiran, R., Shukla, A. and Nain, A. S. (2018). Does geometry of crop affect thermal requirement of mustard crop: An analysis of Indian mustard. *MAUSAM*, 69(4): 630-634.
- Timsina, J., Pathak, H., Humphreys, E., Godwin, D., Singh, B., Shukla, A. K. and Singh, U. (2004). Evaluation of, and yield gap analysis in rice using, CERES Rice ver. 4.0 in northwest India. *Proceedings of the 4th international crop science congress on new directions for a diverse planet*, Brisbane, Australia, 26 Sep - 1 Oct 2004.
- Venugopalan, M. V., Tiwary, P., Ray, S. K., Chatterji, Velmourougane, K., Bhattacharyya, T., ... and Thakre, S. (2014). InfoCrop-cotton simulation model—its application in land quality assessment for cotton cultivation. *Current Science*, 107(9): 1512-1518.

Received: December 14, 2021

Accepted: December 28, 2021