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SENSITIVITY ANALYSIS OF INFOCROP TO WEATHER AND NON-WEATHER PARAMETERS

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SUMMARY

Sensitivity of InfoCrop simulated grain yield under potential and stressed conditions to change in temperature indicated that with incremental unit increase in mean temperature, the simulated yields decreased and *vice versa*. But, the magnitude of change from the respective base yields was more to temperature under stressed conditions. This behaviour of the models was mainly ascribed to the logical function that high temperatures reduced the thermal time requirement for pre anthesis and grain filling and this fact resulted into low yields. The InfoCrop model showed linear response to inputs of TTVG (Thermal time for vegetation), potential grain weight (POTGWT), grain number (GNOCF), initial nitrogen (NSOILI) and water content at sowing (WCLI). Besides the above, InfoCrop exhibited linear response to potential growth rate (RGRPOT) and specific leaf area of variety (SLAVAR) as these governed the leaf area index (LAI), respectively in the initial and later stages.

Key words: **InfoCrop, non-weather parameters, potential yield, sensitivity analysis, stressed condition.**

INTRODUCTION

InfoCrop is a decision support system developed by Aggarwal and his co-workers (2004) at Centre for Applications of Systems Simulation, IARI, New Delhi based on crop models that are designed to simulate the effects of weather, soils and agronomic management practices on crop growth and yield . Its general structure is based on MACROS (Penning de Vries *et al*. 1989) SUCROS (Laar van *et al*. 1997) and WTGROWS (Aggarwal *et al.* 1994). Wheat is one of the models, which InfoCrop includes besides other models of Rice, sorghum, soybean, cotton, pigeonpea, potato etc. Any model before its commercial application would be tested under different situations to ascertain its robustness besides testing its sensitivity to know the behaviour of the model for different values of parameters. Sensitivity analysis also provides a mechanism for testing the simulation results under extremes and also the behavior of the model for different values of parameters. With the same premise, InfoCrop was tested before its commercial release to estimate wheat yields under Anand conditions, which represents central Gujarat. Further, as the model is based on WTGROWS for wheat yield estimation, the sensitivity of the model has been studied in comparison with WTGROWS, but, the text was not included in the article as it is out of scope of the present paper. Moreover, the robustness of the WTGROWS has already been documented.

MATERIALS AND METHODS

The model, InfoCrop was vigorously tested under two paradoxical situations in terms of mathematical logic and

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stability to extreme values of weather and non-weather parameters. The weather parameter selected for this purpose was temperature with their incremental units ranging between ±1 to ±5 °C / MJ m^{-2}. The non-weather parameters tested were potential grain weight, grain number, soil nitrogen and soil water content at sowing. Simulated yields under potential and stressed conditions were considered as base results and the conditions established to generate these results as base conditions. The potential condition was assumed with no limitation of water and nitrogen, while stressed condition was assumed to be with 50 per cent of water and nitrogen availability. The model was calibrated and validated with the field data generated through the experiments carried out, respectively during *rabi*, 2000 and 2001 at B.A. College of Agriculture, Anand Agricultural University, Gujarat. However, potential yield recorded in 2000 was considered for the study as it was more than that recorded for *rabi*, 2001.

Description of InfoCrop

The basic code is in FST- DOS version. But windows version is also available with Visual basic as front end and MS- Access as back end. The former version has been more useful to the model developers while the latter is useful for the model applications. It is more users friendly with application focused front end. It deals with the interactions among weather, crop/variety, soils and management besides major pests. It has the database in respect of Indian soils. It simulates daily dry matter production as a function of irradiance, maximum and minimum temperatures, water, nitrogen and biotic stresses (pests). The crop growth process that can be simulated are: phenology, photosynthesis, respiration, leaf area growth, assimilate partitioning, source-sink balance, nutrient uptake and partitioning, transpiration. These processes are arranged in sub models.

Phenology

In the model, crop developmental stages quantify physiological age with no major effect of growth unless very poor. Factors taken into account while accounting phenological development are temperature, photoperiod, water stress, and nutrient stress besides varietal characters. Crop development in the model is considered in terms of thermal time requirement for three phases; sowing to germination, germination to flowering and flowering to physiological maturity just the same way as it is done in case of WTGROWS. Thermal time is calculated as the sum of mean daily temperature over the base temperatures at which development stops. The assumptions underlying the calculation of thermal time requirement are:

- The temperature response is linear over the range expected for crop growth
- Daily temperature does not fall below the base temperature of crop for a significant part of the day
- The other factors that affect the rate of development are photoperiod, water and nutrient stresses. Water and nutrient stresses accelerate rate of development and their effect is small as compared to that of temperature.

Leaf area development

Leaf area development is described as a function of leaf weight and specific leaf area (source limited). But, at early development stages leaf area growth is accounted as sink limited and it is coupled to temperature through its effect on cell division and expansion. Specific leaf area is calculated as area of leaves per unit dry weight of leaves at different stages. Area of stems as well as that of spikes is considered along with the area of the leaves and also the senescence, while calculating the net photosynthetic area. While simulating senescence, aging, N, water, temperature stresses and mobilization of reserves from leaves are considered as contributing factors.

Photosynthesis

It is calculated as a function of photosynthetically active radiation (PAR), LAI, extinction coefficient and radiation use efficiency (RUE). The RUE considered for wheat was 3.2 g DM per MJ of (Intercepted Photosynthetically Active Radiation (IPAR). The controlling factors of RUE are: radiation, temperature, CO_2, varietal characters and development stage of the crop.

Nitrogen

Mass balances between sinks and sources of various components in the model have been used with time constants to moderate the rate of flow. Total soil N is subdivided into four components. They are: (1) organic N in soil, (2) NH_4 –N and NO_3 – N present in soil and added through fertilizer (3) urea- N added through fertilizer and (4) N added through farm yard and green manure. Fertilizer can be applied in any of three soil layers assumed in the model. The layers can be of any thickness depending upon the soil type and the user has to specify the depth of each layer.

The organic N is mineralized linearly with a specific rate of mineralization and follows first order kinetics. Similar is the case with respect to the processes of urea hydrolysis, nitrification, denitrification and immobilization also. In the other words, these processes also proceed linearly with respect to the respective specific rate of the process concerned. Among the various factors; temperature, moisture and pH were considered to affect the microbial transformation. It is also assumed that these factors will affect the processes of N mineralization, nitrification and urea hydrolysis in a similar way, as all these processes are microbes mediated.

Grain yield

Potential yield and the actual yields in the model are calculated as:

Potential yield = Grain number x potential grain weight

Actual yield = min (potential yield, grain growth rate, current photosynthates + reserves).

RESULTS AND DISCUSSION

Potential condition – varying temperature

The examination of the data presented in the Table 1, on sensitivity of InfoCrop simulated grain yield under change in weather parameters indicated that with incremental unit increase in mean temperature, the simulated yields decreased and *vice versa*. The yield values with a temperature increase of 1 and 5°C above the mean temperature correspondingly decreased grain yields from 5997 to 5201 kg ha^{-1} (Table1) The corresponding values of percentage change from base potential yield were, –4.45 to –17.13. On the other hand, increased simulated yield with decrease in temperature ranged between 6462 kg ha^{-1} at -1°C and 7213 kg ha^{-1} at -5°C, respectively, which was relatively less than the corresponding yield values recorded to increase in temperature. This behaviour of the models was mainly ascribed to reduced duration to anthesis and grain filling with increase in temperature and *vice versa* (Arkins *et al*. 1976, Mass and Arkin 1980, Muchow *et al*. 1990, Aggarwal and Sinha 1993, Aggarwal and Kalra 1994, Bell and Fischer 1994). The InfoCrop model was optimized at 28 °C, while the temperatures rose to nearly 30 °C during the season. Further increase reduced the yields. The results of this study also match with those reported by Semenov and Porter (1995), Riha *et al*. (1996) and Rosenzweig and Tubiello (1996).

Table 1. Sensitivity of the InfoCrop to ambient temperature

Parameter	Simulated yield (kg ha^{-1})	
	potential	stressed
Base yield	**6276**	**2857**
Temperature		
1 °C	5997	2602
2 °C	5764	2520
3 °C	5596	1786
4 °C	5320	1542
5 °C	5201	1189
-1 °C	6462	2913
-2 °C	6594	3070
-3 °C	6904	3206
-4 °C	7113	3315
-5 °C	7213	3517
TTVG %		
10	6727	-
-10	5470	-

Stressed condition – varying temperature

Simulations carried out under stressed conditions with 50 per cent of optimal water and nitrogen availability indicated more decrease in yields with increase in temperature and the magnitude of decrease was about two-fold or more than two fold higher than its counterpart value under potential conditions. The reason for this was the fact that the base result (standard yield) under stressed conditions was more than two fold (2857 kg ha^{-1}) lower than potential yield (6276 kg ha^{-1}). Hence, the impact of this fact was also reflected consequently on simulated grain yield with decreased temperatures as the set of variables used were the same but the temperatures. The nutrient (N) starved and thirsty (less moisture) conditions in conjunction with high temperatures worsened the expression of crop in terms of growth and development and consequently the yield. Those high temperatures reduced the TTVG and consequently resulted in low yields. Paradoxically, the low temperatures increased the yield in the same magnitude as that of reduction in yield with increase in temperatures. The percentage of change was 1.96 (2913 kg ha^{-1}) at -1 °C and 23.10 percent (3517 kg ha^{-1}) at -5°C (Table 1).

Sensitivity analysis to non-weather parameters

The model showed linear response to inputs of TTVG (Thermal time for vegetation). The percentage changes from base yield respectively under potential and stressed conditions; to ten per cent increase in TTVG were 7.19 (Table 1) and 5.60 (Fig.1). The values corresponding to ten per cent of decrease in TTVG were respectively -12.84 (Table 1) and -3.72 for potential and stressed conditions. In the model the duration of phase covering the period from seedling emergence to anthesis has been governed by a single user specified thermal time. This phenophase of wheat crop has been based on development stage, which is calculated by integrating temperature – driven development rates. The rate of development was linearly related to daily mean temperature above the base temperature up to the optimum temperature. The sum of daily temperature is the thermal time. Decrease in thermal time requirement enforced the crop to reach the 'flowering window', which subsequently reduced the crop duration leading to

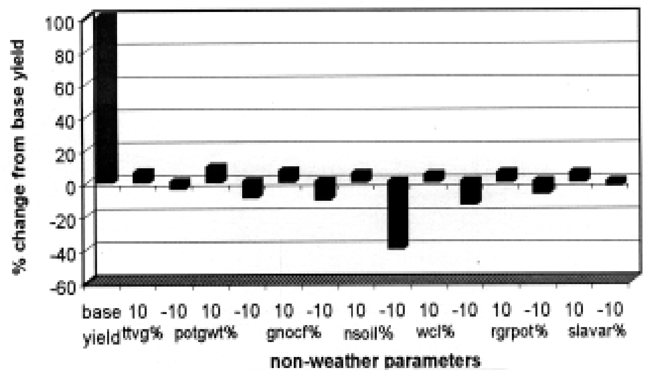

Fig. 1. Senstivity of InfoCrop to non weather parameters under stressed conditions.

yield loss. Moreover, decreased thermal time requirement causes moisture stress during flowering. Moisture stress at flowering hampers translocation of dry matter from leaves to grains, which begins at flowering (Waldren and Flowerday 1979). Moisture stress during the early stages of crop growth, viz. tillering reduced the root growth and thereby hampered the moisture uptake in the subsequent stages of crop growth (Gajri *et al*. 1989).

Under stressed conditions, sensitivity of InfoCrop model was 8.77, 6.40, percentage from base yield to ten per cent increase in POTGWT, GNOCF. Potential grain weight (POTGWT) and grain number (GNOCF) were directly related to grain yield and hence, positive linear response was noticed to ten per cent increase in POTGWT. These respective values corresponding to ten per cent decrease were -9.32, -10.54. The response to ten per cent increase of NSOILI and WCLI, was 4.77 and 4.21, respectively, while similar quantity of down scaling reduced the yield by –29.88 and –13.67 per cent, respectively conveying the message that the model is more sensitive to initial nitrogen content present in the soil at the time of sowing rather than water content. Nevertheless, both nitrogen and water affect photosynthesis, respiration, senescence and carbohydrate partitioning. Thus, nitrogen and water stress in the model decreased transpiration and raised canopy temperature, accelerating phenological development, which subsequently lowered the yields.

Response of InfoCrop to ten per cent of increase in RGRPOT and SLAVAR was 5.36 and 5.11 per cent, respectively. Corresponding values with 10 per cent decrease in these variables were -6.96 and -23.7, respectively. Potential growth rate (RGRPOT) governs the LAI in the initial stages of the crop while specific leaf area of the variety (SLAVAR) governs the same, i.e. LAI in later stages.

The sensitivity analysis of the InfoCrop to change in weather parameters indicated that, with incremental unit increase in mean temperature, the simulated yields decreased and *vice versa*. The model was also more sensitive to initial nitrogen content present in the soil at the time of sowing rather than water content. Thus, sensitivity analysis of the InfoCrop model done under extremes of potential and stressed conditions gave an insight about the importance of these parameters in terms of yield and also enhanced the understanding about plant physiology also; as it is crop development and growth process based model integrating the knowledge of physiology besides, meteorology, genetics and breeding etc.

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REFERENCES

Aggarwal, P.K. and Kalra, N. (1994). Simulating the effect of climatic factors, genotype and management on productivity of wheat in India, p. 156. Division of Environmental Science, IARI, New Delhi.

Aggarwal, P.K., Kalra, N., Singh, A.K. and Sinha, S.K. (1994). Analyzing the limitations set by climatic factors, genotype, water and nitrogen availability on productivity of wheat I. The model description, parameterization and validation. *Field Crops Res.* **38**: 73-91.

Aggarwal, P.K. and Sinha, S.K. (1993). Effect of probable increase in carbon dioxide and temperature on wheat yields in *India. J. Agric. Meteorol.* **48**: 811-814.

Aggarwal, P.K., Kalra, N., Chandar, S. and Pathak, H. (2004). InfoCrop : ageneric simulation model for annual crops in tropical environments, p. 132. Indian Agricultural Research Institute, New Delhi.

Arkin, F.G., Vanderlip, R.L. and Ritchie, J.T. (1976). A dynamic grain sorghum growth model. *Trans, ASAE* **19**: 622-630.

Bell, M.A. and Fischer, R.A. (1994). Using yield prediction models to assess yield gains: a case study for wheat. *Field Crops Res.* **36**: 161-166.

Gajri, P.R.; Prihar, S.S. and Arora, V.K. (1989). Effect of nitrogen and early irrigation on development and water use by wheat on two soils. *Field Crops Res*. **21** : 103-114.

Kropff, M.J., Laar van, H.H. and Mathews, R.B. (1994). ORYZA-1: An ecophysiological model for irrigated rice production. SARP Research Proceedings, p. 110, IRRI, Los Banos, Philippines.

Laar van, H.H., Goudriaan, J. and Keulen van, H. (1997). SUCROS97. Simulation of crop growth for potential and water- limited production situations. Quantitative approaches in systems analysis 14, p 52. Wageningen Netherlands. CT de Wit Graduate School of Production Ecology.

Maas, S.J. and Arkin, G.F. (1980). TAMW: A wheat growth and development simulation model, Research Centre Program and Model Documentation No. 80-3. Blackland Research Centre, Texas Agricultural Experimental Station, Temple, USA.

Muchow, R.C., Evensen, C.I., Osgood, R.V. and Robertson, M.J. (1990). Yield accumulation in irrigated sugarcane. II. Utilization of intercepted radiation. *Agron. J.* **89**: 656-652.

Penning de Vries, F.W.T., Jansen, D.M., ten Berge, H.F.M. and Bakema, A. (1989). Simulation of ecophysiological processes of growth in several annual crops. Simulation Monographs, p. 271, PUDOC, Wageningen, The Netherlands.

Riha, S.J., Wilks, D.S. and Simoens, P. (1996). Impact of temperature and precipitation variability on crop model predictions. *Climatic Change* **32**: 293-311.

Rosenzweig, C. and Tubiello, F.N. (1996). Effects of changes in minimum and maximum temperatures in wheat yields in the central US : A simulation study. *Agric. For. Meteorol.* **80**: 215-230.

Semenov, M.A. and Porter, J.R. (1995). Climate variability and the modelling of crop yields. *Agric. For. Meteorol.* **73**: 265-283.

Waldren, R.P. and Flowerday, A.D. (1979). Growth stages and distribution of dry matter N, P and K in winter wheat. *Agron. J.* **71** : 391-397.