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Validation of CERES-Maize Model Under Different Planting Dates and Moisture Regimes

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ABSTRACT

A study was carried out on maize *(Zea mays* L.), cv. Parbhat to validate the CERES-Maize simulation model under different planting dates (June 10 and June 29) and irrigation levels (at seedling, at kneehigh, at seedling + tasseling, at kneehigh + tasseling and normal irrigation) during kharif season, 1999. The treatments included two dates of planting and five irrigation levels that were replicated four times in randomized block design. The performance of CERES-Maize model in predicting LAI and dry matter accumulation was well matched during the reproductive phase of the crop, under unstressed treatments. Difference between model-predicted and field observed, phenological dates ranged from 1 to 9 days for different phenological events. The model predicted an overestimation of 3.61 to 37.1 per cent in grains m-2 while, underestimation of 5.90 to 23.11 per cent in grains cob^{-1} and underestimation of 10.50 to 20.20 per cent in hundred grain weight was predicted by the model. The model-predicted grain yield fell within 99.98 to 104.74 per cent of the actual yield, under unstressed treatments, while under stressed treatments it fell within 120.93 to 124.60 per cent of the actual yield, showing that model can safely be used to predict the grain yield of maize crop, cv. Parbhat sown on June 10 and June 29 under well watered conditions.

Key words: Simulation model, CERES-Maize, validation, phenological stages, sowing dates, irrigation levels.

Introduction

Performance of a crop in terms of its growth and yield is a result of continuous interactions of its genetic variable with its environment. The quantification of such an interaction of weather in terms of growth and yield of a crop is called crop model. These simulation models can help in better understanding of microclimate interaction and interactions amongst soil, crop, weather, pests and diseases. Such understanding obtained will be helpful in controlling the productive ecosystems in efficient manner. These models also have potential for generating forecast of regional yields in advance of maturity or harvest of a crop.

The maize growth and yield forecast can be done either by an expensive and time consuming approach of developing a crop model, by conducting number of experiments or by using an existing model to simulate the crop growth and yield. Keeping this in view a simulation model of maize growth and development, CERES-Maize, is selected to test and validate CERES- Maize model under different planting dates and irrigation levels.

Materials and Methods

The experiment was conducted with maize cv. Parbhat during kharif season of 1999-2000 at Ludhiana on loamy sand. The experiment was laid out in randomized block design with four replications and ten treatments with two dates of planting (June 10 and June 29) and five irrigation levels viz., irrigation at five leaves stage or seedling stage (I5L), at knee high stage (IK), at seedling + tasseling stage (I5L+ T), at knee high and tasseling stage (IK + T) and normal irrigation (IN) i.e., to keep the crop unstressed throughout the growing season. The soil was sandy loam having 0.13% O.C., 196.0 kg ha^{-1} available nitrogen, and 9.8 kg ha^{-1} available P, 209.5 kg ha^{-1} available K, pH 8.0 and electrical conductivity 0.20 ds m^{-1}.

The field capacity and wilting point were 13.50 and 4.20% respectively.

CERES-Maize Model

Standard version of model was used which is a daily incrementing simulation model of maize growth, development and yield, which was developed by the United States Department of Agriculture, Agriculture Research Service, Temple Texas (Ritchie *et al.*, 1986). This model is designed to simulate the effects of planting date, planting density, cultivars, weather, soil water and nitrogen on crop growth, development and grain yield. Genetic coefficients used in the model are as follows:

GDD from seedling to Juvenile stage (^{0}C days)	625
Photoperiod sensitivity coefficient	0.8
Potential grain number per plant	430
GDD from silking to maturity (^{0}C days)	700
Potential grain growth rate (mg day^{-1})	7.2

Results and Discussion

Validation for phenology

The Comparison of field observed and model predicted phenological stages under both the dates of planting are presented in Table 1. Under each date of planting difference between predicted and observed total crop growth period was of 7 days. Under first date of planting the predicted emergence date was only 1 day earlier while predicted silking date was only 3 days later than field observed dates. The duration of reproductive phase (from tasseling to physiological maturity) was 75 days, while observed duration was 62 days i.e. a difference of 13 days existed Between observed and predicted values. Under second date of planting the predicted emergence and tassel initiation stages were earlier only by 1 day. While, a difference of 7 days was existed between predicted and observed duration of reproductive phase. Under field condition the relatively low mean air temperature of 26°C, under second date of planting, during silking to physiological maturity extended this period by 10 days over that of first date of planting where high mean air temperature of 30°C shortened this phase. The model predicted same trend where the prediction of this extended period was of 4 days. Under each date the phenological phases appeared on the same time under different irrigation levels and the model predicted the same.

Deviation in the simulated and observed phenological dates could be probably due to the linear estimation, by the model, of the relationship between the crop growth rate and thermal time (growing degree days) in predicting the phenophases, while the actual relationship is a curvilinear one (Jaimez, 1997). Also consideration of the same base temperature, throughout the growing season by the model, which actually changes with the advancing stage of the crop development (Iwata, 1975), might have resulted in the above deviation between predicted and observed dates for different phenological events.

Validation for growth parameters

Results for validation of growth parameters are presented for two extreme conditions i.e. I5L (most stressed) and IN (unstressed treatment) other treatments fell in between these.

Leaf Area Index : Under both dates of planting, though the model overestimated the LAI throughout the growing season, but this overestimation was very high for I5L irrigation level, while, for IN level the prediction was well matched, particularly during reproductive stage (Fig. 1 and 2). This overestimation of LAI under all the treatments may be attributed to the calculation of LAI, by the model, based on the inbuilt leaf appearance rate of temperate regions under which conditions model has been developed. While, sub-tropical conditions prevails in North India, where the validation study of model was done. Using the inbuilt leaf appearance rate, overestimation of predicted leaf area was also reported by Xevi *et al.* (1996).

The maximum deviation between predicted and observed LAI under I5L irrigation level was due to the reduced leaf appearance rate and leaf area under water stress conditions (Carberry, 1993), which prevailed under this treatment, but model did not take into account the stress effect on leaves growth rate while predicting LAI.

Dry matter accumulation: Though the model overestimated the dry matter accumulation under all the treatments, with a higher gap (between predicted

Table 1. Comparison of field-observed and model-predicted Phenological stages under June 10 and June 29 dates of planting

Treatment	Parameters											
	Yield (kg ha^{-1})			100 Grain Weight (g)			Total Grains (number m^{-2})			Number of grains per cob		
	P	O	Dev. (%)	P	O	Dev. (%)	P	O	Dev. (%)	P	O	Dev. (%)
June 10 I_{5L}	4174	3350	+24.60	15.12	16.90	-10.50	2333	1702.1	+37.00	311	330.4	-5.90
June 10 I_K	4126	4090	+0.88	14.81	17.90	-17.30	2355	2003.1	+17.57	310	362.2	-14.41
June 10 I_{5L+T}	4333	4360	-0.62	15.55	18.50	-15.90	2355	2065.4	+14.02	310	373.47	-17.00
June 10 I_{K+T}	4333	4390	-1.29	15.55	18.53	-16.10	2355	2150.3	+9.52	310	378.82	-18.16
June 10 I_N	4333	4420	-1.97	15.55	18.80	-17.30	2355	2272.9	+3.61	310	389.65	-20.44
June 29 I_{5L}	4269	3530	+20.93	14.97	17.50	-14.46	2410	1853.8	+30.00	317	344.65	-8.00
June 29 I_K	4315	4210	+2.50	15.13	18.96	-20.20	2410	2084.5	+15.62	317	371.83	-14.75
June 29 I_{5L+T}	4886	4665	+4.74	17.13	19.50	-12.15	2410	2155.7	+11.80	317	384.53	-17.56
June 29 I_{K+T}	4913	4820	+1.93	17.22	20.23	-14.90	2410	2308.2	+4.40	317	400.98	-20.93
June 29 I_N	4924	4930	-0.12	17.26	20.53	-15.93	2410	2273.9	+5.99	317	412.3	-23.11

(+) - overestimation Dev. - Deviation P - Predicted (-) - underestimation O - Observed

Table 2. Comparison between field-observed and model-predicted yield contributing characters and yield

Phenological stage	June 10		June 29	
	P	O	P	O
Emergence	15 June (166)	16 June (167)	3 July (184)	4 July (185)
Kneehigh	14 July (195)	22 July (203)	1 Aug. (213)	6 Aug. (218)
Tassel Initiation	20 July (201)	27 July (208)	8 Aug. (220)	9 Aug. (221)
Silking	31 Aug. (243)	28 Aug. (240)	18 Sept. (261)	9 Sept. (252)
Physiological maturity	3 Oct. (276)	27 Sept. (270)	25 Oct. (298)	19 Oct. (292)

Figures in parenthesis indicate Julian day of the year.

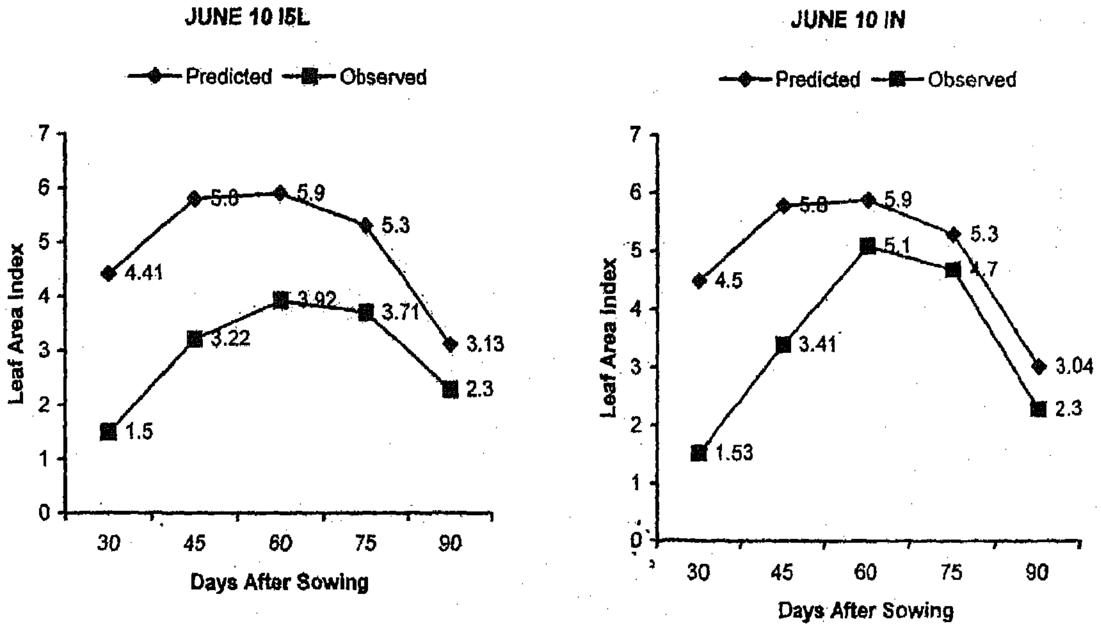

Fig. 1. Comparision of field observed and model predicted LAI (Leaf Area Index) under June 10 data of planting

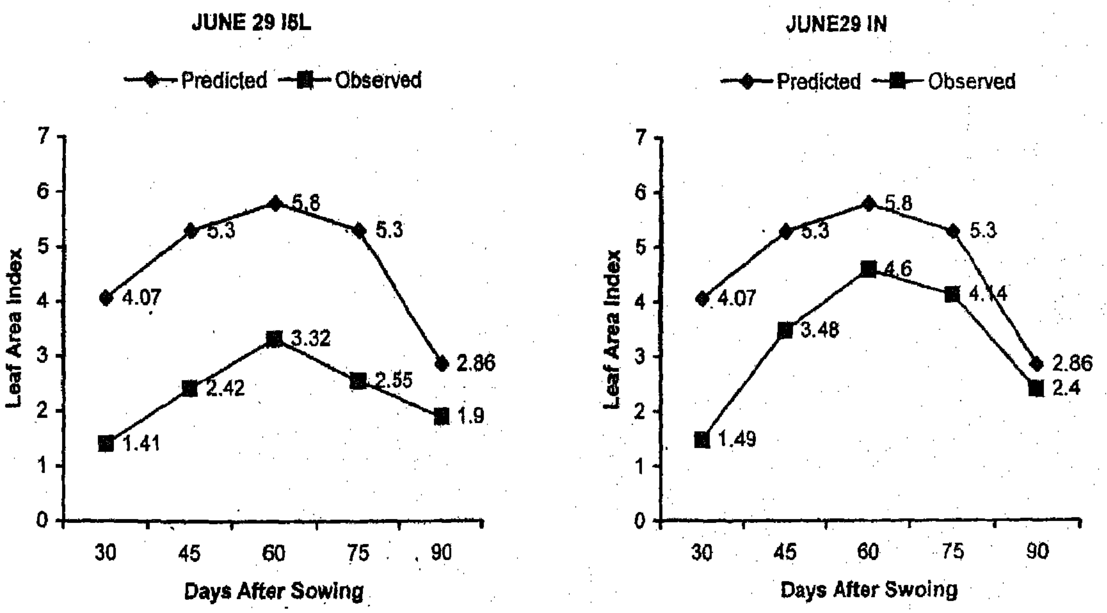

Fig. 2. Comparision of field observed and model predicted LAI (Leaf Area Index) under June 29 data of planting

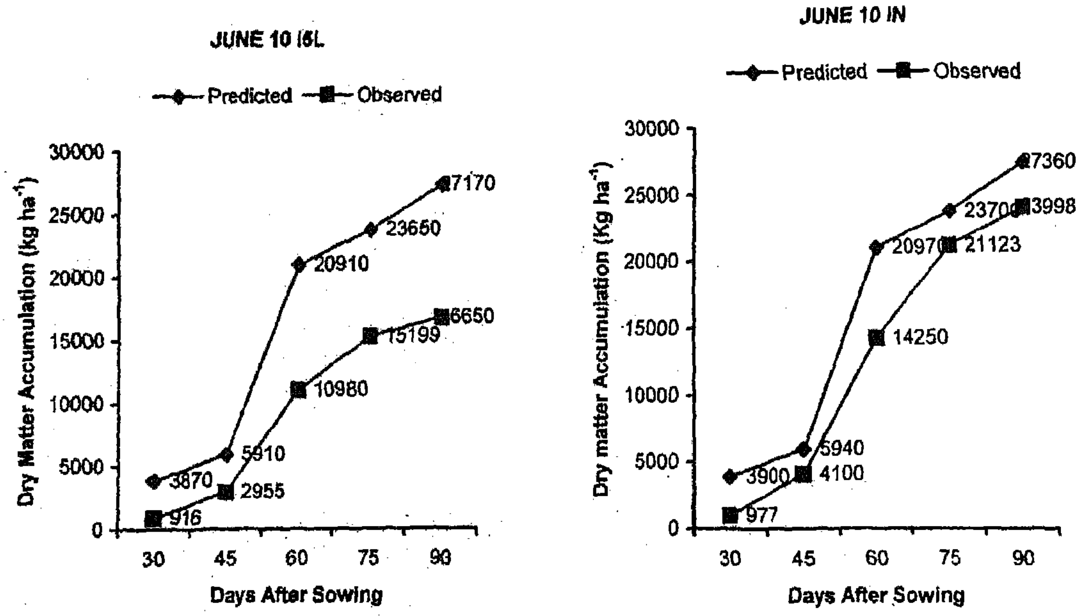

Fig. 3. Comparision of field observed and model predicted dry matter accumulation (Kg ha^{-1}) under June 10 date of planting

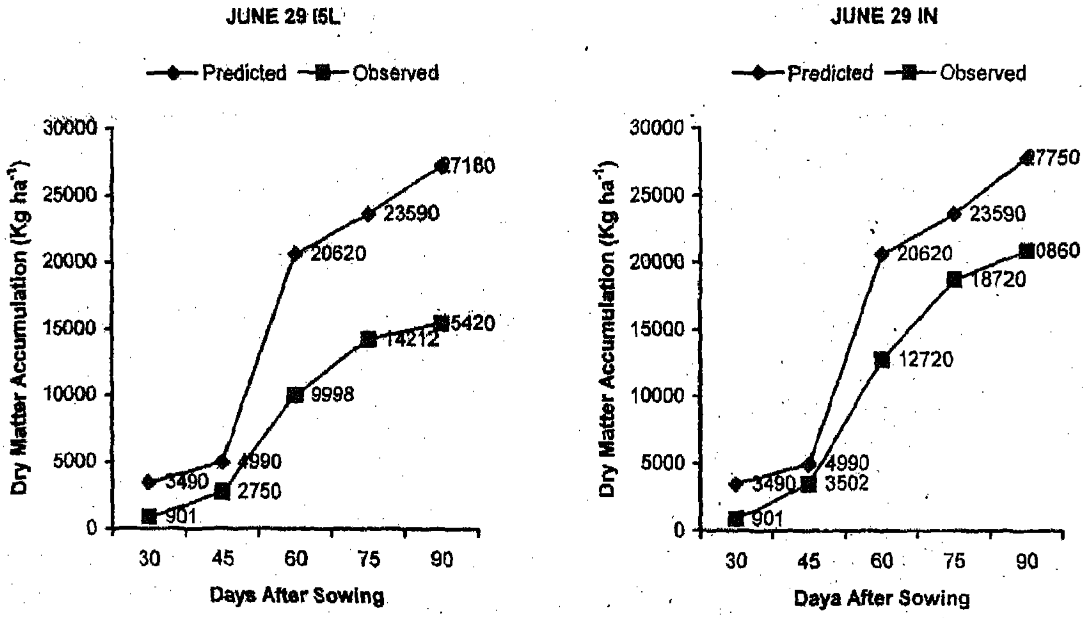

Fig. 4 Comparision of field observed and model predicted dry matter accumulation (Kg ha^{-1}) under June 29 date of planting

and observed) during reproductive stage, the predicted trend was quite similar to that observed in the field (Fig. 3 & 4). The overestimation was highest under I5L irrigation level, which was most stressed, while this difference was narrowed down under unstressed condition.

In CERES-Maize model, dry matter production is predicted as a function of intercepted photosynthetically active radiation (IPAR), which in turn is calculated as a function of LAI (Jones and Kiniry, 1986). Thus, the general tendency of the model to overestimate the dry matter accumulation under all treatments may be partially attributed to the overestimation in predicting LAI. Also, the development and initial validation of the model under temperate conditions and hence, a conversion efficiency of 5 g dry matter per Mega Joule of intercepted PAR was assumed by the model (Jamieson *et al.*, 1998). While, for tropical cultivars a lower conversion efficiency of 3 to 4 g MJ^{-1} was suggested (Sivkumar and Virmani, 1984 and Williams *et al.*, 1968).

Validations for yield attributes and yield

Results on validation of yield and yield contributing characters are presented in Table 2.

Grains per cob : For all treatments model underestimated grains per cob, which resulted in close match of predicted and observed grains per cob for I5L irrigation level, under each date of planting. Under both the dates of planting the model-predicted grains per cob were observed to be the same under each irrigation level which was due to the fact that Ceres-Maize model calculates grains per cob as a function of duration (from silking to beginning of effective grain filling) and cumulative photosynthesis during this period (Jones and Kiniry, 1986). For each date of planting, under all irrigation levels the model assumed that plants remained unstressed during this stage and also experienced a similar duration of this stage, which resulted in same amount of predicted cumulative photosynthesis and hence in almost equal number of grains per cob.

Grains per square meter : Model overestimated total grains per square meter under all treatments. Maximum overestimation was observed under I5L level that was to the tune of 37.0 and 30.0 per cent under June 10 and June 29 date of planting respectively. The prediction showed slight improvement under IK and I5L+T, while it was quite satisfactory for IK+T and IN levels, under both dates of planting.

Overestimation of total grains per square meter, under all treatments, may be attributed to the assumption of the CERES-Maize model as not to allow any partitioning of assimilates to stems after silking, and to divert all the photosynthates to the developing cobs. But post-silking increase in stem weight has been reported (Muchow, 1988.) Also model uses a non-linear (hyperbolic) function (Edmeads and Daynard, 1979) to predict grains per square meter as a function of plant growth rate soon after silking, but its coefficient of determination was relatively low ($r^2 = 0.62$) (Carrbery *et al.*, 1989).

Hundred Grain Weight : Under both the dates of planting the model slightly underpredicted hundred grain weight with that of observed hundred grain weight under all the irrigation levels. Under first date of planting the difference between the model-predicted and field observed hundred grain weight ranged from 10.5 to 17.3 across all the irrigation levels. Under second date of planting this difference ranged from 12.15 to 20.20 per cent for 15L to IN irrigation levels.

Grain Yield : The performance of the model in predicting grain yield under 15L irrigation level was observed to be relatively poor, while, under rest of the levels (IK to IN) the model performed very well in predicting grain yield of maize crop, which fell within 99.88 to 104.74 per cent of the actual grain yield, across the dates of planting. However, under 15L irrigation level model highly overestimated the grain yield, which fell within 122.8 per cent of actual yield, when averaged over both the dates. I5L irrigation level experienced one irrigation only that too at very early stage, along with not well distributed rainfall. This failed to meet the water requirement of the crop particularly from tasseling to silking stage, which are the critical stages for irrigation application in maize crop (Kumar *et al.*, 1986 and Plaut, 1995). This overestimation under 15L level may be attributed to the assumption incorporated in the CERES-Maize model which assumes a hundred per cent efficiency i.e. each gram of stored carbohydrate translocated out of vegetative organs produced 1.0 g of grain, even under stressed conditions, while work of Kiniry *et al.* (1992b) showed this efficiency, during stress period, to be much less with only 0.26 g of grain produced per gram of carbohydrates lost from stems and leaves.

Thus, it shows a very good scope of using CERES Maize model as a tool to predict grain yield under well watered conditions (IK to IN), under these two dates of planting (June 10 and June 29). However, for its commercial use it needs to be validated under different agro- climatic conditions.

References

Carberry, P.S., Muchow, R.C. and McCown, R.L. 1989. Testing the CERES-Maize simulation model in a semi arid and tropical environment. *Fld. crops Res.*, **20** : 297-315.

Edmeads, G.O. and Daynard, T.B. 1979. The relationship between final yield and photosynthesis at flowering in individual maize plants. *Can. J. Plant Sci.*, **59** : 585-601.

Iwata, F. 1975. *Heat unit concept of crop maturity* In: physiological aspects of dry land agriculture Ed US Gupta, Oxford and IBH Publishing Co. New Delhi.

Jaimez, R.E. 1997. Phenology and yield of maize for different sowing dates in a tropical mountain environment. *Revista-de-la-Facultad-de-Agronomia*, **14** (5) : 507-516.

Jamieson, P.D., Porter, J.R., Goudriaan, J., Ritchie, J.T., Keulen, H.V. and Stol, W. 1998. A comparision of the models AFRCHWHEAT2, CERES-Wheat, Sirius, SUCROS2 and SWHEAT with measurements from wheat grown under drought. *Fld. Crops Res.*, **55** : 23-44.

Jones, C.A. and Kiniry, J.R. 1986. CERES-Maize. *A simulation model of maize growth and development.* Texas A & M University Press, Temple,.Texas.

Kiniry, J.R., Blanchet, R., Williams, J.R., Texier, V., Jones, C.A. and Cabelguenne, M. 1992b. Simulating sunflower with the EPIC and ALAMANAC models. *Fld. Crops Res.*, **30** : 403-423.

Kumar, R., Dahiya, D.R., Tyagi, N.K., Yadav, A. and Kumar, R. 1996. Yield, yield attributes and economics of summer maize as influenced by water stress at critical stages. *Haryana Agric. Univ. J. Res.*, **26** (4) : 259-265.

Muchow, R.C. 1988. Effect of nitrogen supply on the comparative productivity of maize and sorghum in a semi-arid tropical environment: III grain yield and nitrogen accumulation. *Fld. Crops Res.*, **18** : 31-43.

Plaut, Z. 1995. Sensitivity of crop plants to water stress at specific developmental stages: reevaluation of experimental findings. *Israel J. Plant Sci.*, **49** : 99-111.

Ritchie, J.T., Kiniry, J.R. and Godwin, D.L. 1986. *Subroutine structure* In : Jones, C.A. and Kiniry, J. R. (eds) CERES-Maize: a simulation model of maize growth and development. Texas A & M University Press, pp 49-111.

Shivakumar, M.V.K. and Virmani, S.M. 1992. Crop productivity in relation to interception of photosynthetically active radiation. *Agric. Forest Meteo.*, **31** : 131-141.

Williams, W.A., Loomis, R.S., Duncan, W.G., Dovrat, A. and Nunez, A. 1968. Canopy architecture at various population densities and the growth and grain yield of corn. *Crop Sci.*, **8** : 181-97.

Xevi, E., Gilley, J. and Feyen, J. 1996. Comparative study of two crop yield simulation models. *Agric. Water Mgt.*, **30** : 155-173.