Journal of Agrometeorology 7 (2) : 149 - 160 (Dec 2005)

Exploring the possibility of second crop in Bastar Plateau region of Chhattishgarh using DSSAT crop simulation model

K. K. SINGH, A.K. BAXLA, J.L. CHAUDHARY*, S. KAUSHIK and AKHILESH GUPTA

NCMRWF, Department of Science and Technology,
A-50, Institutional Area, Phase-II, Sector-62, NOIDA- 201301 (U.P.)
* S.G. College of Agriculture and Research Station, Kumhrawand, Jagdalpur- 494005 (Chhattishgarh)

ABSTRACT

Direct seeded rainfed monocropping is in practice by farmers of the Bastar Plateau region. In order to increase the cropping intensity aimed at improving the socio economic condition of farmers and without loosing soil fertility, concept of sequential cropping of rice followed by gram are being propagated among the farmers by agricultural scientists in this region. The CERES-Rice version 3.5 and CROPGRO-Chickpea crop growth simulation models were used to explore the possibility of second crop in agro climatic conditions of the Bastar Plateau region of Chhattishgarh state. Long term historical weather data (1980-1999) was used for yield analysis using strategy evaluation programme of Decision Support System for Agrotechnology Transfer (DSSAT v3.5). Management combinations simulated were 8 planting dates for rice *cultivar* IR36 under rainfed condition and 3 planting dates for 2 cultivars JG74 and K850 of gram under 2 regimes of irrigation treatments. Genetic coefficients for rice *cultivar* IR36 and chickpea *cultivars* JG74 and K850 developed elsewhere were used for running the crop simulation model. Simulated yields for rice sown on 15 May and 22 May were higher. For chickpea, crop model resulted in higher yield for both the cultivars sown on 4 October under irrigation scenario with two irrigation while simulated grain yield was higher for *cv.* K-850 compared to *cv.* JG-74. irrespective of sowing dates and irrigation treatments.

Key words : DSSAT, CERES- rice, CROPGRO - Chickpea

Crop simulation models are a principal tool needed to bring agronomic sciences into the information age. Through these crop models it became possible to simulate a living plant through the mathematical and conceptual relationships, which govern its growth in the soil atmosphere continuum. CERES (crop estimation through resources and environment synthesis) models were the result of an attempt made in the United States of America to produce a user-oriented, general simulation model for various crops; these models predict the performance of a particular cultivar, sown at any time in any climate, which would lead to transfer of agro technology information.

The science of predictability takes us to planning future operations in advance and always provides us with enough leeway for making profits out of it. The modeling of crop behavior from weather and management practices is an example of this kind of scientific endeavor. The advantage of crop modeling been illustrated in the works of Nix (1976) and de Wit (1978).

Strategic management decision includes selection of cultivars, optimum sowing window and input management. Some of the crop management decisions which can be linked to phenology are: (1) irrigation application which should be made at strategic phenophases to achieve maximum water use efficiency (2) fertilizer application which can be based on tissue analysis at early, mid and maximum tillering and panicle initiation, (3) herbicide application, which can be based on the leaf stage of the crop as well as the target weeds; (4) invertebrate pest control, which must take place prior to a given rice leaf stage, and (5) Harvest.

Direct seeded rainfed monocropping is in practice by farmers of the Bastar Plateau region. Middle of June is sowing period of paddy by farmers. Rice-rice rotation is best under medium to lowland conditions for the moist and hot zone and the rice – wheat rotation is best under the upland to medium land conditions for the dry hot zone, irrespective of the soil groups, with a cropping intensity 108 percent. Under upland condition rainfed kharif rice yield is in the order of 1.2 t ha^{-1} in the farmer's fields. In order to increase the cropping intensity aimed at improving the socio economic condition of farmers and without losing soil fertility, concept of sequential cropping of rice followed by gram are being propagated among the farmers by agricultural scientists in this region. Under this practice rice is sown by direct seeding in the month of May and harvested by month of September. Subsequent to this, gram is sown in the month of October under limited irrigated water condition, supported by recent concept of on-farm water pond development. Studies are directed towards exploring the possibilities of second crop in Baster Plateau region, which may improve the socio-economic status of the farmers of the region.

In light of the high potential of the well calibrated and validated crop simulation models for application in strategic and tactical farm decision making, present study attempts at exploring the possibility of chickpea as a second crop in Bastar Plateau region using CERES-Rice and CROPGRO-Chickpea models.

METHODS

The state represents a sub-tropical climate with hot summer and cold winter. Most of the precipitation occurs during the monsoon, average being about 1200-1600 mm annually. Out of 21.4 % of the gross cropped area, 1.5 % area is irrigated in Baster Plateau. About 96% of the populations are engaged in agricultural

Table 1: Genetic coefficients used in the CERES-Rice simulation model

Name	Description	Genetic coffecients for IR36
(P1)	Time period (expressed as growing degree days [GDD] in °C over a base temperature of 9 °C) from seeding emergence during which the rice plant is not responsive to change in photoperiod. This period is also referred to as the basic vegetative phase of the plant.	450.00
(P2O)	Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate. At values higher than P20 developmental rate is slowed, hence there is delay due to longer day lengths.	149.00
(P2R)	Extent to which phasic development leading to panicle initiation is delayed (expressed as GDD in °C) for each hour increase in photoperiod above P20.	350.00
(P5)	Time period in GDD °C) from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 9 °C.	11.70
(G1)	Potential spikelet number coefficient as estimated from the number of spikelets per g of main culm dry weight (less lead blades and sheaths plus spikes) at anthesis. A typical value is 55.	45.00
(G2)	Single grain weight (g) under ideal growing conditions, i.e. non limiting light, water, nutrients, and absence of pests and diseases.	0.0230
(G3)	Tillering coefficient (scalar value) relative to IR64 cultivar under ideal conditions. A higher tillering cultivar would have coefficient greater than 1.0.	1.00
(G4)	Temperature tolerance coefficient. Usually 1.0 for varieties grown in normal environments. G4 for japonica type rice growing in a warmer environment would be 1.0 or greater. Likewise, the G4 value for indica type rice in very cool environments or season would be less than 1.0.	1.00

sector and rice is the staple food. According to the land slope, soil type and agricultural practices, five broad farming systems are recognized in the region, i.e. Badi (protected), slopy uplands (Mahran and Tikra), fairly leveled upland (Mal) and leveled bunded low land (Gabhar). The major crops during the *kharif* are rice (65%), kodo-kutki (18%), kulthi (4.5%), maize (3%) followed by ragi, jowar, urd and niger. In rabi, only a small area (4%) of the net cropped area is under cultivation, in which rapeseed, mustard, linseed, wheat and kulthi etc are grown with residual moisture and limited irrigation. In order to explore the possibility of second crop under residual moisture, medium duration rice cultivar IR-36 (120 days) and for gram, short duration varieties JG-74 of (95 to 100 days) and K-850 of 105 to 110 days are considered for study. Their genetic coefficients are given in the Table 1 and 2 (Rathore *et al* 2001).

Study area characteristics and data development

i) *Weather and climate:* This region gets pre-monsoon showers in April and May and temperature drops appreciably with the onset of monsoon. Historical weather records for the study area were recorded at weather observatory located at S.G. College of Agricultural Research Station, Indira Gandhi Agricultural University, Bastar, Jagdalpur (19° 5' N, 82° 1' E and 610 m above sea level) in Chhattishgarh state. These records included daily precipitation, maximum and minimum temperatures and bright sunshine hours.

ii) *Soil:* Soils present in Bastar Plateau are laterites, red, yellow and alluvial. Primary laterites are on top of the traps; secondary laterites on valleys, red and yellow soils on hilltops and plateau, alluvial are on riverbeds. Soil pH ranges from 4.5 to 7.6 electric conductivity from 0.04 - 0.09 dsm^{-1} and Cation exchange capacity (CEC) between 10.2 – 28.4 c mol (p+) kg^{-1}. Top upland soils are loamy sand to sandy loam in texture and gravelly poor in organic matter, shallow soil depth, poor fertility and poor water holding capacity. In the leveled areas, the soil ranges from loamy to clayey depending upon the topo-sequence. Upper unleveled soils are fine textured with good drainage. Lower level soils are fertile but tend to be water logged.

iii) *Crop:* Rainfed monocropping for kharif rice under upland condition has been in practice by the farmers of the region. Date of sowing taken by farmers is around 15 June, coinciding with the onset of monsoon.

Model selection and simulations:

The DSSAT crop growth simulation models for rice (CERES-Rice v3.5) (Hoogenboom *et al.*, 1999) and chickpea (CROPGRO-Chickpea) (Singh *et al.*, 1996) were used to simulate the yield for a variety of management and weather combinations. For detailed description of CERES-Rice model structure and initial validation see Alocilja and Ritchie (1988) and Alocilja (1987). The simulation of growth, development, and yield of chickpea is identical to the simulation of the other grain legume crops, e.g., soybean, peanut and dry bean (Boote *et al.*, 1998).

In both CERES-Rice and CROPGRO-Chickpea models the processes simulated on daily basis include phenological development of the crop as

Table 2: Genetic coefficients used in the CROPGRO-Chickpea simulation model

Name	Description	Genetic coefficients for	
		JG 74	K 850
CSDL	Critical Short Day Length below which reproductive development progresses WITH day length effect (for longday plants) (hour)	11.0	11.0
PPSEN	Slope of the relative response of development to photoperiod with time (negative for longday plants) (1/hour)	-0.143	-0.143
EM-FL	Time between plant emergence and flower appearance (R1) (photothermal days)	37.0	41.0
Fl-SH	Time between first flower and first pod (R3) (photothermal days)	8.0	11.0
Fl-SD	Time between first flower and first seed (R5) (photothermal days)	15.0	14.0
SD-PM	Time between first seed (R5) and physiological maturity (R7) (photothermal days)	38.0	26.0
Fl-LF	Time between first flower (R1) and end of leaf expansion (photothermal days)	42.0	34.0
LFMAX	Maximum leaf photosynthesis rate at 30 C, 350 vpm CO_2, and high light (mg CO_2/m^2-s)	1.700	1.700
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)	150.0	150.0
SIZLF	Maximum size of full leaf (three leaflets) (cm^2)	10.0	10.0
XFRT	Maximum fraction of daily growth that is partitioned to seed + shell	1.00	1.00
WTPSD	Maximum weight per seed (g)	0.283	0.190
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)	29.00	22.00
SDPDV	ed per pod under standard growing conditions (#/pod)	1.00	1.60
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)	18.00	18.00

governed by the genetic characters of the crop variety and weather, growth of leaves, stems and roots, biomass accumulation and portioning among leaves, stem, panicle, grain and roots, soil water balance and water use by the crop, soil nitrogen balance and uptake by the plant. The analytical relationships of the soil water balance and nitrogen transformation and uptake leading to the quantification of these stress factor are presented by Jones and Kiniry (1986).

Simulations for Bastar region over 20 years (1980-1999) were made using the Strategy Evaluation programme of DSSAT. Management combinations simulated were 8 planting dates for rice cultivar under rainfed condition and 3 planting dates for 2 cultivars of gram under 2 regimes of irrigation treatments.

Table 3: Experiments details required for running the model

Types of information	Details of information
Field characteristics	Weather station name, soil and field description details
Soil analysis data	Soil properties used for the simulation of nutrient dynamics, based on filed nutrient sampling, if any
Initial soil water and inorganic nitrogen conditions	Starting condition for water and nitrogen in the profile and also used for root residues carry over from the previous crop and N symbiosis initial conditions when needed
Seedbed preparation and planting geometries	Planting date, population, seeding depth and row spacing data
Irrigation and water management	Irrigation dates, amounts, thresholds and rice flood water depths
Fertilizer management	Fertilizer date, amount and type information
Organic residue application	Addition of straw, green manure, animal manure
Chemical applications	Herbicide and pesticides application date
Tillage operations	Dates and types of tillage operations
Environments modifications	Adjustments factors for weather parameters as used in climate change and constant environment studies (*e.g.* constant day length, shading, constant temperature)
Harvest management	Harvest dates and plant components harvested
Specification of simulation options	Starting dates
On/off options for model components	Water and nitrogen balances
Outputs options	

Details of rice management:

The planting dates considered for simulation of crop cultivar IR36 under rainfed condition were 01, 08, 15, 22 and 29 May, 05th, 12th and 19th June. Plant population at the time of emergence was 150 plants m^{-2} with the row spacing of 15 cm and planting depth of 5 cm. The crop was sown by direct seeding method with the basal dose of 30 kg urea applied.

Details of gram management:

Simulation experiments for two different cultivars JG74 and K850 were carried out with 3 different dates of sowing viz: 4th, 11th and 18th October; and two different irrigation scenarios. Following the limited water availability in the Bastar Plateau during *rabi* season, two irrigation scenarios prescribed for simulation were (i) single irrigation of 40 mm water applied at 40 days after sowing (DAS), designated as IW1 and (ii) combination of 2 irrigations,

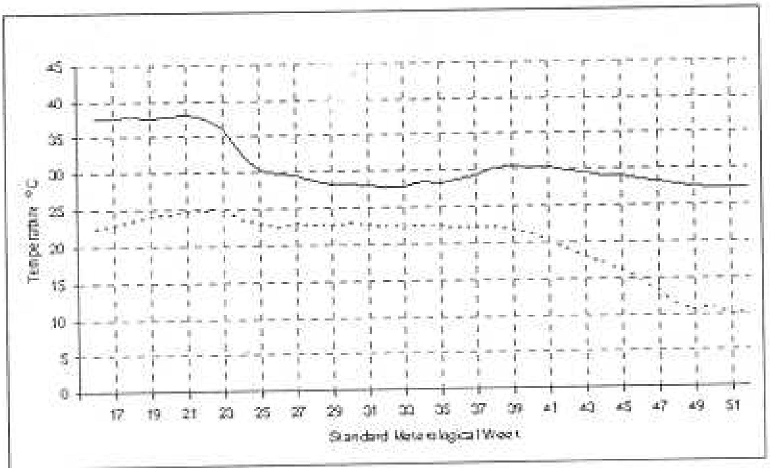

Fig. 1 : Mean weekly maximum and minimum temperature of Bastar plateau

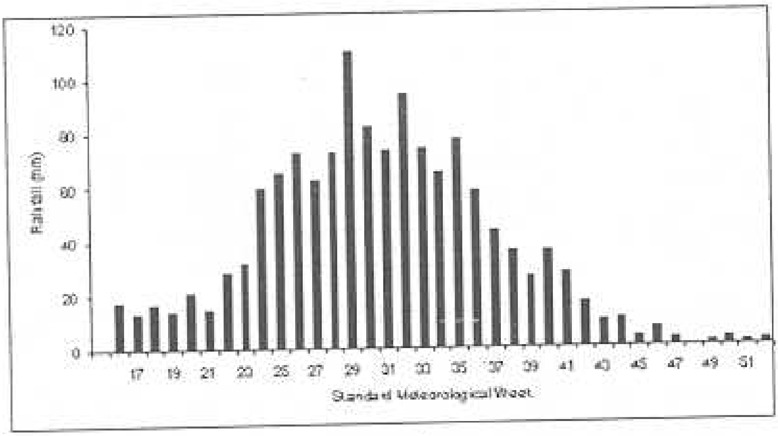

Fig. 2 : Mean weekly rainfall of Bastar plateau

each of 40 mm applied at 40 DAS and 62 DAS, designated as IW2. The plant population was 30 plants/m² with row spacing of 30 cm and planting depth 5 cm. Basal dose of 30 kg urea was applied.

RESULTS AND DISCUSSION

Saseendran *et al.* (1998a) evaluated the performance of the CERES Rice v3.0 for the climatic conditions of the state of Kerala and found that in four experiments using different transplanting dates during the Virippu (June-September) season under rainfed conditions, the flowering date and crop maturity was predicted within an error of four and two days respectively. Also the

Table 4: Model Simulation of rice cultivar IR-36 for different sowing dates

Date of sowing	Grain yield (kg ha^{-1})			Seasonal ET (mm)	Date of maturity
	Average	25-percentile	75-percentile		
1 May	2242	2118	2389	368	1 Sep
8 May	2075	2003	2180	373	7 Sep
15 May	1961	1914	2121	384	14 Sep
22 May	1852	1665	2054	401	20 Sep
29 May	1733	1545	1967	420	27 Sep
5 Jun	1611	1499	1783	437	2 Oct
12 Jun	1463	1239	1587	459	9 Oct
19 Jun	1306	1034	1495	479	16 Oct

Table 5: Model Simulation of chickpea *cv.* K-850 for different sowing dates

Irrigation treatment	Date of sowing	Grain yield of *cv.* K-850 (kg ha^{-1})			Seasonal ET (mm)	Date of harvest
		Average	25-percentile	75-percentile		
IW1	04 Oct	763	293	858	216	12 Jan
	11 Oct	639	347	617	206	20 Jan
	18 Oct	558	285	543	197	28 Jan
IW2	04 Oct	1458	819	1769	257	16 Jan
	11 Oct	1302	796	1340	246	24 Jan
	18 Oct	1076	746	1147	235	31 Jan

Table 6: Model Simulation of chickpea *cv.* JG-74 for different sowing dates

Irrigation treatment	Date of sowing	Grain yield of *cv.* JG-74 (kg ha^{-1})			Seasonal ET (mm)	Date of harvest
		Average	25 Percentile	75 Percentile		
IW1	04 Oct	575	192	643	212	6 Jan
	11 Oct	483	230	432	203	15 Jan
	18 Oct	441	219	427	196	24 Jan
IW2	04 Oct	1150	615	1439	250	10 Jan
	11 Oct	1048	703	1039	242	18 Jan
	18 Oct	929	633	981	234	26 Jan

grain yield prediction was within an error of 3% for all transplanting dates. Saseendran *et al.* (1998b) utilized the validated and calibrated CERES Rice v.3.0 model for deriving the optimum transplanting dates for rice at various locations in Kerala.

In the present study, the simulations (20 years) were analyzed to generate average, 25 and 75-percentile values of output factors (grain yield etc.) for each management combination. The 25 and 75-percentile values are the 5th and 15th values in a set of 20 observations arranged in ascending order. These percentiles indicate the probability of getting less than or equal to a certain values of the parameter being analyzed.

CERES-Rice simulation results of grain yield, evapotranspiration and maturity date of rice *cv.* IR-36 for 8 different sowing dates (Table 4) indicate that grain yield decreases with delay in sowing dates considered from 1 May onward. Climate of Bastar plateau (Fig. 1 and 2) clearly indicates that day temperature during hot season is around 38 °C and it starts decreasing during end of May and first week of June. The risk associated with dates of sowing on 1 May and 8 May is high as rain water is not sufficient with pre monsoon rain to meet water requirement of the crop in the initial stage and also the crop may suffer during juvenile stage encountered with higher day temperature. For the dates of sowing 29 May onwards, besides low yield, crop is harvested by end of September or in October, which does not pr vide the lead-time for sowing of chickpea as second crop. The dates 15 May and 22 May, thus, may be considered suitable for sowing of rice in upland condition.

CROPGRO-Chickpea simulation run for chickpea for 2 different irrigations scenarios and 3 sowing dates were presented in table 5 for cv. K-850 and table 6 for cv. JG-74. Grain yield simulated was highest against sowing date of 4th October (Table 5) followed by crops sown on 11th and 18th October. Actual evapotranspiration showed the same trend as observed in case of grain yield. Yield was higher under irrigation treatment IW2 compared to IW1 irrespective of sowing dates. Simulated grain yield and evapotranspiration was highest for JG-74 (Table 6) against sowing date of 4th October followed 11th and 18th October sowing. Irrigation scenario IW2 showed higher yield than IW1. Simulated grain yield for all the sowing dates was higher for cv. K-850 compared to JG-74. This could be attributed to shorter pre-anthesis period and longer post-anthesis period of cv. K-850 compared to that of cv. JG-74.

The cumulative probability function distribution of yield simulated for chickpea were plotted for different cultivars and irrigation treatments. The curve (Fig. 3) indicates that probabilities are almost the same, up to 50-60% for both cultivar with one irrigation. It means that chickpea yield level simulated against 3 dates of sowing does not vary in 50-60 % of the year. Further variation in grain yield for different sowing dates (P>.60) signifies different weather realized during the crop season in remaining years. For probability >0.60, simulated yield of chickpea sown on 4 October was higher than that sown on 11th and 18th October under irrigation scenario IW1. Under irrigation scenario IW2 the curve (Fig. 4), indicates that probabilities

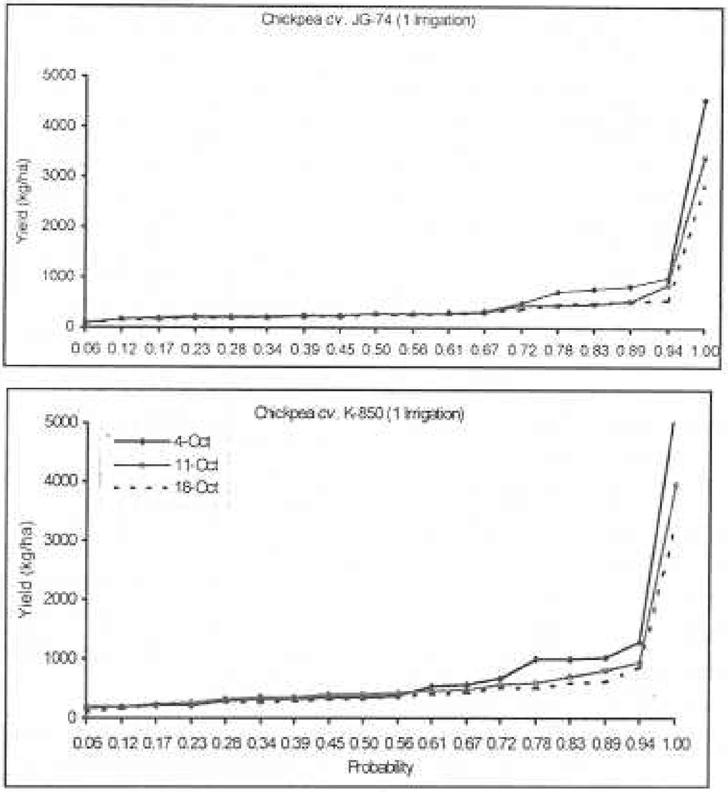

Fig. 3 : Cumulative probability function distribution of yield for irrigation scenario IW1

of crop yield for 3 sowing dates for cv. JG - 74 are almost same up to 50-60% and for probabilities >0.60 yield for crop sown on 4 Oct is distinctly higher than other two sowing dates. For cv. K-850, yield simulated for the crops sown on 4 & 11 Oct has same probability up to 60% while crop sown on 18 Oct gives lower yield for the same probability. For probability >0.60, crop yield for different dates of sowing varies and again yield simulated against 4 Oct sowing date is higher than other dates.

CONCLUSION

A 20 year simulation of rice yield under upland rainfed condition of Bastar Plateau region indicates that 15 May and 22 May may be considered suitable for sowing of rice. For chickpea as a second crop, model results indicate that both the cultivars K-850 and JG-47 show higher yields if sown on 4 October under irrigation scenario IW2. Simulated grain yield was higher for *cv.* K-850 compared to *cv.* JG-74, irrespective of sowing dates and irrigation treatments. It is

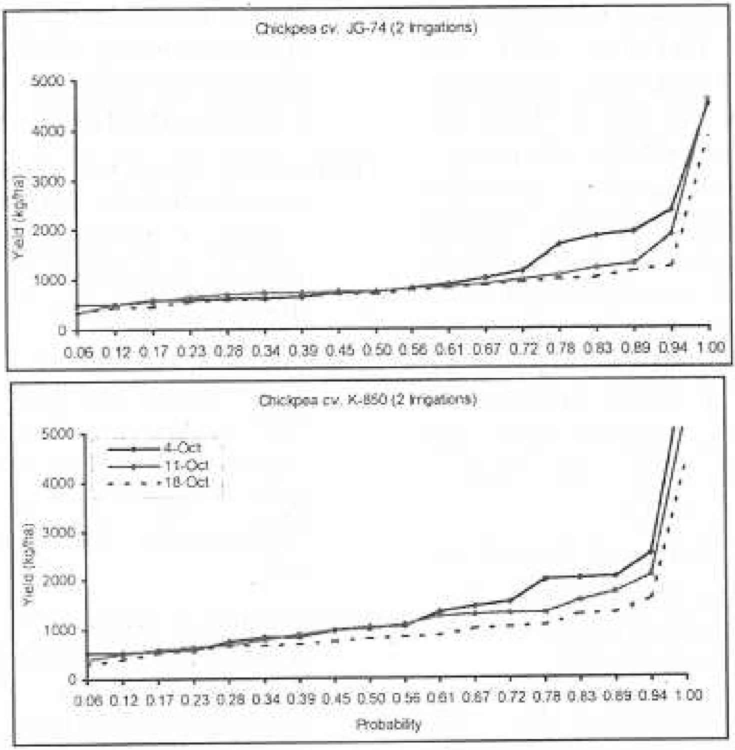

Fig. 4 : Cumulative probability function distribution of yield for irrigation scenario IW2

necessary to carry out further field experiments to support the model results.

LIMITATIONS

The model does not include the nutrient factor i.e. phosphorus, potassium and other plant essential nutrients. These nutrient factors are assumed to be in abundant supply in the soil so as not to cause any stress on crop. Similarly loss due to weed, pest and diseases are also not included in the model. Due to favorable weather conditions the pest and diseases infestation may cause loss to the crop, that loss cannot be simulated at present by the model.

REFERENCES

Alocilja, E. C., 1987. Simulation-multicriteria optimization technique as a decision support system for rice production, Ph.D dissertation, Michigan State University of California, Davis.

Alocilja,E.C. and Ritchie, J.T., 1988. Upland rice simulation and its use in multicriteria optimization. *IBSNAT Research Project Series* 01, IBSNAT.

Boote, K. J., J. W. Jones, G. Hoogenboom, and N. B. Pickering. 1998. The CROPGRO model for grain legumes. p. 99-128., In: [G. Y. Tsuji, G. Hoogenboom, and P. K. Thornton, editors]. *Understanding Options for Agricultural Production.* Systems Approaches for Sustainable Agricultural Development. Kluwer Academic Publishers, Dordrecht, the Netherlands (ISBN 0-7923-4833-8). de Wit, C. T., 1978, *Simulation of Assimilation, Respiration and Transpiration of Crops.* Pudoc. Wageningen, 141 pp.

Hoogenboom, G., Wilkens, P. W. and Tsuji, G. Y. (eds.)., 1999. DSSAT v3.5, In DSSAT 3 vol. 4. Univeristy of Hawaii, Honolulu, Hawaii, 95-244.

Jones, C. A. and Kiniry, J. R., 1986. CERES-Maize: A simulation model of maize growth and development, Texas A&M University press, Collage Station, TX.

Nix, H. A., 1976. Climate and crop productivity in Australia. *Agrometeorology of the Rice Crop*, International Rice Research Institute, Los Banos, Philippines, 495-508.

Rathore,L.S., Singh,K.K., Saseendran .S. A, and Baxla,A.K., 2001. Modeling the impact of climate change on rice production in India. Special issue *Mausum*, 52 (1) : 263-274

Saseendran, S. A., Rathore. L. S., Singh K. K., Nisha Mendiratta and Singh, S.V., 1998a. Validation of CERES-Rice v3. model for the tropical humid agroclimate of Kerala state, Meteorological applications, 5: 385-392.

Saseendran S. A., Hubbard, K. G., Singh, K. K., Nisha Mendiratta, Rathore. L. S. and Singh, S. V., 1998b. Transplanting dates for rice in Kerala, India determined using both CERES and ClimbProb. *Agron. J.*, 90: 185-190.

Singh, P. and S. M. Virmani, 1996. Modeling growth and yield of chickpea (*Cicer arietinum L.*). *Field crops Res.*, 46:41-59.