MAUSAM, **68**, 1 (January 2017), 93-98

551.583 : 633.852.52 (540.51)

Impact assessment of climate change on groundnut yield of middle Gujarat region

S. B. YADAV, H. R. PATEL, S. K. MISHRA*, P. K. PARMAR, B. I. KARANDEY and V. PANDEY

Department of Agricultural Meteorology, Anand Agricultural University, Anand, Gujarat – 388 110, India

**Punjab Agriculture University, Ludhiana, Punjab, India*

(*Received 27 May 2013, Accepted 30 August 2016*)

e mail : sbmet@yahoo.in

सार – इस शोध पत्र में मध्य गुजरात के कृषि जलवायविक क्षेत्र का आनंद केन्द्र में A_2 सिनोरियो का PRECIS परिणाम तथा बेस लाइन डेटा का उपयोग करते हुए मूंगफली की (cv. Robat 33-1 एवं GG-2) प्रजातियों पैदावार पर जलवायु परिवर्तन के प्रभाव का अध्ययन किया गया है। जलवायु परिवर्तन से उत्पादन पर अनुरूपण का अध्ययन PNUTGRO (DSSAT v4.5) मॉडल द्वारा किया गया। इस शोध पत्र में वर्ष 2008 से 2011 के दौरान मूंगफली cv. Robat 33-1 एवं GG-2 नामक प्रजातियों पर किए गए क्षेत्र परीक्षण के आंकड़ों का उपयोग करके इस मॉडल का अंशांकरन तथा मूल्याकंन किया गया है। A_2 सिनोरियो (2070-2100) द्वारा प्रदर्शित की गई मौसमी स्थिति यह दर्शाती है कि बेस लाइन (1961-90) की तुलना में उस समय 13.7% अधिक वर्षा होगी। अधिकतम और न्यूनतम औसत तापमान उनके बेस लाइन तापमान 19.1 एवं 29.8 ºC की तुलना में क्रमश: 3.6 एवं 5.1 ºC अधिक होगा। cv. Robat 33-1 एवं GG-2 नामक प्रजातियों के फली उत्पादन में (pod yield) प्रदर्शित अवधि के दौरान उनके बेस उत्पादन की तुलना में करीब 21 एवं 31% की गिरावट पाई गई है। उत्पादन में अधिकतम गिरावट देर से बुआई करने (15 जुलाई) पर cv.GG-2 प्रजाति में तथा न्यूनतम गिरावट समय से बुआई (D_1) करने पर cv. Robat 33-1 प्रजाति में देखी गई है। इस प्रदर्शित अवधि के अंतर्गत बताया गया है कि अनुकूलन के उपाय करके उत्पादन गिरावट को 7 से 16 प्रतिशत तक कम किया जा सकता है। उदाहरणार्थ फसल की बुआई 15 दिनों पूर्व कर दी जाए और बुआई के पूर्व खेतों की सिंचाई कर दी जाए तथा रासायनिक खाद के बजाय जैविक खाद का प्रयोग किया जाए।

ABSTRACT. The impact of projected climate change on groundnut (cv. Robut 33-1 and GG-2) yield have been studied for Anand station of middle Gujarat Agro-climatic region using PRECIS output of A_2 scenario and base line data. Yield simulation study was performed by PNUTGRO (DSSAT v4.5) model. The field experiment data on groundnut cv. Robut 33-1 and GG-2 during the years 2008 to 2011 have been used to calibrate and validate the model. The weather condition as projected by A_2 scenario (2070-2100) showed that there will be 13.7% higher rainfall as compared to base line (1961-90). The mean maximum and minimum temperature will be higher to the tune of 3.6 and 5.1 °C as compared to their base temperature of 19.1 and 29.8 °C respectively. Nearly 21 and 31% pod yield reduction was noted in Robut 33-1 and GG-2 as compared to their base yield during projected period. Highest yield reduction was recorded in late sowing (15th July) and cv. GG-2 and lowest yield reduction was noted in timely sowing (D_1) and cv. Robut 33-1. Under projected period. 7.0 to 16.0% yield benefited by adaptation strategies, *viz*, fifteen days earlier shifting of sowing with one pre sowing irrigation and Application of organic manure instead of chemical fertilizer.

Key words – Climate change, PRECIS, Simulation, PNUTGRO (DSSAT v4.5).

1. Introduction

During the recent decade, with the growing recognition of the possibility of climate change and clear evidence of observed changes in climate during 20th century, an increasing emphasis on food security and its impact has come to forefront of the scientific community. Agricultural sector is one of the most sensitive areas which would be influenced by the projected global warming and associated climate change. In spite of the uncertainties about the precise magnitude of climate change on regional scale, an assessment of the possible impacts of changes in key climatic elements on our agricultural resources is important for formulating response strategies.

Groundnut is essentially a tropical plant. It requires a long and warm growing season. The most favorable climatic conditions for groundnut are a well distributed rainfall of at least 500 mm during growing season, abundance of sunshine and relatively warm temperatures. Adequate and well distributed rainfall during the growing season, especially during flowering, pegging and pod formation stages, is essential for maximum yield and

TABLE 1

Trend analysis of weather condition over different locations of middle Gujarat region

Para-meter	Period/Season	Slope				
		Anand	Ahmedabad	Dahod	Panchmahal	Vadodara
*T*max. (°C)	Winter	0.033	0.041*	-0.131	0.02	0.036
	Summer	0.043	0.023	0.111	0.01	0.033
	Monsoon	0.019	0.048*	-0.106	0.01	0.018
	Post-monsoon	0.049	0.062*	-0.091	0.01	0.039
	Annual	0.033	0.039	-0.054	0.01	0.031
*T*min. (°C)	Winter	0.020	-0.032	0.049	-0.03	0.021
	Summer	0.043	-0.035*	0.172	-0.01	0.040
	Monsoon	0.019	0.024	0.001	0	0.017
	Post-monsoon	0.029	-0.029	-0.046	-0.02	0.026
	Annual	0.024	-0.014	0.044	-0.01	0.022
Rainfall (mm)	Annual	2.14	-0.432	1.732	1.73	2.11

quality of groundnut. Warm and moist conditions are very favorable than cool and wet climate, which results in slow germination and seedling emergence, increasing the risk of seed rot and seedling diseases. Temperature is a major environmental factor that determines the rate of crop development. Well - drained, light - textured, loose, friable sandy - loam or sandy clay loam soil is most suitable for groundnut crop. Seed germination and seedling emergence are favoured in loose, friable and sandy - loam soils. The normal yield of groundnut can be obtained on fairly heavy soils with good tilth and favourable moisture conditions.

In India, about 80% of area under groundnut cultivation is confined to five states, *i.e*., Gujarat, Andhra Pradesh, Tamilnadu, Karnataka and Maharashtra, which account for 84% of the total production. Gujarat state occupies 1.95 m ha area, *i.e*., 28.93% of the total area 3.39 MT production, *i.e*., 42.43% of the total production of groundnut in the country with 1734 kg ha^{-1} average productivity (http://dacnet.nic.in/eands). The major groundnut growing districts in Gujarat are Junagadh, Jamnagar, Amreli, Bhavanagar, Rajkot, Mehsana and Bhuj. Anand district of Gujarat state records the area, production and yield as 7000 ha, 1200 MT and 1701 kg/ha of groundnut crop, respectively (Annon, 2011).

Various crop models are being used optimizing natural resources to assess the impact of future potential climate on crop production (Rosenzwieg and Iglesias, 1998; Rao and Sinha, 1994; Rosenzwieg and Parry, 1994). Assessment of impact of climate change on crop production using simulation approach is usually associated with two uncertainties. One deals with predicting climate change scenarios using General Circulation Model (GCM). The other relate to simulation models themselves. In this paper an attempt was made to evaluate the likely impact of climate change on groundnut yield of middle Gujarat region of India under A_2 scenario (IPCC, 2007). For this purpose user friendly version of 'PNUTGRO' (DSSAT v4.5) (Duncan *et al.*, 1978; Boote *et al.*, 1989 and Hoogenboom *et al*., 1999), a generic simulation model was used.

2. Materials and method

2.1. *Data requirement DSSATv4.5 'PNUTGRO' model*

Weather data : The DSSAT model requires daily weather data of maximum and minimum air temperature, solar radiation, vapour pressure, wind speed and rainfall. For calibration and validation of the model, observed weather data were obtained from Agrometeorological observatory, Deptt. of Agril. Meteorology, AAU, Anand.

Soil data : The soil data file of sandy loam soil with 5 soil layers, *i.e*., 5 cm, 10 cm, 15 cm, 20 cm and 30 cm were created using actual soil data of experimental site for model required parameters .

Crop management data : All the crop management data required for the model were obtained from AICRP on Agro. Met. Project AAU, Anand.

Calibration and validation of the model : The field experiment data on groundnut (cv. Robut 33-1 and GG-2) during the year 2008-2011 have been used to calibrate and validate the model. The actual field observed data of 2008 and 2009 used for calibration and generate the genetic coefficients are presented in Table 2. The observed data of 2010 and 2011 were used for validation of the model.

2.2. *Climate change study*

For climate change impact study, weather data for A_2 scenario was derived from PRECIS downscaled model output prepared by IITM Pune in a grid size of 0.4 degree. Two period of 30 years each, one for base line, *i.e*.,

TABLE 2

Genetic coefficients for groundnut cv. Robut 33-1 and GG -2 at Anand condition

	Parameter	ROBUT 33-1	GG-2
CSDL	Critical Short Day Length below which reproductive development progresses with no day length effect (for short day plants) (hour)	11.84	11.84
PPSEN	Slope of the relative response of development to photoperiod with time (positive for short day plants) (1/hour)	0.00	0.00
EM-FL	Time between plant emergence and flower appearance (R1) (photothermal days).	12.0	27.1
FL-SH	Time between first flower and first pod (R3) (photothermal days)	11.1	7.60
FL- SD	Time between first flower and first seed (R5) (photothermal days)	19.0	25.50
SD-PM	Time between first seed (R5) and physiological maturity (R7) (photothermal days)	75.00	52.40
FL-LF	Time between first flower (R1) and end of leaf expansion(photothermal days)	52.00	58.00
LFMAX	Maximum leaf photosynthesis rate at 30° C, 350 vpm CO_2, and high light (mg CO2/m^2-s)	01.23	1.20
SLAVR	Specific leaf area of cultivar under standard growth conditions(cm^2/g)	230	265
SIZLF	Maximum size of full leaf (three leaflets) (cm^2)	22.00	19.00
XFRT	Maximum fraction of daily growth that is partitioned to seed + shell	0.74	0.81
WTPSD	Maximum weight per seed (g)	0.386	0.360
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)	41.00	25.00
SDPDV	Average seed per pod under standard growing conditions (#/pod)	1.65	1.63
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)	29.50	15.00
THRSH	The maximum ratio of [seed / (seed+shell)] at maturity. Causes seed to stop growing as their dry weights increase until shells are filled in a cohort.(Threshing percentage)	78.0	74.0
SDPRO	Fraction protein in seeds [g(protein)/g(seed)]	0.270	0.270
SDLIP	Fraction oil in seeds [g(oil) / g(seed)]	0.510	0.510

1961-1990 (base line period) and another for A2 projected Scenario, *i.e.*, 2071-2100 (IPCC, 2007) were considered for climate change impact study. There are gross difference between PRECIS base line daily weather data and actual weather data for the same period. Thirty year monthly average of daily weather parameters of base line data was subtracted from corresponding projected A_2 scenario data and the difference obtained were used for computing weather data for projected period using actual observed data. In case of rainfall percentage difference on monthly sum of 30 years average data, between projected output and base line output were used as correction factor.

2.3. *Adaptation strategies*

For minimizing adverse effect of climate change we have used low cost adaptation strategies, *viz*., Use of organic manure in place chemical fertilizers and change in sowing window **(**15 days earlier from onset of monsoon by applying one sowing irrigation) in management file of Crop Growth Simulation Model (DSSAT 4.5). For adaptation study most popular variety of middle Gujarat, GG-2 was used.

3. Result and discussion

3.1. *Trend analysis of weather conditions over different locations of middle Gujarat*

The linear regression analysis was carried out to analyse the trends of temperature and rainfall using long term data, *i.e*., baseline (1980-2011) of Anand, Ahmedabad, Vadodara, Dahod, Panchmahal. The results of analysis are presented in Table 1. Showed that all the weather parameters, *i.e.*, maximum temperature, minimum temperature and rainfall were not showing any specific significant trend except Ahmedabad. In Ahmedabad district positive significant trend for minimum temperature under winter, monsoon and post monsoon season was observed, while during summer season minimum temperature trend was found significant negative.

3.2. *Projected weather over base line*

The maximum and minimum temperature of Anand, Ahmedabad, Vadodara, Dahod , Panchmahal to the tune of 6.0, 4.1, 4.0, 5.0, 4.5 and 5.1, 3.5, 4.3, 3.8, 4.1 °C, respectively against the base line periods (1961-90). While rainfall will be recorded at Anand, Ahmedabad, Vadodara, Dahod and Panchmahal districts to the 42.0, 28.14, 20.95, 70.0 and 49.7% respectively as compare to baseline period. The PRECIS model output showed that highest temperature (6.0 °C) will be rise in Anand district while it was lowest (4.0 °C) at Vadodara district. In case of rainfall the highest (70%) average rainfall of projected period under A_2 scenario will be rise in Dahod and lowest (20%) in Vadodara district in comparison to their respective baseline rainfall of all the districts, (Fig. 1).

3.3. *DSSAT (v4.5) model calibration and validation results of Peanut*

The model perfectly simulated yield of cv.V_1 (Robut 33-1) at D1 (onset of monsoon) sowing as compared to V_2

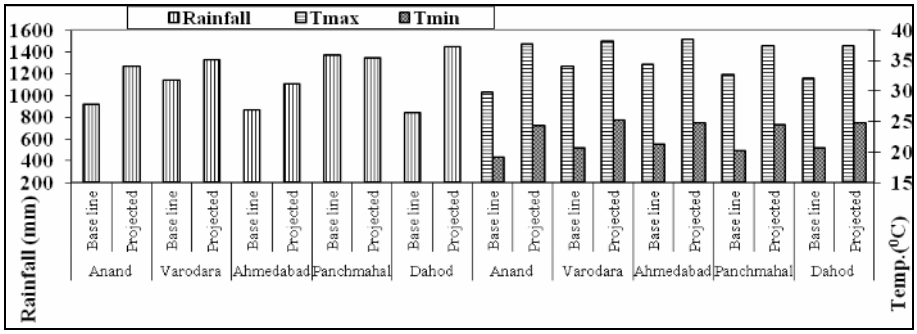

Fig. 1. Comparison of Base line and Projected weather at different locations of middle Gujarat

TABLE 3

Test criteria in evaluation of model (Average of both varieties) for various yield and yield attributing characters for groundnut

Parameters	Days to anthesis	Days to maturity	Pod Yield	Haulm yield	LAI
OM	30.85	123.5	2132.69	7434.88	3.18
SDo	1.16	3.74	422.47	547.64	1.20
SM	31.35	125.4	2097.78	8025.62	2.98
SDs	0.89	5.45	424.85	663.15	0.97
r	0.89*	0.71*	0.92**	0.68*	-0.70*
MAE	1.60	5.11	87.52	1407.58	1.82
MBE	1.70	-5.21	-30.75	1307.48	0.99
RMSE	2.29	6.86	136.52	1289.45	2.12
PE	8.05	6.39	8.25	14.03	22.18

where, OM - Observed mean, SDo - Standard deviation of observe values, SM - Simulated mean, SDs - Standard deviation of simulated values, r - correlation coefficient, MAE- Mean absolute error, MBE - Mean bios error, RMSE- Root mean square error, PE - Percent error

(cv. GG-2). PEANUTGRO model perfectly simulated pod yield while haulm yield was found overestimated by the model. Validation of days to anthesis was found perfect in cv. Robut 33-1 as compared to cv. GG- 2. Leaf area index was under estimated in all treatments and shelling percentage overestimated by the model except D_2V_2 treatments. Days to first pod was underestimated in D_1 except D_1V_1. Days to first seed and harvest index was under estimated by the model whereas days to maturity were underestimated except D_1V_2 treatment.

The average errors of both variety and sowing date as computed by MAE, MBE, RMSE and PE were 1.60, 1.70, 2.29 and 8.05, 5.11, -5.21, 6.86 and 6.39, 87.52, -30.75, 136.52 and 8.25, 1407.58, 1307.48, 1289.45 and 14.03, 1.82, 0.99, 2.12 and 22.18, of days to anthesis, days to maturity, pod yield, haulm yield, LAI respectively (Table 3). This indicates that, the model was satisfactorily simulated durations of different phenophases, yield, biomass and yield contributing characters under middle Gujarat climatic conditions. Therefore, DSSAT4.5 model was used to evaluate impact of future climate change on groundnut yield under middle Gujarat agro-climatic zone.

3.4. *Projected climate*

The summary of projected climate and its comparison with base line period is presented in Fig. 1. The weather condition as projected by A2 scenario (2070-2100) showed that there will be 13.7% higher rainfall as compared to base line (1961-90). The mean maximum and minimum temperature will be higher to the tune of 5.1 and 3.6 °C as compared to their base temperature of 29.8 and 19.1 °C.

3.5. *Trends of groundnut yield, yield attributing characters and phenological variation during projected period*

3.5.1. *Impact on pod yield*

The climate change impact of projected period (2071-2100) on groundnut pod yield with % reduction from base line period (1961-90) is presented in Fig. 2. The model simulated results shows that the mean pod yield (irrespective of cultivars and dates of sowing) will be reduced 19.7%. While under D_1 (Onset of monsoon)

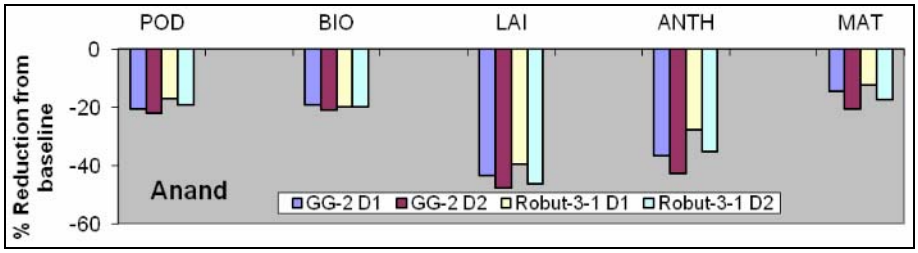

Fig. 2. Impact on yield and phenology of groundnut Anand station of middle Gujarat agro-climatic zone

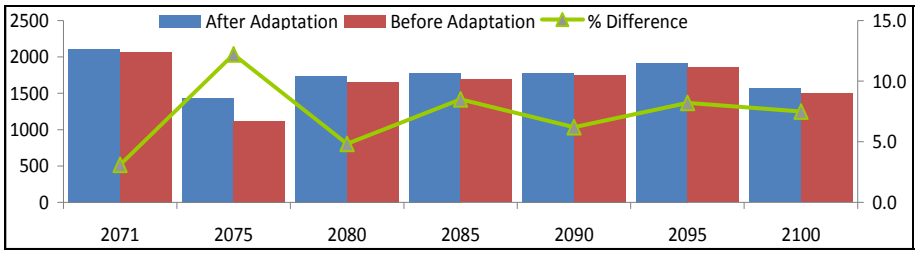

Fig. 3. Yield difference by adaptation of organic manure instead of chemical fertilizer at Anand station of middle Gujarat agro-climatic zone

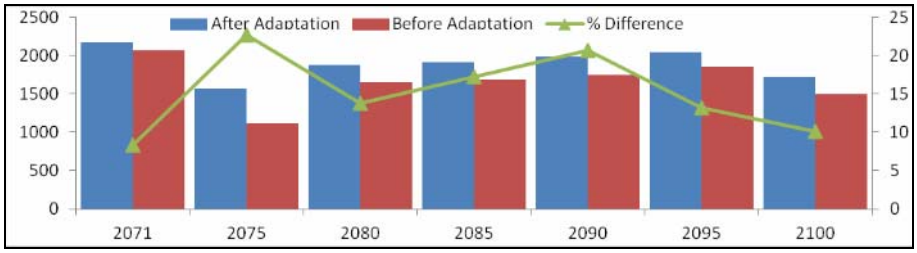

Fig. 4. Yield difference by adaptation of shifting sowing date instead of normal sowing date (Onset of monsoon) at Anand station of middle Gujarat agro-climatic zone

sowing in both variety GG-2 and Robut-3-1 yield will be reduced 20.5 and 17.2% respectively. However under D_2 sowing (15 days after onset of monsoon) it will be 22.2 and 19.2% in GG-2 and Robut-3-1 respectively. Result supported to Mall *et al*. (2006).

3.5.2. *Impact on biomass yield*

There was no much variation in biomass reduction under different dates of sowing and varieties. Lowest biomass reduction (19.0) was noted in GG-2 D_1 sowing while it was highest (21%) under D_1 sowing in GG-2. On and average mean biomass reduction (irrespective of cultivars and dates of sowing) was 20% (Fig. 2). Aggarwal *et.al* (2004) found similar result found for wheat crop for Indo-gagatic plan zone.

3.5.3. *Impact on LAI*

Impact of climate change on LAI the reduction (47%) under A_2 scenario will be highest in D_2 sowing as compare to onset of monsoon sowing (43%) in both variety. While average (irrespective of cultivars and dates of sowing) reduction was noticed 44% (Fig. 2).

3.5.4. *Impact on anthesis date*

Higher advancement (43%) in anthesis date was seen at onset of monsoon sowing under D_2 sowing in GG-2 cultivar and lowest (28%) was in robut-3-1variety. The average reduction in anthesis days was noticed 35% average (irrespective of cultivars and dates of sowing)

3.5.5. *Impact on maturity date*

Less reduction in maturity days was noted at onset of monsoon sowing in both varieties 14 and 12% respectively. While highest reduction (20%) was noticed at onset of monsoon sowing in GG-2 variety and average reduction from baseline (irrespective of date and cultivars) was 16% as compare to baseline.

3.6. *Adaptation measures*

3.6.1. *Use of organic manure*

The GG-2 cultivar under D_1 sowing was applied recommended fertilizer dose in the form of organic manure and yields are compared with chemical fertilizer application. Results showed that on an average 7% yield increment was achieved through use of organic manure alone during projected period (Fig. 3). Similar type of results was obtained in maize and groundnut by Dimes *et al*. (2010) at Zimbabwe.

3.6.2. *Shifting of sowing window*

The GG-2 groundnut cultivar was sown 15 days earlier of onset of monsoon by applying one sowing irrigation. Under this option mean 16% yield increment was achieved as compared to onset of sowing (Fig. 4). Similar type of results was obtained in maize and groundnut by Dimes *et al*. (2010) at Zimbabwe.

4. Conclusion

A_2 scenario (2070-2100) showed that there will be 13.7 % higher rainfall as compared to base line (1961-90). The mean maximum and minimum temperature will be higher to the tune of 5.1 and 3.6 °C as compared to their base temperature. The groundnut cv. GG-2 was found more heat and moisture stress resistant in terms of yield as compared to Robut 33-1. Lowest yield reduction was found in cv GG-2 in early sowing (15 days before onset of monsoon) by supplying one pre sowing irrigation. The moisture stress during pod formation and seed formation stage of late sowing of both varieties was significant negatively correlated with the yield. Under projected period. 7.0 to 16.0% yield benefited by adaptation strategies fifteen days earlier shifting of sowing date with one pre sowing irrigation and Application of organic manure instead of chemical fertilizer.

Acknowledgement

The Authors sincerely acknowledge to IITM Pune for providing PRECIS downscaled model output data, financial and technical support received from Network Project on Climate Change (NPCC) sponsored by ICAR, New Delhi for carrying out this research work.

References

Aggarwal, P. K., 2008, Global climate change and Indian agriculture: impacts, adaptation and mitigation. *Indian J. Agric. Sci*., 78(10), 3–11.

Anonymous, 2011, www.agricoop.nic.in/Agricultural statistics.

Boote, K. J., Jones, J. W., Hoogenboom, G., Wilkerson, G. G. and Jagtap, S. S., 1989, "PNUTGRO v1.02 Peanut Crop Growth Simulation Model", *User Guide - Florida Agricultural Experiment Station Journal No. 8420*, University of Florida, Gainvesville, Florida, 45.

Dimes, J. P., Cooper, P. and Rao, K. P. C., 2010, "Climate change impact on crop productivity in the semi tropics of Zimbabwe in 21st century", *Proceeding of Ghana climate change*, 1-11.

Duncan, W. G., Mc Cloud, D. E., McGraw, R. L. and Boote, K. J., 1978, "Physiological aspects of peanut yield improvement", *Crop Science*, **18**, 1015-1020.

Hoogenboom, G., Wilkens, P.W., Thornton, P.K., Jones, J.W Hunt, L.A., Imamura, D.T., 1999, "Decision support system for agrotechnology transfer" v3.5 In: Hoogenboom, G.,Wilkens, P.W., Tsuji, G.Y. (Eds.), DSSATversion 3, vol. 4 (ISBN 1-886684-04-9). *University of Hawaii, Honolulu*, HI, p136.

IPCC, 2007, "*Synthesis Report*". Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change". [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, p104.

Mall, R. K., Singh, R., Gupta, A., Srinivasan, G. and Rathore, L. S., 2006, "Impact of climat change on Indian agriculture", A review, *Climatic Change*, **78**, 445-478.

Rao, Gangadhar, D., and Sinha, S. K. (1994), "Impact of Climate Change on Simulated Wheat Production in India," in C. Rosenzweig and I. Iglesias (eds.), *Implications of Climate Change for International Agriculture: Crop Modelling Study*, United States Environmental Protection Agency, Washington D. C., 1–17

Rosenzweig, C. and Iglesias, A., 1998, "The use of crop models for international climate change impact assessment", In *Understanding Options for Agricultural Production*, G. Y. Rosenzweig, C. K. Strzepek, D. Major, A. Iglesias, D. Yates, A. Holt, and D. Hillel. 2005. Water availability for agriculture under climate change: Five international studies, Global Environmental Change.

Rosenzweig, C. and Parry, M. L., 1994, "Potential impact of climate change on world food supply", *Nature*, **367**, 133-138.