Testing the Performance and Application of BRASSICA Model

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Abstract: The technique of crop growth simulation modelling and subsequent system analysis has made it easier for farmers and policy makers to judge and rectify the mismatching of the requirements of crops, products and practices to the physical characteristics of the land, and the resources and social set up of the farmers. Moreover, the developments in the field of information and computer technology have further paved the way for applying crop modelling techniques to simulate yields and growth of several crops under varied soil and weather conditions with different management practices. The approach is simple and requires use of crop specific models and a minimum data set for crop, soil and weather.

A crop model is able to simulate crop growth, development and final yield in a given environment, but before that the model needs to be tested for the location and thereafter requires validation. The BRASSICA model developed at the Indian Agricultural Research Institute, Delhi (Rao, 1992) was tested for its performance with *Brassica juncea* L. (Cjern & Coss.) also known as Indian mustard at Hisar (29°10' N, 75° 46' E at 215m). The observed values on phenology, growth and yield from field trials conducted during five crop seasons were compared with the predicted values. The model was quite efficient in predicting the phenology except the initiation of flowering where the model has an in-built limitation of not taking less than 40 days period as is required to be specified to run a simulation. The year to year variations were large enough for growth and yield parameters implying poor application of the model. However, the predicted values of total biomass production and the number of seed per siliqua were more or less closer to those observed. Further, with the average of 5 crop seasons, the deviations for various parameters were marginalized and became single digits except for maximum leaf area index, test weight and the harvest index where it still remained in the vicinity of 20 per cent.

Keywords: *Mustard, Brassica juncea, Modelling, Phenology, LAI, Biomass, Seed yield, Yield attributes*

1. INTRODUCTION

Since globalisation of the economies world over, the agriculture practised in developing countries like India have undergone tremendous change and is becoming more market oriented rather than following the popular traditional farming of subsistence. During the last three decades, we have witnessed a substantial increase in food production in this part of world accompanied by serious damage to the already fragile agroecological environment. The present agriculture needs to be looked on more as a system which should not only be sustainable but perfect as well. Farming the world over has been largely a risky enterprise where farmers and policy makers are constantly faced with the task of matching and allocating time and resources to efforts that are likely to produce desired outcome. The traditional agricultural research involving on-farm-experimentation to work out feasible, risk free and sustainable agricultural technology requires many years of evaluation. On the other hand, regression models using environmental factors as independent variables have been widely used to predict crop yields. However, lately the process-based crop simulation models based on soil, crop and weather variables have been found to be effective research tools for planning alternative strategies for cropping, land use and water management (Jordan, 1983). Further, these models also have the potential for yield forecasting (Arkin and Dugas, 1984; Huda and Virmani, 1980; Nix, 1976). Moreover, the systems analysis and simulation technique of crop growth simulation modelling have made it easier for farmers and policy makers to judge and rectify the mismatching of the requirement of crop, products and practices to the physical characteristics of land, and the resources and behavioural characteristics of the farmers. In addition, the developments in the field of information and computer technology have further paved the way for applying crop modeling techniques to evaluate the biological requirements of crops and match these to the physical characteristics of the land. The approach is simple and requires the use of crop specific models and a minimum data set for crop, soil and weather.

A crop model is able to simulate crop growth, development and final yield in a given environment, but such a model may not best serve its purpose if applied directly at sites/locations other than where it was originally developed. Thus before using such model for locations other than of its origin, the model needs to be tested for those locations and thereafter it requires validation. This paper describes the results obtained in testing the application of the BRASSICA model (developed by Rao, 1992 at Indian Agricultural Research Institute, Delhi) for its performance in predicting the phenology, growth and yield at Hisar (29°10' N, 75° 46' E at 215m above m.s.l. located around 170 km north-west of Delhi).

2. MATERIALS AND METHODS:

'**BRASSICA**' is a process-oriented growth and simulation model for *brassica* oilseed crops grown under non-limiting moisture and nutrient conditions. Since this model does not consider diseases and pests, only potential growth and yield predictions can be made. The input data required to run the model are:

Planting data: Sowing date, plant population m^2, flowering date

Weather data (daily, sowing to maturity): Maximum and minimum temperatures, bright sunshine hours

Location data: Latitude and longitude

The model accounts for the processes such as phenology, leaf area development and light interception which are independently calculated and used as sub-models. The potential dry matter production is calculated from radiation intercepted. Partitioning of dry matter into different plant parts is based on the stage of development of the plant. The final seed yield per unit area is calculated by multiplying the plant density with the seed yield per plant at the physiological maturity.

The model was run to simulate different aspects of phenology, growth and yield of *Brassica juncea* (Czern. & Coss.), variety RH-30, for 21 data sets comprising three planting dates viz., 5 October, 20 October and 5 November for 7 crop seasons (October-March) at Hisar (29°10' N, 75° 46' E at 215m above mean sea level). The aspects studied included the number of days taken to attain first flower open (**FFO**), first full seed (**FFS**), physiological maturity (**PHM**), maximum leaf area index (**LAI**), number of silique m^{-2} (**SIL**), seeds siliqua^{-1} (**SPS**) 1000-seed weight (**TSW**), seed yield kg ha^{-1} (**SYK**), biomass production kg ha^{-1} (**BYK**) and harvest index per cent (**HI%**). The observed data on the aspects mentioned above were recorded by conducting field experiments in the corresponding crop seasons. The soil of the experimental field was sandy loam in texture, alkaline in reaction (pH 8.1), poor in available nitrogen, medium in available phosphorus and rich in potash. The field was irrigated prior to sowing of the experimental crop. The crop was grown with optimal management that provided an adequate amount of soil moisture and nutrients following the full recommended package of practices except the sowing date. For the simulation of growth and development in different crop seasons, the model was run using the actual daily weather parameters viz., maximum and minimum temperatures and number of bright sunshine hours recorded at the Agrometeorological Observatory located in the vicinity of the experimental site during the corresponding crop season.

For testing the performance of the model the observed and simulated values were compared for different data sets. Beyond this simple comparison, the per cent deviation was also calculated so as to better comprehend the findings and achieve greater acceptability and applicability than if only the average picture was presented. The per cent deviation was calculated using the following formula:

Per cent deviation = 100 * (Simulated – Observed)/Observed

While scrutinizing the deviation values for three sowing dates it was realized that these were higher in the case of the late (November) sown crop and as such the size of the data set was reduced from 21 to 15. Using the observed and simulated values from these 15 data sets the trendlines were plotted. The regression equations of significance have been depicted graphically.

3. RESULTS AND DISCUSSION

The performance of the BRASSICA model was tested for predicting of various aspects of phenology, growth and yield in mustard. The performance of model was evaluated in climatologically potential production conditions i.e. when crop is not affected by any biotic and abiotic stresses. The various growth and yield parameters simulated by using the model were days taken to first flower open, days to first full seed, days to physiologically maturity, maximum leaf area index (LAI), number of silique m-^{2}, number of seeds siliqua^{-1}, seed yield and biomass production kg ha^{-1} and harvest index (%). The values are shown in Table 1.

Table 1: Comparison of average observed (O) and simulated (S) values of different aspects: (a) 15 data sets; (b) 21 data sets

(a)			
Aspect	O	S	% Deviation
FFO, days	43.4	44.3	2.2
FFS, days	81.7	83.5	2.2
PHM, days	138.1	137.5	-0.4
LAI	3.44	4.39	27.6
Silique m^{-2}	4824	4976	3.2
Seed siliqua^{-1}	11.80	11.59	-1.8
1000- seed wt., g	5.92	5.36	-9.5
Seed yield kg ha^{-1}	2461	2523	2.5
Biomass yield kg ha^{-1}	10787	10501	-2.7
HI%	23.6	24.3	2.7
(b)			
FFO, days	43.3	45.6	5.3
FFS, days	82.7	86.8	5.0
PHM, days	139.6	135.4	-3.0
LAI	3.30	4.62	39.8
Silique m^{-2}	4606	5056	9.8
Seed siliqua^{-1}	11.86	11.61	-2.1
1000- seed wt., g	5.82	4.90	-15.7
Seed yield kg ha^{-1}	2293	2438	6.3
Biomass yield kg ha^{-1}	10364	9279	-10.5
HI%	22.0	26.0	18.2

3.1 Phenology

The simulated duration of the various growth stages was invariably different from those observed for different data sets and the per cent deviation values were quite higher for first full seed and physiological maturity as compared to first flower open. However, when averaged, the picture was quite different and the simulated and observed values got quite close with a drastic reduction in the deviations (Table 1). Further, with exclusion of data sets for November sown crop the values came still closer and the per cent deviation for FFO and FFS was 2.2 and for PHM it was -0.4 (Table1) indicating the applicability of the model in predicting the phenology in timely sown crop during October month which is the recommended time of sowing for the crop at Hisar.

3.2 Growth

The model seems to be imperfect in simulating the maximum leaf area index as is evident from the wide difference noted between the observed and simulated values for individual data set and the averaged values over 15 and 21 data sets. Likewise, the per cent deviation of observed and simulated values was quite large and as such, the model highly overestimated the LAI (Table 1).

3.3 Yield and its attributes

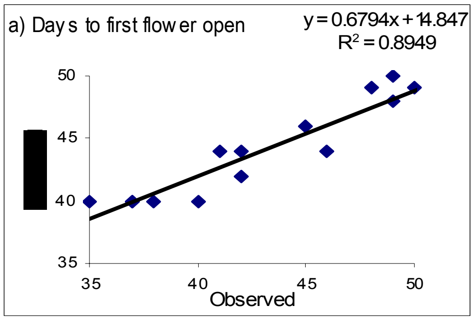
Very large differences were recorded between the observed and simulated values of silique m^{-2}, seeds siliqua^{-1}, 1000-seed weight, the seed and biomass yield kg ha^{-1}and harvest index among the individual data sets. However, by averaging the 21 data sets for observed and simulated values for these aspects, the differences were reduced drastically (Table 1). Further, by discarding the data sets from the November-sown crop the differences were further narrowed down.

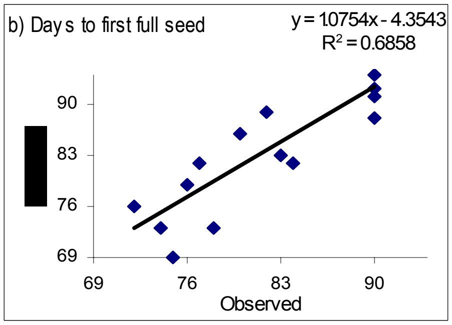
The model overestimated the number of silique, seed yield and harvest index in case of both the averaging conditions. On the other hand, the number of seeds, 1000-seed weight and biomass were underestimated. Hence, the model was quite efficient in predicting the yield and yield attributes with reasonable accuracy.

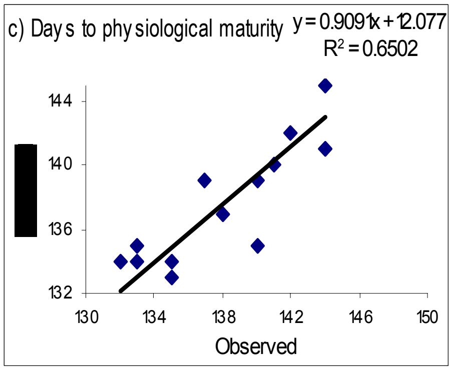
3.4 Regression studies

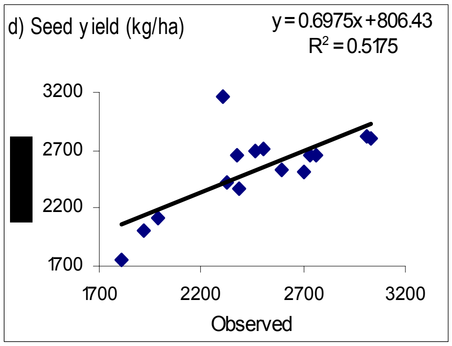
The simple regression of observed and simulated days to first flower open, first full seed and physiological maturity (Fig.1a, 1b and 1c) yielded reasonably high value of R^2 (0.89, 0.69 and 0.65, respectively). The observations were very close on the trendline indicating the acceptability and applicability of model in predicting the phenological development in mustard.

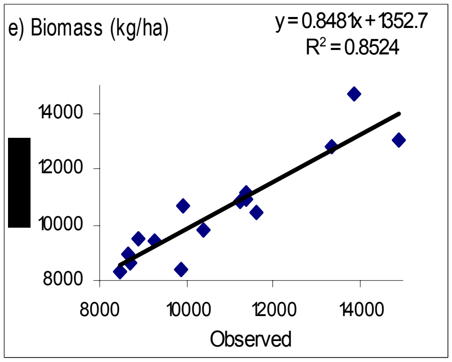
Fig.1: Relationship between observed and simulated values for different aspects

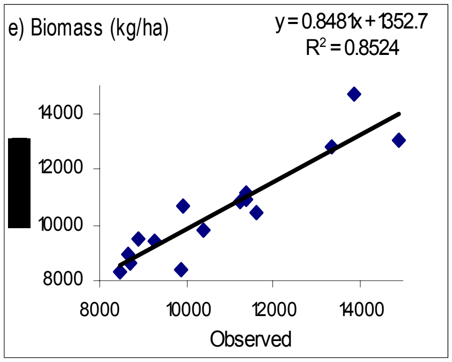


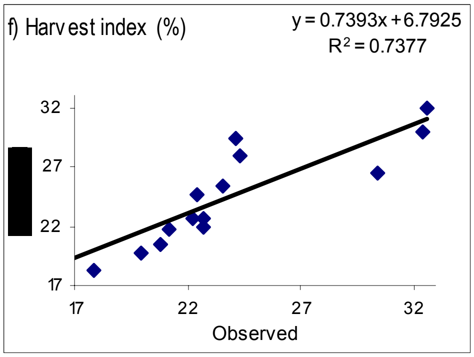












The observed and simulated maximum leaf area index values showed a poor relationship because of under or over-simulation by the model depending on the sowing time and crop season, thereby proving non-suitability of the model in simulating the LAI. Similarly, the relationship between the observed and the simulated values of number of silique m^{-2}, seeds $siliqua^{-1}$ and 1000-seed weight yielded R^2 values below 0.50 and as such the predictability of these parameters was poor indicating unsatisfactory performance of the model under varying sowing time and crop season.

The relationship between observed and simulated seed yield has been depicted in Fig.1d. Though the R^2 of 0.51 was rather low the model performed quite satisfactorily in some seasons and simulated seed yield with reasonable accuracy. However, the over or under-estimation could be expected because of the poor relationship observed for yield attributes.

There was a very close relationship between the observed and simulated biomass production yielding a R^2 value of 0.85. The fairly low values of the intercept and slope indicated the acceptability of the model's capability to predict the biomass (Fig.1e). Similarly, the relationship between the observed and simulated harvest index, as depicted in Fig.1f, showed the acceptability of the model's capability to predict the harvest index because of a reasonably high R^2 value of 0.74.

Though the model simulated the biomass yield and harvest index quite well, the seed yield simulation was poor because of its dependence on the yield contributing attributes. As discussed earlier, the performance and application of model in simulating the yield attributes were highly variable and yielded very poor R^2 values. In addition there was an underestimation in the case of two of the yield attributes (seed siliqua^{-1} and 1000 seed weight) and underestimation in case of another one, namely the number of silique m^{-2} thus resulting in poor seed yield simulation.

4. CONCLUSIONS

The performance of the BRASSICA model was tested by predicting various aspects of phenology, growth and yield in mustard. The model simulates these aspects only under non-limiting moisture and nutrient conditions. In conclusion, it may be recalled that the model predicted phenological development (first flower open, first full seed and physiological maturity) quite efficiently and hence can be applied without much problem. The predictions with respect to the biomass, seed yield and its attributes were also within acceptable limits of accuracy. However, the model has a very poor applicability in predicting the LAI. To achieve the wider applications for the model, there is a need to study the model in detail and bring about necessary changes in sub-routines, if required. In addition, to make the model more versatile there is a need to incorporate the soil moisture, nutrient and pest response sub-routines.

5. REFERENCES

Arkin, G.F. and W.A. Dugas. Evaluating sorghum production strategies using a crop model. In: *Proc. Int. Symposium on Agrometeorology of Sorghum and Millet*. ICRISAT, Patancheru, A.P., India, 289-295, 1984.

Huda, A.K.S. and S.M. Virmani. A system analysis approach to developing cropping system in semi-arid tropics. In: D. Yaron and C. Tapiero (Eds.) *Operations research in Agriculture and Water Resources*. North-Holland Publishing Company, Amsterdam, The Netherlands, 239-248, 1980.

Jordan, W.R. Whole plant responses to water deficits- An Overview. In: H.M. Taylor, W.R. Jordan and T.R. Sinclair (Eds.) *Limitation to Efficient Water Use in Crop Production*. Madison, Wisconsin, USA: American Society of Agronomy. 289-317, 1983.

Nix, H.A. Climate and crop productivity in Australia. In: *Climate and Rice*, International Rice Research Institute, Los Banos, Philippines. 495-508, 1976.

Rao, T.R. Growth and development of mustard and pearl millet in relation to light interception and photosynthesis and modeling for *Brassica species*. Ph.D. thesis: Indian Agricultural Research Institute, New Delhi. 265, 1992.