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Adoption of weather forecasts – A precursor towards adaptation to climate change

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ABSTRACT

Perception of farmers in Dharwad and Bijapur Districts of Karnataka on the utility of weather forecasts for taking up farming operations is presented. The University of Agricultural Sciences Dharwad develops and disseminates short range weather forecasts to farmers in seven Districts of North Karnataka, through e-communication by sending bulk messages from a dedicated web control panel, in order to sensitize the farmers towards weather forecast based farming. About 2500 farmers in Dharwad and Bijapur Districts receive forecast messages by 11.00 a.m. Feedback of the farmers was collected as to how they utilized the forecasts they had received. The perception of sixty farmers of Dharwad District and forty farmers of Bijapur District interviewed was wide and varying. The utility varied from hundred per cent for spraying in grape gardens to eight per cent for inter-cultivation activities in field crops. Thus, by adopting the weather forecasts for important agricultural operations, the farmers are getting ready to face the adverse effects of climate change.

Key words: Area specific weather forecast, adoption of weather forecasts, climate change, Karnataka

It is perceived that climate change would increase the already prevailing instability in weather. Many technologies are being proposed / improved to face the unfavorable weather conditions of the future. However, it is also necessary that not only the advice reaches the farmer, but also the farmers are sensitized to climate change events and pursue them to be prepared for adaptations in future scenarios. For this to happen, it is important that the farmer adopts weather forecast based farming before the eventualities overtake him. In the present days itself, the farmer in India is in need of timely and location specific weather forecasts and advice that cater to his day to day field operations. Presently short range weather forecasts are available to him through mass media for a Meteorological Subdivision, which is a group of districts with nearly homogenous climate. The limitation of these forecasts is felt by the farmers, as they are not specific to their area. This has led to low confidence of the farmers on weather forecasts. To overcome this, it is necessary to build confidence in him on the weather forecasts. Without this the farmers cannot be persuaded to shift to climate based agriculture. Further, the farmers get to know of the weather forecasts only either in the evening or the next morning of issue of the forecast, depriving them to put the forecast to use immediately. These bottlenecks need to be cleared with sustained efforts of region specific forecasting and disseminating them to farmers in a timely manner.

Global circulation models, electronics, satellite technology and information and communication technologies are invaluable tools towards providing good weather forecasts and timely dissemination of weather based advisories to farmers on near real-time basis. Use of SMS is a resourceful mode of communication to help the farmers (Venkatesh et al., 2011). The technologies were successfully used by the AICRP on Agrometeorology, Bijapur Centre and the Institute for Agricultural Research on Climate Change (IARCC), UAS, Dharwad (Venkatesh et al., 2012) for development of weather forecasts and their dissemination in the form of text messages to the farmers in districts of northern Karnataka for suitable adoption.

MATERIALS AND METHODS

Synoptic maps (current and forecast) and satellite cloud pictures (covering the past 2-3 days) were downloaded from four websites (www.imd.gov.in; www.sat.dundee.ac.uk; oiswww.eumetsat.org; www.monsoondata.org ;) at near real-time and short range weather forecasts were developed particularly with respect to cloudiness and rainfall, including possible time of occurrence (morning/evening/night) for individual districts.

The main points of interest are

- Spatial and temporal changes in sea level pressure
- Temporal and spatial dynamics of vortex motions in the lower and upper atmosphere, over India and neighborhood
- Hotspots of convective activity
Comparison of two weather generators for rainfall simulation: A case study for humid and semi arid environments

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ABSTRACT

This paper presents a comparison of two multi-site weather generators for simulation of point rainfall occurrences at a network of 125 rain gauge stations under humid and semi arid region in the state of Andhra Pradesh in India. Observed daily data were first used to calculate site specific parameters. These parameters were then used for LARS-WG to generate synthetic data series. The performances of the models were evaluated based on the effect of the region and seasonality. Per cent error and D-index between observed and generated mean monthly data was calculated. The results revealed that LARS-WG performed better than the MarkSIM. LARS-WG performed well during monsoon season as compared to dry period and post-monsoon season. During monsoon season, per cent error ranged from -4 to 2 in most of the study area and gave better results than MarkSIM. Models performed better in the coastal region than dry and semi arid regions. D-index values ranged in most of the sites between 0.9 to more than 0.95 with both the models.

Key words: Weather generator, LARS-WG, MarkSIM, rainfall simulation

Simulation of weather variables at multiple point locations simultaneously is often desired in many hydrological and agricultural applications. However, observed records of these variables providing sufficient temporal and spatial coverage are rarely available. To overcome this, stochastic models are commonly used to generate synthetic sequences of weather variables that are statistically consistent with the observed record. Point rainfall at a daily time scale usually forms one of the key variables in these applications. Rainfall at individual point locations is often generated by assuming low-order Markovian dependence (Wilks and Wilby, 1999).

The problem of data availability is more confounding as the density of meteorological stations is often low, especially in developing countries, and reliable and complete long-term data are scarce. With a few exceptions from developed countries (Thornton et al., 1997), daily interpolated surfaces of meteorological variables rarely exist. Even if they are available (IMD) they cover large area often 1 degree or 0.5 degree which are not normally sufficient for agricultural applications (crop modelling etc.) due to the fact that there is a great variability in rainfall at short distances. More commonly, weather data used in applications that cover large geographic regions come from interpolated surfaces of weekly or monthly climate variables (Jones and Thornton, 2000). From these interpolated surfaces, daily weather data for crop simulation models are then generated using statistical models that attempt to reproduce a series of daily data with means and variability similar to what would be observed at a given location.

Both amount and distribution of precipitation are among the most important environmental variables which influence the soil water balance, crop growth and other processes. Precipitation is also strongly related to other weather variables such as solar radiation, temperature and humidity (Geng et al., 1986). Unfortunately, precipitation is the most difficult weather parameter to generate. Numerous weather generators are available such as Climgen, Cligen, WGEn, LARS-WG, MarkSIM etc. for synthetic generation weather variables such as temperature, precipitation etc. Utilisation of weather generators has become essential for climate change studies as the GCM output is often in terms of anomalies at monthly interval. In order to make use of the datasets for crop modelling studies and hydrologic studies, it is essential that the information be temporally downscaled using weather generator.

The objective of this study was to compare the performance of the weather generators LARS-WG and MarkSIM with emphasis on precipitation for Andhra Pradesh and their utilisation in climate change studies as they are the frequently used weather generators by the research community. Weather generators typically calculate daily precipitation first and use this information to guide the generation of other weather variables, such as daily solar radiation, maximum and minimum temperature, and potential evapotranspiration (Hutchinson, 1987; Thornton et al., 1997). Daily precipitation is usually generated by modeling the occurrence of wet days and the amount of rain on a wet day (Geng et al., 1986). First order Markov chains are often used to describe the occurrence of wet days (Geng et al., 1986).
Evaluation of pedostructure based model Kamel® under soils with varying clay content for prediction of soil moisture

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ABSTRACT

This study involves a comparison between Kamel® and Hydrus_1D® for soil moisture simulation under two different soil types. Both models simulate the flux of water within the soil, in response to weather condition dynamics and water uptake by roots. The field sites under investigation are located in the Upper Cedar Creek Watershed (UCCW), Dekalb County in northwestern Indiana, USA. The field site AS-1 has been managed as a no-till field under a corn-soybean rotation, while site AS-2 is under rotational tillage with Corn-soybean rotation. Clay content of AS-1 site varied from 20-37% with depth while clay content for AS-2 was 28-40%. The calibration for Kamel® was carried out for a 15 day time period for determining the non-measured parameters. The calibrated parameters were used for the validation of both models under sites AS-1 and AS-2. Both models were found to be in good agreement with measured water content at 5 and 20 cm layer for site AS-1, however performance of Kamel® was better than Hydrus-1D® for deeper layers. For AS-2 site, Kamel® performed better than Hydrus-1D® irrespective of the depth of soil. However, Kamel® and Hydrus-1D® models fail to keep account of variable root water uptake during different growth stages. Kamel® could do as well as Hydrus-1D®, a more known and experimented soil water model; however, indicating the need to incorporate variables / parameter for better root water uptake simulation. Kamel® was more promising in terms of ability to couple dynamics of the internal hydrostructural state of the soil medium to external climatic conditions and biological processes in the critical zone.

Key words: Kamel model, Hydrus-1D, hydrostructural parameters

Water is an important natural resource and its increasing scarcity has resulted into the emergence of various issues for its efficient use, management and sustainability. Only 2.7 per cent of the global water is available as fresh water, out of which only 30 per cent can be used for meeting the demand for agriculture, municipal and industrial sectors. Water scarcity is considered as an increasing constraint to food security and sustainable development of agriculture. Also water is the major carrier of transport mechanism for nutrients and contaminants through the soil. The transport of solutes is made complicated by networks of interconnected pathways which can transmit water and its solutes at varying velocities. These pathways result from biological and geological activities, such as subsurface erosion, faults and fractures, shrink-swell cracks, animal burrows, worm holes, decaying roots, etc. and as such makes the prediction of water flow in heterogeneous soil complicated.

A large body of literature exists on water flow, but now when simulation modeling tools have become available, a number of soil water flow models have been developed by various research workers to incorporate macropore flow in soil, but most of them have not been validated under field conditions. Braudeau et al. (2004) developed a functional model of the unsaturated soil water medium that recognizes the hierarchical nature of the soil structure and its swelling properties and named the functional representative volumes of the soil water medium as Pedostructure. They developed relationships for all the structural specific volumes (air, water and pores system) as a unique function of soil water content at equilibrium state as defined by the shrinkage curve. Later on Braudeau and Mohtar (2006) developed pedostructure-based parametric functions for the soil structure and water interaction represented by soil shrinkage and matric water potential curves to derive the swelling curve equation. This equation represents the kinetic of absorption of water by swelling of the primary peds within the pedostructure. Braudeau et al. (2009) developed a soil water structure model Kamel®, based on the hierarchical soil structure taking into account its thermodynamic properties. The Kamel® model runs with a set of 15 soil input parameters called as pedostructure parameters consisting of physically based equation of four soil characteristic curves that can be measured in laboratory. Singh et al. (2012) reported that performance of Kamel® model for simulation of soil was better as compared to a well-developed Hydrus-1D® model.
Leaf miner, Aproaerema modicella and late leaf spot disease, Phaeosariopsis personata are the most important yield limiting factors in groundnut in India. A degree day forecast model for leaf miner and a leaf wetness based decision support advisory model for late leaf spot were evaluated in groundnut field experiments conducted over four seasons using wireless sensor network (WSN). Microclimate data was collected by deploying motes in crop canopy and transferred via gateway subsystem to web server for analysis using models and dissemination of advisories to registered users through short message service (SMS). In case of leaf miner, 460 growing degree-days (GDD) calculated from the field temperatures using first catch in pheromone traps as bio-fix date for accumulating GDDs, accurately predicted timing of second generation in kharif 2008 and third generation in kharif 2009. WSN deployed in 2009 and 2010 validated late leaf spot decision support advisory model for fungicide sprays based on leaf wetness index (LWI). The decision criteria like threshold value of leaf wetness index (7-day sum of daily LWI ≥ 2.3), disease threshold of 10% and a spray interval of 14 days were used for providing fungicide spray advisory. Accordingly, 4 fungicide applications were made to control leaf spot disease in rabi 2009 and 3 fungicide applications in kharif 2010. Highest incremental benefit: cost ratio was obtained with WSN based fungicide spray applications during both the seasons compared to scheduled sprays and farmers practice. This is the first report on application of WSN for validation of pest and disease forecast models and dissemination of spray advisories in groundnut through SMS.

Key words: Groundnut, pest, disease, leaf wetness, degree-days, prediction, wireless sensors

Groundnut (Arachis hypogaea L.) is an important oilseed crop in India cultivated in 8 m ha. Low productivity of groundnut in the country (1 tonne ha⁻¹) could be attributed to its cultivation on marginal soils under rainfed conditions and damage inflicted by several pests and diseases. Groundnut leaf miner (GLM), Aproaerema modicella (Deventer), is a key insect pest responsible for significant foliar damage particularly under low rainfall conditions causing up to 50% yield loss (Shanower et al., 1993a). Temperature drives the development of GLM generations under field conditions. About 460 degree-days are required for completing egg to adult development (Shanower et al., 1993b) and it is possible to calculate field based degree-days from temperature data to predict the timing of the next generation of leaf miner for taking up timely control interventions. Epidemics of the late leaf spot (LLS) disease caused by Phaeosariopsis personata (Berk. and Curtis.) Deighton occur mainly during kharif coinciding with periods of favourable crop microclimate in the semi-arid tropics (Wadia and Butler, 1994). Long periods of leaf wetness were associated with disease severity (Shew et al., 1988). However, in the semi-arid tropics, enhanced infection was reported when leaves were exposed to intermittent wetness compared with continuous wetness (Wadia and Butler, 1994). The infection process of LLS takes about 6-8 days (Butler, 1990). Das et al. (1997) earlier developed a weather dependent spray schedule for LLS management in groundnut with fungicide spray advised when cumulative leaf wetness hours in a week exceeded a set threshold.

Wireless sensor network (WSN) combines various technologies like sensing, processing and wireless communication into a system architecture that interfaces the physical world with cyberspace (Puccinelli and Haenggi, 2005) and therefore is amenable for use in pest and disease forecasting. WSN can aggregate microclimate information from agricultural fields by integrating sensors spatially distributed within the crop canopy. This can support analysis of various weather factors influencing crop growth, pest and disease dynamics and aid the development of decision support advisory models to help farmers in better crop management (Burrel et al., 2004).

In this paper we report the use of WSN for collection and transfer of microclimate data from temperature and leaf wetness sensors via a field gateway, over the internet to a remote computer for analysis based on decision criteria.
**InfoCrop – a crop simulation model for assessing the climate change impacts on crops**

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**ABSTRACT**

This study presents results of evaluation in terms of its validation and impact of climate change on Indian mustard (*Brassica juncea*), sorghum (*Sorghum vulgare*) and maize (*Zea mays*) by using the crop simulation model, ‘InfoCrop’. Simulated results of mustard model showed a spatial variation in yield among all five regions in both irrigated and rainfed mustard. Under irrigated conditions, the yield reduction in 2020, 2050 and 2080 would be highest in Eastern-IGP (Indo-Gangetic Plain) region followed by Central-IGP. This was due to maximum projected rise in temperature in Eastern-IGP where maximum and minimum temperature would rise by 5.1° and 5.6°C in 2080. The reduction of irrigated mustard yield was least in Northern-IGP under almost all scenarios. But in Western India, yield reduction gradually increased from 2020 to 2080. In future climate change scenarios, the rainfall would be projected to increase in 2050 irrespective of the locations. But in 2020 and 2080 rainfall would reduce in Northern-IGP, Western and Central India. This was reflected higher yield reduction in rainfed mustard in these three locations. In sorghum, the future climate change scenario analysis showed that the yields (CSH 16 and CSV 15) are likely to reduce at Akola, Anantpur, Coimbatore and Bijapur. But yield of CSH 16 will increase slightly in Gwalior (0.1%) at 2020 and thereafter it will decline. At Kota the sorghum yield is likely to increase in 2020 (3.3 and 1.7 % in CSH 16 and CSV 15 respectively) with no change in 2050 and yields will be reduced at 2080 in both varieties. Maize trend is similar from the sorghum impact except in the UIGP where rainfall could be projected to increase in the future. In MIGP and SP(Southern Plateau), expected reduction would be 5%, 13%, 17% and 21%, 35%, 35% in 2020, 2050 and 2080 respectively from the current level.

**Key Words:** Climate change, *InfoCrop*, validation, simulation, scenario

Climate is usually defined as the average weather or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The climate change refers to a statistically significant variation in either the mean stage of the climate or in its variability, persisting for an extended period. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Constant increase in greenhouse gases concentrations, since pre-industrial times, has led to positive radiative forcing of the climate, tending to warm the surface.

The fourth assessment report of IPCC (Intergovernmental Panel on Climate Change) confirmed the rise in atmospheric temperature by 0.74 °C over the last 100 years due to global warming and projected a temperature increase of 1.8 to 4 °C by 2100. Global warming induces events such as frequent occurrence of warmest year, heavy intensity rainfall, flash flood, frost, etc., posing potential threat to ecosystems especially, agricultural production and productivity throughout the world. Agricultural production is the most sensitive and vulnerable to climate change, as climate is the primary determinant of agricultural productivity (Watson *et al.*, 1996). Crop productivity is projected to decrease for the increase of local temperature (1-2 °C) at lower latitudes, especially in seasonal dry and tropical regions of the world (IPCC, 2007).

The crop simulation models are useful tools for considering the complex interactions between a range of factors that affect crop performance, including weather, soil properties and crop management (Shamim *et al.*, 2012). *InfoCrop* - a crop simulation model is used to study the impact and adaptation of climate change on mustard, sorghum and maize to climate change in India. Model has been validated for dry matter and grain yields of several annual crops, losses due to multiple diseases and pests, and emissions of carbon dioxide, methane and nitrous oxide in a variety of agro-environments.
Assessing impacts of projected climate on pigeonpea crop at Gulbarga

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ABSTRACT

Pigeonpea [Cajanus cajan(L.) Millsp] is an important semi-arid legume crop in India. In Karnataka, pigeonpea is largely grown in the northern parts of the state especially in Gulbarga, which is called “Pulse Bowl of Karnataka”. Climate change is one of the major challenges being faced by agriculture in the Semi-Arid Tropics (SAT) of the country. Pigeonpea productivity in Gulbarga is affected by large variations in rainfall amount and distribution, increased temperatures, depleting soil productivity and disturbing water balance. Based on daily weather data of 41 years (1969-2009), productivity and water use of pigeonpea under eleven climate scenarios are assessed using the pigeonpea model in Agricultural Production Systems Simulator (APSIM). Simulations are done with automatic sowing based on rainfall and soil moisture availability during the sowing window (15 Jun to 20 Aug) and following recommended crop management practices. Simulations show that increase in temperature by 2°C could reduce pigeonpea yields by about 16%. Rainfall decrease of 10% from present coupled with 2°C increase in temperature could reduce yields further by 4%, making the total reduction to be at 20%. Crop duration was shortened by about 10 days and water use reduced by 25 mm with increase in temperature. Increased rainfall scenarios have considerably reduced the adverse effects of higher temperature. Breeding of varieties tolerant to higher temperature and adoption of better water management (both in-situ and ex-situ) practices achieved through integrated watershed approach could play a major role in sustaining pigeonpea productivity under future climate scenarios.

Key words: Climate change, Gulbarga, pigeonpea, simulation model, APSIM

Pigeonpea [Cajanus cajan(L.) Millsp.] is a major legume crop and rich source of protein for vegetarian population of India, largely grown in semi-arid regions of the country. It is the second most important pulse crop after chickpea. In 2010-11, it was cultivated in about 4.37 Mha (17% of the total area under pulses in the country) and contributed about 16% to the total pulses production with an average productivity of 0.66 t ha⁻¹ (DES, 2012). In Karnataka, pigeonpea is largely grown in the northern parts of the state especially in Gulbarga, which is known as “Pulse Bowl of Karnataka”. Pigeonpea occupies an area of about 0.38 M ha in Gulbarga with a production of about 0.22 M tonnes and thus the district average productivity is 0.57 t ha⁻¹. Major soils of the district are Vertisols and associated intergrades (deep black, medium black, shallow black) and lateritic, with water holding capacity of 200-230 mm, and are suitable for pigeonpea cultivation. Gulbarga district experiences a typical semi-arid climate. Normal annual rainfall for Gulbarga station is 834 mm received in 48 rainy days (IMD, 2010). Kharif (Jun-Oct) rainfall is about 720 mm, which is 86 per cent of the annual rainfall. May is the hottest month with an average maximum temperature of 40°C and December is the coldest month with an average minimum temperature of 15.9°C.

Climate change due to global warming is posing a serious threat to agriculture which is one of the major challenges presently faced by agriculture in India, more so in the Semi-Arid Tropics (SAT) of the country. Increased concentration of greenhouse gases (GHGs) in the atmosphere is causing increasing temperatures across the globe (IPCC, 2007). Variability in rainfall is increasing and extreme rainfall events are occurring more often. The annual mean area-averaged surface warming over the Indian subcontinent to range between 3.5 and 5.5 °C over the region during 2080s. During winter, India may experience between 5 and 25% decline in rainfall, which is likely to be significant and may lead to droughts during the dry summer months (Lal et al., 2001). A study using long-term gridded weather data sets of IMD revealed that 5.1 M ha have become drier and 5.6 M ha have become wetter during the periods 1971-1990 and 1991-2004 (Wani et al., 2012). Largest shifts are seen in Madhya Pradesh where an additional 3.82 M ha became semi-arid. In Karnataka semi-arid area increased by 0.23 M ha. Devappa and Khageshan (2011) reported a decreasing trend in the annual rainfall @ 3.44 mm per year for Gulbarga district, based on data for 1961-2008. Variations in rainfall amount and distribution, increased temperatures, depleting soil...
Response of tomato (*Lycopersicon esculentum* Mill.) genotypes to elevated temperature


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**ABSTRACT**

Global warming is an important issue threatening agriculture and allied sectors with serious consequences on food production. Tomato being sensitive to temperature would be influenced by elevated temperatures under climate change scenarios. Physiological response of five tomato genotypes, Arka Vikas, Arka Saurabh, Abhinava, RF4A and 2195 to mild elevated temperatures at peak flowering and peak fruiting stages was evaluated in temperature gradient tunnel (TGT) facility. The increase in temperature above the optimal, caused reductions in net photosynthesis rate, transpiration and stomatal conductance with differences in response among the five genotypes. The reductions were large at peak flowering stage compared to peak fruiting stage. The Photochemical efficiency of PSII was also reduced at both peak flowering and fruiting stages due to increase in temperature. At peak fruiting stage, due to increase in temperature, leaf epicuticular wax content increased across the genotypes and higher total soluble sugars, reducing sugars and proline content contributed to increase in leaf osmotic potential. Overall, better performance of germplasm line 2195 and cv. Arka Vikas was observed under elevated temperature.

**Key words:** Climate change, elevated temperature, tomato, TGT, chlorophyll florescence

The Fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) estimated that the current global mean surface temperature is about 0.42 to 0.54 °C above the 1961-1990 annual average and multi model averages indicated the temperature increases in the range from 1.1 to 6.4 °C during 2090-2099 relative to 1980 to 1999 (IPCC, 2007). The increase in temperature under climate change situations would considerably influence crop yields and in turn the sustained supply to meet growing demands. Crop plants need optimum growing conditions for attaining genetic yield potential. However, the occurrence of abiotic stresses at critical growth stages seldom allows crops to attain genetic yield potential and global climate change further threatens sustenance of crop yields. Tomato is an important horticultural crop in India; currently it is the second largest produced vegetable. This feat has been achieved with country wide area of 8.65 lakh ha with 168.26 lakh tons production. Optimal mean daily temperatures for tomato are between 21 and 24 °C, depending on developmental stage (Geisenberg and Stewart, 1986). The optimum temperature for net assimilation rate is between 25-30 °C (Khavari-Najad, 1980). Temperatures only a few degrees above optimal can reduce fruit production and seed set in tomato (Peet *et al*., 1997).

Supra optimal temperatures cause a series of complex morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity (Wang *et al*., 2003). Photosynthesis can be completely inhibited by high temperature before other symptoms are detected (Berry and Bjorkman, 1980). Some studies on the effect of elevated temperatures on tomato have been conducted with extremely high temperatures. Camejo *et al*. (2005) subjected two tomato genotypes to 45 °C for two hours and observed the reductions in photosynthesis rate and the photochemical efficiency of PSII (Fv/Fm) in the heat susceptible tomato cultivar, Campbell-28. In another study, Heckathorn *et al*. (1998) exposed tomato plants to 43 °C for 6 hours and reported significant reductions in PSII electron transport. On the contrary some studies have been conducted under high and moderately high temperatures. In a study on effect of two temperature regimes, 37/27 °C and 37/22 °C, Abdelmageed and Gruda (2009) reported differences in photosynthesis rate among eight genotypes with reduction at higher temperature regime. Exposing tomato plants to moderately high temperature of 35 °C for eight hours caused decreased photosynthetic activity and changes in carbohydrate metabolism (Zhang *et al*., 2012). Studies on the effect of chronic mild heat stress (32/26 °C) on five tomato cultivars showed that generally, in all the five cultivars, photosynthesis rate was lower in plants kept at 32/26 °C compared to plants kept at 28/22 °C. However, there was no significant relationship between photosynthesis rate and fruit set. All these studies have shown the influence of temperatures slightly above the optimal on photosynthetic
Effect of sunlit leaf area index (L*) on total dry matter and crop growth rate of potato planted under different dates and nitrogen levels

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ABSTRACT

The sunlit leaf area index (L*) is a better growth index than leaf area index, as it measures the illuminated area in a crop canopy. To generate scientific information, a two year experiment (2010-11 and 2011-12) was conducted on potato (Kufri Jyoti) planted on five dates, starting from 15th November at an interval of seven days with two N-doses (N1 = 200 kg ha\(^{-1}\) and N2 = 150 kg ha\(^{-1}\)) in a split plot design at the District Seed Farm, BCKV. The L* was computed from Photosynthetically Active Radiation data, measured within the potato canopy at 11:30 h with the help of line quantum sensor on 30, 45 and 60 days after planting (DAP). The total dry matter (TDM) and crop growth rate (CGR) were computed for the respective dates. The TDM and CGR were found to be the polynomial functions of L*. The relationship between L* and TDM and L* and CGR were found to be significant during the later stage of growth (60 DAP). About 99.6 and 92.1 per cent variations in TDM and CGR could be explained through the variation in L* during 60 DAP (active tuberization). Under higher N-dose, the strength of association between the L* and CGR gradually increased from 30 to 45 DAP. 73% variation in CGR was explained through the variation in L* at 60 DAP. The reduction of N recorded the similar trend; however, the strength of association was strongest at 60 DAP. The result suggested the importance of leaf illumination during the tuberization phase of potato.

Key words: L*, potato, total dry matter, crop growth rate

MATERIALS AND METHODS

Experimental site

The experiments were carried out during rabri (November-March) seasons of 2010-11 and 2011-12 at the District Seed Farm, Bidhan Chandra Krishi Viswavidyalaya, (Latitude 22° 58’ N and Longitude 88° 32’ E), West Bengal, India. The study site is flat and is located at an altitude of 9.75 m above mean sea level (AMSL). The soil is sandy loam with a pH of 8.35 and has total nitrogen - 261 kg ha\(^{-1}\), available phosphorus - 30.22 kg ha\(^{-1}\), available potassium - 194.88 kg ha\(^{-1}\) and 0.48% organic carbon.

Climate

The experimental site falls under tropical humid climate having a short and mild winter spanning from November to February with an annual rainfall of 1457 mm, 85% of which is received during June to September. The average monthly temperature ranges from 10 to 37 °C. The potato growing season is marked by low temperature (occasionally mercury reaches below 10 °C), low humidity and little rainfall.
Agrometeorological indices in relation to phenology, biomass accumulation and yield of rice genotypes under Western Plain zone of Uttar Pradesh

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ABSTRACT

Field experiments were conducted during kharif season of three consecutive years 2008-2010, following randomized block design with three replications to evaluate 12 coarse grain rice genotypes to reveal the effect of different agrometeorological indices on the grain yield. The growing degree days (GDD) required for panicle initiation (GDDPI), 50% flowering (GDD FL) and for physiological maturity (GDD PM) were higher (1273.6 oCd, 1474.5 oCd and 2069.8 oCd respectively) in Narendra 359, whereas these values were lower (846.1 oCd, 1008.8 oCd and 1546.8 oCd respectively) in Poornima. Heliothermal unit, Photothermal unit and phenothermal index also significantly varied among the rice genotypes. On total biomass basis, heat use efficiency (HUE, kg ha⁻¹ oCd⁻¹) was significantly high in Pant Dhan 10, whereas it was highest in PR 115 on grain yield basis. Radiation use efficiency (RUE, g MJ⁻¹) on total biomass basis was significantly highest in Pant Dhan 10. Correlation coefficients indicated that grain filling duration had a positive and significant correlation (P<0.05) with the grain yield of the cultivars. Flowering duration (FD) was positive and significantly associated with grain yield (r=0.37**) and total biomass accumulation (r=0.33**) of the cultivars. Cultivars with longer crop duration viz., Narendra 359 and Naveen may be the suitable choice for the optimum yield during short photoperiod/cloudier crop season under projected climate change scenario.

Key words: Growing degree days, photothermal unit, heliothermal unit, phenothermal index, rice genotypes

The world population is expected to reach 8 billion by 2030 and rice production must be increased by 50% in order to meet the growing demand for the world (Khush and Brar, 2002). The geographical distribution of rice growing areas in different parts of the world reveals that it is cultivated in highly diverse conditions from 50° N to 35° S (Swaminathan, 1999), indicating vast diversity in global rice album. India is the largest rice-growing country under varying climatic conditions (8° N to 34° N latitude) and it accounts for more than 40% of food grain production, providing direct employment to 70% people in rural areas. Being the staple food for more than 65% of the people, national food security hinges on growth and stability of its production (Shamim et al., 2012). Uncertainty of weather conditions is one of the key risk factors associated with crop production in western Indo-Gangetic alluvial plains. Photoperiod and temperature are two main environmental factors determining the flowering time in the rice (Brar, et al., 2011). Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat unit system because plants have a definite temperature requirement before they attain certain phenological stage (Sikder, 2009). Global mean surface air temperature increased by approximately 0.5°C in the 20th century and is projected to further increase by 1.5 to 4.5°C in this century (Houghton et al., 1995). In the past century, daily minimum night time temperature increased at a faster rate than daily maximum temperature in association with a steady increase in atmospheric greenhouse gas concentrations (Karl et al., 1991; Easterling et al., 1997). Although the effects of projected climate change on crop yields have been evaluated by using crop-simulation models (Rosenzweig and Parry, 1994; Shamim et al., 2012), there are few studies on the effects of agrometeorological indices based on observed weather parameters on crop growth and yield. In the present study, the objective was to indentify strong agrometeorological indices which relate cultivar performance directly to the growing season weather conditions of Indo-Gangetic alluvial plains.

MATERIALS AND METHODS

Field experiments were conducted at main research farm of Project Directorate for Farming Systems Research (PDFSR), Modipuram, Meerut (U.P.) during kharif 2008-2010. The soil of the experimental field was typic Ustochrepts, sandy loam, deep and mildly alkaline (pH 8.2) with low to medium fertility (OC–0.40 %, available P₂O₅–32.5 kg and K₂O–125 kg ha⁻¹). The climate is categorized as hot, dry and semi-arid subtropical with moderate summer and severely cold winters. Average annual rainfall is about 800 mm and potential evapo-transpiration of 1600 mm. The experiment was conducted following randomized block
Impact of drought on spatio-temporal pattern of phenology in Rajasthan

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ABSTRACT

This study presented the impact of drought on spatio-temporal pattern of crop phenology and also showed interannual variation in phenological parameters in Rajasthan state of India. The GIMMS NOAA-AVHRR NDVI dataset from 1982 to 2005 was used to generate kharif season phenology analogues such as start of season, end of season, time of peak vegetative stage, length of season and maximum NDVI and also their temporal trend using TIMESAT software. Drought resulted in delayed in sowing and timing of peak vegetative growth, sometimes causing early maturity of crops and thus leading to overall shortening of crop season. The temporal trends in phenology parameters are showing an early shift in kharif season as well as a general reduction in its duration. Partly these trends could be the result of adaptation to increasing rainfall deficit with time.

Key words: Phenology, NDVI, remote sensing, drought, Rajasthan

Drought is one of the most common environmental stresses that affects growth and development of plants (Aslam et al., 2006). The usual effects of drought on the development of a plant are a lowered production of biomass and changes in crop phenology of agroecosystem.

Vegetation phenology examines life cycle events such as bud burst, flowering, and leaf senescence (Schwartz, 2003). It is an independent measure on how ecosystems are responding to climate change and therefore experiencing renewed interest from the scientific research community. The effect of global warming and climate change on biological processes has been well documented (Badeck et al., 2004). In the present context of climate change and increasing land degradation and desertification (Le Houerou, 1996), being able to calculate the impact of a drought on crop phenology is crucial in determining the environmental consequences of a hypothetical change in climatic conditions.

Recent technological advances in studying the Earth from space have resulted in a new field of phenological research that is concerned with observing the phenology of whole ecosystems and stands of vegetation on a global scale using proxy approaches. Among various satellite-derived indices, the NDVI has evolved over a period of time as a primary tool for monitoring vegetation changes and interpretation of the impact of climatic/weather events on the biosphere. However, phenological parameters extracted by remote sensing are only an approximation of the true biological growth stages.

A number of approaches using a variety of satellite remote sensing products have been used to derive metrics related to land surface phenology (Sakamoto et al., 2005; White and Nemani, 2006; Jonsson and Eklundh, 2002, 2004; Sehgal et al., 2009; Chakraborty et al., 2011; Patel et al., 2011). However, Land Surface Parameters (LSP) databases have not yet been satisfactorily validated due to difficulty in obtaining sufficiently extensive ground observations throughout the growing season. Even without extensive validation, a number of applications areas have employed LSP data successfully, including studies on ecosystems analysis, disasters, land use, and climate change (Reed et al., 2009).

Using NDVI time series from AVHRR, positive trends of Lenth of Growing Season (LGS) have been detected for North America and Eurasia (Zhou et al., 2001). Sehgal et al. (2009) derived the spatial pattern of temporal trends in phenology metrics and productivity of crops grown, at disaggregated level in Indo-Gangetic Plains of India using time series of AVHRR PAL NDVI dataset.

Present study employed the TIMESAT software (Jonsson and Eklundh, 2004) to estimate phenological parameters from the time series GIMMS AVHRR NDVI dataset. The objective of this article is to investigate changes in vegetation phenology during kharif season due to impact of drought at regional scale in the Rajasthan state of India. The phenological parameters were derived for kharif season for 24 years from 1982 to 2005.
Variation of crop evapotranspiration from the potato field at two selected locations of West Bengal, India

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ABSTRACT

For water management in crop field, the assessment of crop evapotranspiration (ETc) is of prime importance. Owing to the difficulty for obtaining accurate field measurements, ETc is commonly computed from weather data and can be obtained from CROPWAT 8.0 model which is based on Penman-Monteith equation. In the present research work, the CROPWAT model has been used to determine year-wise and season-wise variation of ETc from the potato field in two selected stations of West Bengal. The ETc values estimated by CROPWAT model was compared with that measured by field water balance (FWB) method. Once the model gave reliable result (RMSE = 0.18, R² = 0.73), the model was used for calculation of ETc for various years at two locations, namely, Bankura (23.25°N, 87.05°E) of Red-Lateritic Zone and Balurghat (25.21°N, 88.78°E) of Alluvial Zone, for the period 1996-97 to 2007-08. In Bankura, the crop ET varied from 1.82 mm/day to 2.06 mm/day, whereas in Balurghat varied from 1.7 mm/day to 1.95 mm/day. It is apparent that the drier nature of Red-Lateritic zone causes higher ETc. Moreover, relatively higher mean seasonal temperature during potato growing season causes higher ETc. Overall, the ETc variation showed increasing for both the stations. Such type of study will enable to assess the future water demand for irrigation.

Key words: Potato, evapotranspiration, CROPWAT, West Bengal

For water management in crop field, the assessment of crop evapotranspiration (ETc) is of prime importance (Sharma and Singh, 1992; Hess et al., 1997). Owing to the difficulty for obtaining accurate field measurements, ETc is commonly computed from weather data. The reference evapotranspiration and crop coefficients are used to determine ETc. The value of ETc can be obtained from CROPWAT 8.0 model which is based on Penman-Monteith equation (Kiziloglu et al., 2006; Jose et al., 1999). Presently the threat of climate change compels us to rethink about the impact of climatic variables on crop growth. Moreover, the water available for irrigation for different crops including potato, the most important and remunerative horticultural crop in southern West Bengal, may be scanty due to probable climate change. Considering the above facts, a study was conducted to observe the change detection of ETc and irrigation requirement of potato at two selected stations of West Bengal.

MATERIALS AND METHODS

Study area and field data collection

The field experiment was conducted in the C Block Farm, BCKV, Kalyani, Nadia, West Bengal and the meteorological data were collected from the Kalyani observatory (22.97° N, 88.43° E) for assessing the ETc calculation and subsequently to validate the CROPWAT model. Maximum temperature, minimum temperature, humidity, wind speed, bright sunshine hour and rainfall data on daily basis were collected from the said observatory. Apart from this, the daily meteorological data were also collected from Bankura and Balurghat.

The data on soil texture was based on the analysis of the representative soil samples, collected from the potato field of three said stations. Other required properties like total available soil moisture, maximum rain infiltration rate, maximum rooting depth, initial soil moisture depletion, initial available soil moisture were also measured using standard procedures.

Evapotranspiration (ET) calculation by field water balance method

To estimate evapotranspiration using field water balance (FWB) method, first the soil moisture content of the field and depth of rainfall or irrigation applied in the field were measured. To get the deep percolation away from the root zone the difference of soil moisture in the last layer of vadose zone were considered. Then the evapotranspiration of potato for that field were calculated using following equation:

\[ ET = P + I - S - C - R \] ... ... (1)

Where, \( P \) = Precipitation; \( I \) = Irrigation; \( S \) = Difference of soil moisture contents; \( C \) = Deep percolation; \( R \) = Runoff (here, negligible due to field-bund) [all units were in mm].
Optimizing sowing dates and selection of varieties of wheat through long-term crop and weather analysis

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ABSTRACT

Wheat being a temperature sensitive crop, its development and productivity respond significantly to dates of sowing. An attempt has been made here to identify optimum sowing date and better crop variety at three wheat growing centres Kanpur, Ludhiana and Raipur through analysis of long-term crop and weather data. For identifying optimum sowing dates, three percentiles of yield and sowing dates over the years were worked out for each variety and centre. Phenophase-wise maximum and minimum temperatures were averaged over years under each percentile of yield and sowing dates. The meteorological standard weeks 48, 46 and 49 based on yield percentiles and 47, 45 and 47 based on percentiles of sowing dates were respectively identified as optimum sowing dates at Kanpur, Ludhiana and Raipur centres. These optimum dates were found to be supported by the prevalence of optimum thermal conditions (low temperature) during critical periods viz., milk stage at Kanpur and Raipur and booting to maturity at Ludhiana than the temperatures in crop sown later. Based on the rate of decrease of yield and the rate of increase in maximum and minimum temperatures (during critical stages) with days of delay in sowing, cultivars K-9107, PBW-343, and GW-273 were identified as better cultivars for sowing under thermal stress conditions or late sowing.

Key words: Wheat, cultivars, thermal conditions, sowing time

Wheat (Triticum aestivum L.) is the second most important cereal crop being grown in 29.2 million hectares in India (Anon., 2011). It is one of the component crops of the most important cropping system (rice-wheat) responsible for food security in India. Wheat is grown in rabi season (October-April) after the harvest of kharif crops of rice or cotton. Though average sowing dates in major wheat growing states is within optimal sowing window, starting around last week of October and ending around November 10 (Ortiz-Monasterio et al., 1994), very often the sowing of wheat in India gets delayed due to the delay in harvesting of kharif crops of the sequene. Delay in sowing by each day causes roughly 0.8-1.5 % yield loss in wheat according to field experiments at Ludhiana (Randhawa et al., 1981; Ortiz-Monasterio et al., 1994) and simulation models (Aggarwal and Kalra, 1994), largely due to terminal heat stress.

The choice of sowing date and cultivar were identified as important management options to optimise grain yield in Mediterranean conditions (Connor et al., 1992; Turner, 2004; Bassu et al., 2009). In India, agronomists and breeders have been conducting experiments for decades to find optimum sowing dates and cultivars based on yield. Adopting suitable sowing date and appropriate cultivar choices were estimated to be avoiding 7-18% of global yield losses due to changed scenarios of temperature and precipitation in 2050s (Deryng et al., 2011). Waha et al., (2012) simulated optimum sowing dates of 11 major annual crops, including wheat at global scale based on daily temperature and precipitation conditions, crop-specific temperature and precipitation requirements. In the above mentioned paper, sowing dates were simulated on the basis of temperature and precipitation seasonality criteria. Sowing dates for large parts of the earth were estimated through this approach. An overall yield gain of at least 5% average across India can be explained by the shift in sowing of wheat by one week earlier because of the adoption of zero-till or reduce-till practices by farmers in wheat sowing (Lobell et al., 2012). In Indian conditions, Patra and Sahu, (2007) attempted to identify suitable sowing dates of wheat through agrometeorological indices. Crop sowing dates may be chosen, more so to ensure favourable weather conditions during later stages of crop like flowering and post flowering than ensuring optimal conditions in the early growth stages.

The objective of the study is to determine optimum sowing dates and cultivars of wheat through analysis of long-term crop and weather data recorded at three centres of All India Coordinated Research Project on Agrometeorology.
Mandal-wise analysis of dry spell probability during different growth stages of rice in Medak district of Andhra Pradesh

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ABSTRACT

Rice is the important cereal crop grown in Medak district of Andhra Pradesh under canal and ground water irrigation. Weather plays a dominant role in the growth and yield of rice crop. Studies at national and international level suggest that the climate variability and change may increase vulnerability of this crop. Variability in onset of monsoon rains and their uneven distribution in recent years are leading to frequent drought like situations resulting in drying up of bore-wells and reservoirs leading to reduced inflow in canals and area under rice cultivation in India. In view of above, a study was conducted to look at the mandal-wise distribution pattern of rainfall and occurrence of dry spells during different growth stages of rice in Medak district. Mandal-wise rainfall data from 1971-2010 collected. Dry spells of less than 20 mm rainfall were worked out using Weathercock v1.0 software. Results showed that eastern part of district had dry spell probability of 60-70% during seedling phase (24-26 standard meteorological weeks SMW). The probability of dry spell during active vegetative phase (27-30 SMW) falls to about 50% in all mandals. Most of mandals (with few exception) received rainfall of 20 mm or more from 31-32 SMW coinciding with vegetative lag phase. During reproductive phase (33-38 SMW), except 11 mandals, the probability for a dry spell is less than 50% in the remaining mandals. Dry spells are likely to occur during the ripening phase (39-43 SMW) with probability exceeding 60%. Information generated in the present study may prove useful for all stakeholders for judicious use of available water while sustaining the crop during dry spells and enhance crop productivity.

Key words: Rice, dry spell, rainfall, probability, growth stages

The knowledge of climate and weather is being increasingly used in various agriculture activities. The success or failure of crops particularly under rainfed conditions is closely linked with the rainfall distribution/patterns. Simple criteria related to sequential phenomena like dry and wet spells could be used for analyzing rainfall data to obtain specific information needed for crop planning and for carrying out agricultural operations (Sastry, 1976). It is important to know the probability of occurrence of dry and wet weeks (Pandharinath, 1990) for crop management purpose. Markov chain probability model has been found suitable to describe the long term frequency behavior of wet or dry spells (Victor and Sastry, 1979). Agriculture planning as well as operations depend considerably on the success of dry and wet spells (Subramaniam and Rao, 1989). In rainfed agriculture, it is a pre-requisite in contingent crop planning that selection of varieties within a crop should be based upon probability of rainfall (Chaudary, 1998).

Medak district with a geographical area of 9,519 km², is part of southern plateau and hills climatic region. It lies between longitude of 77°28’ - 79°10’E and latitude of 17° 27’-18° 19’N (Dwarakanath, 2007). The annual rainfall of the district is 803 mm, of which southwest monsoon contributes about 80%. The onset of monsoon usually takes place by 2nd week of June and withdrawal by 2nd week of October. Rice crop in kharif season is mainly dependent on monsoon rains. Occasionally there would be breaks in monsoon, which sometimes causing disastrous consequences to crop failure over a large area.

MATERIALS AND METHODS

Mandal-wise daily rainfall data from 1971 to 2010 for Medak district was obtained from Directorate of Economics and Statistics, Government of Andhra Pradesh, Hyderabad and analyzed using Weathercock v1.0 (Rao et al., 2007) software.

Markov chain probability method makes use of the fact that the atmosphere is persistent in its behavior meaning thereby that the events of the atmosphere are not independent of those, which closely precede them. The probability analysis was carried out following methodology provided by Pandarinath (1990). In the present study, a threshold of 20 and 30 mm per week was considered to demarcate dry weeks. Considering minimum crop water requirement of the crop being 3 mm/day and 4.3 mm/day, thus accumulate to 21 mm and 30 mm per week, respectively in a crop season.
Impact analysis of climate variability on rice productivity in eastern agroclimatic zone of Haryana by using DSSAT crop model

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ABSTRACT

The productivity trends in rice due to climatic variability were simulated using crop simulation modeling approach and the long-term trends of on-farm productivity were compared. The productivity of rice in paddy growing areas of eastern agroclimatic zone of Haryana ranged from 21.0 to 34.0 q ha⁻¹ during the study period (1978-2008). Different synthetic climate scenarios of maximum, minimum temperature and carbon dioxide concentration were used as input in DSSAT (Decision Support System for Agrotechnology Transfer) ver. 4.0.2.0 model to understand the impact of climate variability on rice productivity. Results indicate increment of minimum temperature by 0.5 °C from normal (1977-2008) would have negative impact on simulated rice productivity whereas, up to 1 °C increment of maximum temperature would allow yield enhancement by 3.83 and 3.48% from mean yield in Ambala and Karnal, respectively.

Key words: Climatic variability, rice productivity, DSSAT, Haryana, eastern agroclimatic zone

The variations in the meteorological parameters, in combination with other parameters such as soil characteristics, cultivar, pest and diseases, etc. have paramount influence on agricultural productivity. Crop phenology and economic yield are sensitive to short-term changes in weather as well as to seasonal, annual and longer term variations in climate. However, multiple sources of bias make estimates of climate change impact on rice production uncertain. The magnitude of the bias is estimated to range from 1 to 32 per cent. In India rice accounts for 43% of the total food grain production and is cultivated in 43 mha, which is about 30% of the net cultivated area, the rice production was estimated at 94.08 million tonnes during 2008-09. Rice production of Haryana has dipped to 32.31 lakh tonnes in 2008-09 against, 36.13 lakh tonnes in 2007-08, productivity also plummeted to 27.14 q ha⁻¹ from 33.61 q ha⁻¹ during the year 2007-08 (Anonymous, 2008).

For almost two decades now, application of knowledge based systems approach in agricultural management is in vogue, and it involves the dynamic simulation modeling of crop growth and development. After proper validation, the models are capable of predicting the crop growth response to different environments that may result from either adoption of different management strategies or climatic variations and can be applied in testing and evaluation of various alternative management options which can be adopted under different situations. The impact of climatic variability on yield of crops is generally studied by simulation approach, which has been employed by a number of researchers in different parts of the world for a number of crops (Peart et al., 1989; Abraha and Savage, 2006; Mall et al., 2004; Tubiello and Ewert, 2002; Peng et al., 2004). The literature reveals that amongst the various crop simulation models studied the DSSAT (Decision Support System for Agrotechnology Transfer) has been found to be best suited for crop-climate interaction studies for its versatility and simplicity (Tsuji et al., 1994).

The model requires daily weather data of maximum and minimum air temperature, radiation and rainfall to simulate crop yield. To estimate the likely impact of climatic variability on agriculture, it is necessary to obtain quantitative representation of the variation of climate. Climatic variability is created by change in one variable at a time and its effect on the crop yield is assessed with the dynamic simulation.

MATERIALS AND METHODS

Present investigation has been carried out for major rice growing region in the Eastern agroclimatic zone of Haryana with representative locations being Karnal and Ambula (29°43’ N, 76°58’ E. 245 MSL and 29°59’ N, 76°81’ E 276 MSL). Crop management data (as per package of practices for rice in Eastern agroclimatic zone by Department of Agriculture, Haryana) included the information on planting date, planting density, row spacing, planting depth, irrigation applications and fertilizer recommendations. Daily weather data from 1977 to 2008 were collected from Central Soil Salinity Research Institute and India Meteorological Department for Karnal and Ambala, respectively. Actual average rice grain yield during 1977 to 2008 were collected

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Influence of weather variables on phenology and productivity of 
Bt and N Bt cotton in rainfed vertisols

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ABSTRACT
A field experiment was conducted during two consecutive years 2009-10 and 2010-11 at Regional Agricultural Research Station, Lam, Guntur with 10 cotton entries (JK 99Bt, MRC 7301Bt, MRC 6301Bt, MRC 7326Bt and MRC 7351Bt and their non Bt (N Bt) versions) in a randomized block design to study the effect of weather variables on phenology, growth, development and productivity of Bt and N Bt cotton. Bt cotton hybrid could complete its growth period within short span of time compared to non Bt by efficient utilization of rainfall. Plant height of Bt and N Bt has showed a strong positive correlation with total rainfall, minimum temperature and growing degree days and negative correlation with sunshine hours during all the growth stages. Plant height had a negative correlation with maximum temperature during flowering to boll formation in N Bt, whereas negative correlation was noticed during boll formation to boll bursting stage in Bt. All the weather parameters except sunshine hours during sowing to flowering have shown a strong positive correlation with seed cotton yield and harvest index in Bt and N Bt cottons. Maximum temperature during flowering to boll formation stage showed negative correlation and during boll bursting to final harvest showed positive correlation both in Bt and N Bt, maximum temperature during boll formation to boll development has shown a negative correlation with seed cotton yield in non Bt and positive correlation in Bt cotton. The physiological parameters viz; total dry matter production and crop growth rates in flowering to boll formation stage, boll formation to boll stages of plant growth showed a strong positive correlation with sunshine hours in both Bt and N Bt cottons. From the experiment, it is revealed that the Bt cotton requires low but well distributed rainfall compared to N Bt cotton which is needed under rainfed conditions.

Key words : Bt and N Bt cotton, CGR, TDM, weather parameters, seed cotton yield

Cotton is the world’s most important fibre crop and the second most important oil seed crop. The primary product of the cotton plant is the lint that covers the seeds within the seed pod or boll. The lint has been used for thousands of years for clothing the people. The cotton seeds, the primary byproduct of lint production are an important source of oil for human consumption, and a high protein meal used as livestock feed. The waste after ginning is used as fertilizer, and the cellulose from the stalk can be used for products such as paper and card board. Cotton is the most important crop extensively cultivated under rainfed conditions. With the introduction of Bt (Bacillus thuringiensis) cotton in India, its area continues to grow from a mere 50,000 ha in 2002 (when Bt cotton was first commercialized) to 8.4 million ha in 2009 representing an unprecedented 168 fold increase in eight years (Choudary and Gaur, 2010). In Andhra Pradesh, cotton is cultivated under subtropical climate conditions in vertisols, red sandy loams and sandy loams mostly under rainfed conditions. The realization of the potential capacity of the crop (partitioning assimilates efficiently to harvest organs) is determined by the weather variables prevailed during the growth and development. Cotton requires air temperature of 15 °C for germination, 21-27 °C for vegetative growth and 27-32 °C during the fruiting period. Mauney (1986) stated that all the process leading to the square, blossom, boll formation and maturation are temperature dependent. Cool nights are beneficial during the fruiting period. But extreme temperatures (low or high) can result in delayed growth and aborted fruiting sites. Gipson and Joham (1967 a, b and c) documented that suboptimal temperatures retarded growth and fibre development. For water not to be a limiting factor on yield, cotton needs between 550 mm and 950 mm during the season in a consistent and regular pattern (Doorenbos et al., 1984). Untimely rainfall and/or irrigation as well as humid weather during later stages of crop growth, primarily once the bolls begin to open may complicate defoliation, reduce yield and quality, lowers the cotton ginning properties (Freeland et al., 2002) or promote the attack of insect pests and disease organisms, such as boll rot (Boyd et al., 2004). Keeping all the points in view, an attempt was made to study the effect of different weather variables on the productivity of Bt vs N Bt hybrids in vertisols of Guntur district under rainfed conditions.
Assessment on the reduction of Green House Gas (GHG) emission by nitrification inhibitor under intensive rice system of Cauvery Delta Zone (CDZ)

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ABSTRACT

This investigation was carried out to evaluate the potential of Dicyandiamide (DCD), a nitrification inhibitor for minimizing N2O emission from paddy soil representing Cauvery Delta, a major rice growing region in Tamil Nadu. Measurement of N2O efflux was carried out from soils integrating different approaches of N application with DCD as N inhibitor. All the treatments have recorded the maximum N2O efflux on the second day following the fertilizer application. The mean emission recorded on the 0th day was 0.71 mg/m2/day which subsequently increased to 1.83 mg/m2/day on the first day, reached a maximum on second day (2.78 mg/m2/day) and decreased to 1.40 mg/m2/day on the third day. Thus a marked temporal variation pattern in N2O efflux in tune with the depletion of the substrate was noticed. Among the treatments, Leaf Colour Chart (LCC) based N (@30 kg N/ha keeping the LCC value 4 as standard) + DCD @ 10 % of applied N followed by Site Specific Nutrient Management (SSNM) based N with fixed split approach {35 % N at 15 Days After Transplanting (DAT), 40 % N at 30 DAT, 25 % at 45 DAT} with use of LCC at each stage + DCD @ 10 % of applied N recorded lower mean emissions of 0.46 mg/m2/day and 0.61 mg/m2/day, respectively. The maximum emission was recorded as 5.14 mg/m2/day under the treatment comprising early completion of N application (25 % basal 50 % at 20 DAT and 25 % at 40 DAT). Among the stages the flowering stage recorded mean maximum emission of 2.12 mg/m2/day of N2O and the mean seasonal emission was estimated as 0.16 kg ha⁻¹.

Key words: Nitrogen fertilizer, nitrous oxide, paddy soils, dicyandiamide

Nitrous oxide (N₂O) is a trace gas responsible for global warming and depletion of O₃ in the stratosphere. It accounts for 5% of the total greenhouse effect and 250 times more effective than CO₂ on molecule-to-molecule basis in absorbing infrared radiation with its atmospheric lifetime of 150 years (Robertson, 1993). It indicates that it neither reacts with the atmospheric chemicals nor precipitated by the moisture in the atmosphere and moves uninterrupted to the stratosphere to damage O₃ layer, indirectly through NO formation (Houghton, 1994). As with many greenhouse gases, the atmospheric concentration of N₂O has increased from about 285 ppbv (Khalil and Rasmussen, 1988) in the pre-industrial era to about 310 ppbv in 1996 (Khalil, 1999). N₂O is biologically produced during the cycling of nitrogen in the ecosystem. Soil is reckoned to be a major source of atmospheric N₂O (Bouwman, 1990). Application of N fertilizers increases N₂O emissions (Bronson et al., 1992). Emissions of N₂O from N-fertilized croplands vary considerably, ranging between 0.001% and 6.8% of applied N (Bouwman, 1990; Eichner, 1990). From the agricultural soils, nitrification and denitrification are the two processes responsible for formation of N₂O. In both these processes, nitrite (NO₂⁻) is formed as an intermediate compound. During the process of nitrification, NH₄⁺, in aerobic condition, gets oxidized to NO₃⁻ via hydroxylamine and nitrite, releasing N₂O as a byproduct, while in denitrification, the NO₃⁻ gets completely reduced to N₂, evolving N₂O as an intermediate product. Therefore, the end product of nitrification works as substrate for denitrification. Hence, controlling the first process will certainly help in regulation of second process to some extent. Nitrification inhibitors are compounds that reduce the rate at which ammonium is converted to nitrate either by killing or interfering with the metabolism of nitrifying bacteria. Dicyandiamide (DCD) is one of the most widely used bacterio-static nitrification inhibitors in the agriculture (Zacherl and Amberger, 1990) and decomposes in soil to non-toxic products. Effect of DCD on N₂O emissions has been reported by Klein et al. (1996) in grass land, Mosier et al. (1996) in wheat and maize and McTaggart et al. (1997) in ryegrass, grassland and spring barley. The present study was undertaken to observe the effect of DCD on N₂O efflux from irrigated rice soils of Cauvery Delta Zone to assess its suitability for decreasing N₂O emission to the atmosphere.

MATERIALS AND METHODS

This investigation was carried out to assess the role of dicyandiamide (DCD) along with different nitrogen management practices on the emission of N₂O from agricultural soils. A field experiment was conducted at Tamil Nadu Rice Research Institute, Aduthurai during 2010 to 2012
Discrimination of wheat crop using remote sensing in Tarai region of Uttarakhand

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ABSTRACT

A peak vegetation cover based strategy was developed for discrimination of wheat (Triticum aestivum L.) crop using remote sensing at Pantnagar. A year (2008-2009) having maximum number of cloud free remote sensing images was selected and the field boundary of wheat crop having good crop cover was digitized to generate the spectral library. Crops were discriminated by using both ground truth data and spectral properties. For generating crop growth profile, the plots of the respective crops were selected by overlaying the digitized boundaries. Spectral profile was recorded and analyzed for wheat crop and it was found that with increasing vegetation cover, the reflectance in NIR band increases, reaching to a maximum level at peak vegetation (60-70 days after sowing) stage of the crop. The LANDSAT-ETM image of the 27th January 2009 was used to demonstrate the capability of remote sensing to discriminate the crop from other spatial features. During this time of the year the crops of sugarcane and lahi/mustard are generally harvested and wheat enters the peak vegetation stage in Pantnagar and surrounding region. The confusion matrix for all the classes was prepared for accuracy assessment. Results showed that wheat is always different from other categories with 100 per cent accuracy.

Key words: Supervised classification, weather parameters, LANDSAT-ETM images, ENVI-4.8.

Crop identification and crop yield estimates can be done as early as possible during the agricultural season, which is quite helpful for supporting agricultural policies. The use of remote sensing imagery for mapping, assessing and monitoring of agricultural crop conditions and production has been steadily increasing in recent years. Advances in the spatial, spectral and temporal resolution of remote sensing (Johannsen et al., 1998) as well as potential positive changes in cost (remote sensing images of various resolutions are available free of cost) and availability of remotely sensed data may make it a profitable tool for more farmers. The remarkable development in space borne remote sensing technology and its application during the last three decades have firmly established immense potential for mapping and monitoring of various natural resources. Data from remote sensing satellites are used for various applications of resources survey and management under the National Natural Resources Management System (NNRMS). The first multi-spectral airborne study in the country was conducted during 1969 jointly by Indian Space Research Organization (ISRO) and Indian Council of Agricultural Research (ICAR) for identification of root-wilt disease in coconut using aerial false color, photograph over Kerala (Dakshinamurti et al., 1971). Since then there have been many investigations carried out on various aspects of crop identification and area estimation using air-borne to space borne sensors for different crops and agricultural regions in India.

Monitoring of crop conditions is most important for agricultural development. The use of remote sensing has proved to be very important in monitoring the growth of agricultural crops and their yield estimation. Crop discrimination and yield forecasting are just two examples of how satellites can be of great value for agriculture. Remote sensing technology has been increasingly considered for standardized and possibly cheaper and faster methodology for crop discrimination surveys (Bauman, 1992). The crop discrimination/mapping using space data is carried out either by visual or digital interpretation techniques. Visual techniques generally are based on standard FCC (False Color Composite) generated using green, red and near infrared bands assigned blue, green and red colors respectively. The digital techniques are applied to each pixel and use full dynamic range of observations and are preferred for crop discrimination. A multi-temporal approach is used when single date data does not permit accurate crop discrimination.

Early studies using space borne data employed visual mapping of crops such as wheat (Munshi, 1982) and rice (Rao and Rao, 1987; Singh, 1983). The nature and amount of electromagnetic radiation reflected, absorbed or transmitted from a leaf depend on the wavelength of radiation, angle of incidence, surface roughness and the differences in the optical properties and biochemical content of the leaves (Kumar et al., 2001). Remote sensing is largely concerned with measurement of surface reflectance of energy from the
Assessment of nitrogen status of castor using remote sensing techniques

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ABSTRACT

Field studies were conducted with an objective to assess the leaf nitrogen status based on spectral relationship in castor crop, Nalgonda district, Andhra Pradesh for better nitrogen management. Study locations (n=20) were selected based on cropping intensity and leaf samples were collected at different growth periods for nitrogen analysis. Satellite data (IRS P6 - LISS III) were obtained corresponding to vegetative and reproductive stages of crop growth. Digital data obtained was processed using ERDAS imagine image processing software. Normalized Difference Vegetation Index (NDVI) values were extracted from 20 different locations under study. Results revealed that nitrogen content was high at vegetative phase (2.40 to 3.86%) and gradually decreased with crop advancement and ranged between 2.50 to 3.61% at reproductive stage. NDVI values ranged from 0.012 to 0.296 (vegetative stage) and 0.211 to 0.584 (reproductive stage). NDVI derived from satellite data was correlated with castor yield and leaf nitrogen percent at different crop growth stages. Positive and significant linear correlation existed between leaf nitrogen at vegetative phase versus castor yield ($R^2=0.74$) and satellite derived NDVI ($R^2=0.79$). Results indicated that nitrogen status of castor can be assessed and effectively monitored during crop period for nitrogen management using remote sensing techniques.

Key words : Remote sensing, NDVI, satellite data, leaf nitrogen, castor

Nitrogen management practices under field conditions include soil test based nitrogen recommendation, tissue analysis based nitrogen management, site specific real time nitrogen management using leaf colour charts and SPAD chlorophyll meters. However, these are all specific to the given field and only point information is generated. The objective of nitrogen management is to adjust the amount of nitrogen to the varying yield potential of sub-areas of fields so as to optimize yield, farmer’s profit, and Nitrogen Use Efficiency (NUE). Therefore, nitrogenous fertilizers need to be applied in optimum quantities to achieve the highest possible crop yield without leading to serious environmental effects. Since existing methods of soil and plant analysis are costly and time consuming (Peoples et al., 1995 and Oertli, 1980), focus is shifting towards approaches using remote sensing technologies.

Remote sensing techniques have a unique capability of recording data in visible as well as invisible (i.e., reflected infrared, thermal infrared and microwave etc.) parts of electromagnetic spectrum, where the spectral characteristics of plants are good indicators of their health and nitrogen content in the tissues (Blackmer et al., 1996a). Chlorophyll is the most important factor affecting reflectance in the visible spectrum (VIS) of most field crops, but it has no influence on the reflection properties in the near infrared (NIR). Several mathematical combinations of spectral information have been found to be good descriptors of N taken up and chlorophyll concentration. Remote sensing is a valuable tool in the evaluation of plant nitrogen status and is of great interest in agricultural communities because nitrogen stress is often an important limitation of crop productivity. Thus, accurate spectral characterization at both leaf and canopy levels would allow improved optical determination of nitrogen deficiency (Filella et al., 1995 and Botha, 2001). Physiological changes resulting from nitrogen limitations can be translated into clear spectral differences between treatments, thus demonstrating the relationship among leaf reflectance and leaf chlorophyll and nitrogen concentrations (Botha, 2001). The Normalized Difference Vegetation Index (NDVI) is highly correlated with nitrogen uptake. The NDVI has been used as a powerful tool in crop nutrient (Nitrogen) monitoring in crop production. Several studies have been made to use real-time sensor based spectral measurements to derive nitrogen fertilizer requirements of crops (Blackmer et al., 1996b).

Castor is an important non-edible oil seed crop and India accounts for about 57.7% of the global castor area (1.52 m ha) and 71% (1.58 m t) of the total castor production (FAO, 2010). It is mainly raised under rainfed conditions characterized by nutrient poor marginal soils particularly low in nitrogen. It is a relatively long duration crop and requires efficient nitrogen management strategies. A considerable research effort has been devoted to detecting crop nitrogen stress using remote sensing. In general, different levels of nitrogen stress can be easily detected in aerial images (Beatty et al., 2000).
The latest developments and advancements in the information and communication technologies, rainfed agriculture is subjected to the vagaries of the monsoon, and the production is limited by the fluctuations in the weather parameters like temperature, rainfall, relative humidity, wind speed. Dryland agriculture is especially affected by this. Timely information at the proper time will provide the necessary inputs to the farmers for the effective management of risk associated in maintaining profitable agriculture on sustainable basis in the case of extreme weather events. It will also help in conservation of natural resources and environment (Ramakrishna et al., 2008). The ability of the farmers to make decisions and planning about choice of crops, technologies is often limited by the non availability of customised weather information. Hence, information on weather is helpful to farmers in organizing the activities of farm operations and management of the resources available to them effectively and thereby minimizing the losses due to weather fluctuations. Anurag et al. (2012) stated that the advancements in ICT can be utilized for providing accurate, timely, relevant information and services to farmers, thereby facilitating an environment for more remunerative agriculture.

Weather based agro-advisories disseminate needful information to manage the weather sensitive crop operations before and during the crop season, harvest and post harves which also becomes a part of risk management for weather aberrations. It also prepares the farmer to adapt to weather variability and climate change. Rajireddy et al. (2013) expressed the difficulty for extension specialists to deal with the climate uncertainty and variability and to make to inform the farming community on the selection of best options through agro-advisories on real time basis under the rapid changing climate situations. As the dissemination of weather based information in a timely and cost effective manner is a challenge to traditional extension approaches, use of the modern extension tools like information communication technologies is the need of an hour.

Hence, an attempt was made in this study to deliver the timely and need based location specific weather information through the usage of different channels for reaching the unreached. It is in this context that CRIDA's NAIP project on “Sustainable rural livelihoods through enhanced farming systems productivity and efficient support systems in rainfed areas”, which is an action research pilot project in selected village clusters of the 8 backward districts
Climate change and coastal aquaculture in West Godavari District, Andhra Pradesh: Impacts, vulnerability, adaptations and mitigations for resilience

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ABSTRACT

The predictions of climate change during the recent decades viz., consistent warming trends (increase in frequency of hot days and multiple-day heat wave), increase in extreme rains, and more frequent and intense extreme weather events (flood, cyclone and drought) has greater impact on aquaculture. This impact has been disproportionately felt by small-scale farmers who are already amongst the poor and vulnerable members of the society. The present study in West Godavari District of Andhra Pradesh documented the climate change events experienced by aqua farmers in brackishwater and freshwater areas and their perceptions, attitudes, risk management behaviour, adaptive capacities and impacts on aquatic farming systems through focus group discussion (FGD), extensive survey of 120 farmers through standard questionnaires, and stakeholder workshop (SW). Assessment based on consequence and livelihood scores revealed that seasonal variations with 20-40% loss in production was the highest risk in both the areas followed by cyclone in brackishwater and high temperature in freshwater areas. Though not very common in every year, cyclones, the major extreme climatic event results in 50 to 100% loss in production. Among the studied aqua farmers, 14% were highly vulnerable to climate change, whereas 55% were moderately vulnerable. Farmer’s adaptation measures, science and technology solutions and policy adaptation measures are discussed to make aquaculture as climate resilient.

Key words: Coastal aquaculture, climate change, vulnerability, adaptation, Andhra Pradesh

The impact of climate change (CC) is likely to have serious influence on agriculture, fisheries, and aquaculture sectors and eventually on the food security and livelihoods of a large section of the rural population in developing countries (IPCC, 2007). The Stern Review on Economics of CC concluded that ‘climate change threatens the basic elements of life for people around the world, access to water, food production, health, and use of land and the environment’ (Stern, 2007). In this context, the availability and access to fish supplies will become an increasingly critical issue as a source of quality protein, particularly to rural populations in the developing world, of which food fish accounts for over 40 per cent of the animal protein intake.

Aquaculture is known to be impacted by many facets of climate change, such as temperature, precipitation, drought, storms/floods, sea level rise (De Silva and Soto, 2009; Ponniah and Muralidhar, 2009). There is a trend of increasing surface temperature and decreasing rainfall on the Indian subcontinent (Singh and Sontakke, 2002). Annual mean temperature over the Indian subcontinent could increase in the range between 3.5 and 5.5°C by 2080 (Lal et al., 2001). All these studies show that India could experience warmer and wetter conditions as a result of climate change including an increase in the frequency and intensity of heavy rains and extreme climatic events. Impacts of CC on the fisheries sector in India (Sugunan and Maurye, 2003), as well as globally (Cochrane et al., 2009; De Silva and Soto, 2009), in spite of its economic value as well as a means of livelihoods, have not got the attention that it deserves. Hence, a study was carried to increase our understanding on CC events, impacts and risks perceived by shrimp farmers and their vulnerability, and formulate appropriate strategies to increase the adaptive capacity of the farmers.

MATERIALS AND METHODS

Study area

Andhra Pradesh (AP) contributes more than half of the country’s shrimp production and has been in the forefront since the beginning of shrimp farming in the early 1980s. West Godavari District in AP (Area -7742 km²; latitude and longitude -17°N and 81.17°E) was identified to carry out the present study in 2011 due to (i) designated by Planning Commission of the country as one of the hundred districts vulnerable to climate change (ii) shrimp farming is being practiced in larger area including both summer and winter crops in brackish and freshwater areas compared to other districts in the state.
Suitability of cashew growing areas in India – an appraisal using GIS

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ABSTRACT

An analysis has been carried out to determine the suitability of cashew growing areas in India using Arc GIS. Suitable areas for cashew (Anacardium Occidentale L) were determined using a multi-criteria evaluation approach based on the crop requirements, climatic conditions and characteristics of the land. It was found that cashew growing area lies along loamy red and lateritic soil, mixed red and black soil, coastal and deltaic alluvium derived soil. The textures of the soils in high productivity areas were found as loam, sandy loam, silty loam and coastal sand. The elevation of the cashew growing areas ranged from 0 to 1000 m above mean sea level (MSL) and the productivity of cashew was higher in regions upto 750 m above MSL. Mean annual rainfall in cashew area ranged from low (300-600 mm in Gujarat) to high rainfall (2700 to 3500 mm along West coast and NEH region). The productivity was highest in Maharashtra region with annual rainfall of 600 to 1500 mm and next to that, portions of Andhra Pradesh, Orissa and West Bengal with a rainfall of 600 to 1800 mm. The overlay maps showed that the mean annual temperature in cashew growing areas ranged from 20 to even more than 27.5 °C whereas, the productivity was higher in regions with 22.5 to 27.5 °C. Minimum and maximum temperature in suitable area ranged from 10 to 22 °C and 32 to 40.1 °C, respectively. The productivity of cashew was lower in regions where the minimum temperature drops below 10 °C.

Key words: Cashew, GIS, cashew growing regions, suitability

Cashew (Anacardium Occidentale L), is one of the highest foreign exchange earning perennial horticultural crop in India. Annually, India exports more than 1.1 lakh tonnes of cashew kernels and earns about Rs. 2900 crores as foreign exchange. Even though India needs 12-13 lakh tonnes of raw cashew nuts to feed the cashew processing industries, only 6.95 lakh tonnes from 8.93 lakh hectare are produced and the balance is imported from Africa and other nations (Bhat, 2010). The current productivity of cashew in the country is as low as 0.72 t ha⁻¹ against the target of 2.0 tonnes ha⁻¹ year⁻¹. In order to increase the productivity of cashew in India, replacing senile/seedling originated cashew gardens with improved varieties, adoption of proper management practices and identifying most suitable areas for its growth are very important. Most of the area under cashew falls in Maharashtra, Goa and Karnataka along the west coast, and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the east coast (Rupa et al., 2012).

Cashew is now fast spreading even in non-traditional areas such as Gujarat, Jharkhand, North Eastern Hilly (NEH) Region, Andaman & Nicobar Islands, Bastar region of Chhattisgarh and Kolar (Plains) region of Karnataka. While selecting any new area, land suitability and climate play an important role in achieving sustainable production. Cashew comes up well even in steep slopes with proper soil and water conservation followed by manure application and pest management (Rejani and Yadukumar, 2010; Rejani and Yadukumar, 2012). Cashew is generally grown as rainfed crop along neglected lands unsuitable for other crops. With climate change there may be variation in yields, flowering, fruit setting, nut development, kernel quality, diseases and water stress.

The mean annual temperature for the country as a whole has risen by 0.56 °C during 1901-2009. Since 1990, the minimum temperature is steadily rising and rate of its rise is slightly more than that of maximum temperature (IMD Annual Climate Summary, 2009). Cashew requires a mild humid tropical climate. The variation in relative humidity during pre-flowering period influences the yield of cashew (Haldankar et al., 2003). The humidity of suitable region ranged from 60-80% (Nair, 1979). A well distributed rainfall during growing and pre-flowering phase (from September to November) favours higher productivity (Venugopal and Khader, 1991). Any unusual rains during November and December inordinately delay the reproductive phase of late-season varieties (Rao, 1994; Rao, 1999). Prolonged and unseasonal rainfall accompanied with high velocity wind during flushing and flowering period of cashew adversely affect the yield (Yadukumar et al., 2010). The flowering of cashew requires low minimum surface air temperature ranged from 16 to 20 °C with more dew nights and moderate dew in humid climates. It requires bright sunshine (>9 h day⁻¹),
Phenology, thermal time and phasic development of pigeonpea
(*Cajanus cajan* L. Millisp.) grown under intercropping system

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ABSTRACT

A field experiment was conducted during kharif/rabi seasons of 2010-11 and 2011-12 on deep black soil under rainfed condition at the Main Agricultural Research Station, Dharwad, on intercropping of pigeonpea with maize in 1:2, 2:2 and 2:4 row ratio and pigeonpea sole stand with four dates of sowing namely, June first fortnight, June second fortnight, July first fortnight and July second fortnight. Sixteen treatment combinations were laid out in a Randomized Complete Block Design with factorial concept and replicated thrice. The results indicated that pigeonpea cv. Asha matured between 195 to 225 days in 2010-11 and 174 to 209 days in 2011-12 depending on sowing dates and 208-221 and 182-200 days under different cropping systems. The thermal time required to attain different phenophases were worked out and a linear regression model based on the phenophase-wise data was derived for predicting the onset of a particular crop phenophase. The results revealed that thermal units accumulated to reach physiological maturity ranged from 2528 to 2980 °C days in the year 2010-11, while in 2011-12, it ranged from 2300 to 2816 °C days under different sowing dates. Whereas, among the different intercropping systems it ranged from 2734 to 2887 °C days and 2438 to 2653 °C days in the year 2010-11 and 2011-12, respectively. The linear model indicated that GDD accounted for 95-98 per cent variation in the onset of different phenophases under different cropping systems. The deviations between actual and predicted days for each phenophase from emergence to 50 per cent podding was comparatively small (-2 to -10 days) as compared to later phenophases i.e. from 50 per cent podding to physiological maturity (-9 to -15 days) in different treatments.

Key words: Pigeonpea, phenology, planting date, growing degree days

Phenology is the study of timing of recurring of natural phenomena, especially in relation to climatic condition. The term phenology has been derived from the Greek word “phaino” meaning to ‘show’ or to ‘appear’. Temperature is an important environmental factor influencing the growth and development of crop plants. Phenology is an essential component of the crop growth model, which can be used to specify the most appropriate rate and time of specific developmental process. Increasing appreciation has been shown in recent years for predicting crop development under field conditions. The duration of each growth phase determines the accumulation and partitioning of dry matter into different organs as well as crop response to environmental and external factors. The duration of particular stage of growth is directly related to temperature and this duration for particular species could be predicted using the sum of daily air temperature.

Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Chakravarty and Sastry 1983 and Bishnoi et al., 1995). Plants have a definite temperature requirement before they attain certain phenological stages. To forecast the phenology and crop production attributes for large areas, there is need to develop crop model (Doraiswamy and Thompson, 1982). The heat unit system was adopted for determining the maturity dates of different crops (Bierhuizen, 1973). In a view of potential significance of phenological studies on crop-weather interactions, a field experiment on pigeonpea was planned to develop a thermal time based model.

MATERIALS AND METHODS

The experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, during kharif/rabi seasons of 2010-11 and 2011-12 under rainfed condition. The geographical coordinates of Dharwad are 15° 26’ N latitude and 75° 7’ E longitude with an altitude of 678 m above MSL. The soil of experimental plot was clayey having pH 7.5 with low in available nitrogen content (223.8 kg N ha⁻¹) medium in available phosphorous (31.6 kg P₂O₅ ha⁻¹) and high in available potassium (332.3 kg K₂O ha⁻¹). The experiment consists of four dates of sowing D₁: June I fortnight, D₂: June II fortnight, D₃: July I fortnight and D₄: July II fortnight; and four cropping systems C₁: maize + pigeonpea 2:1, C₂: maize + pigeonpea 2:2 and C₃: maize + pigeonpea 4:2 row ratio along with sole pigeonpea (C₄). The
Effect of weather and growth stage of crop on Alternaria leaf spot development and progress in safflower (Carthamus tinctorius L.)

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ABSTRACT

Alternaria leaf spot is a major and destructive fungal disease of safflower (Carthamus tinctorius L.) which infects leaves, stem, head and seed. An experiment was carried out during post rainy seasons of 2006-07 to 2010-11, to study the effect of weather factors along with a crop phenological factor i.e. crop age on Alternaria leaf spot disease development and progress at Agricultural Research Station (ARS), Tandur. Weather data were collected from the Automatic Weather Station located at ARS, Tandur. The studies revealed that per cent disease index (PDI) progressed at a linear rate throughout the plant growth and it was negatively correlated with maximum temperature, relative humidity (I & II) and positively correlated with minimum temperature and crop factor i.e. the age of the crop. The weather conditions during 38 to 43 meteorological weeks (MW) were observed to be most congenial for the crop infection and further rapid build-up of the disease. Receipt of rains coupled with high humidity above 90% and temperature in the range of 23 to 30°C favoured the primary infection of the crop and rapid progress occurred as the plant matures. By employing a step down linear regression technique, based on preceding one week averages, the incidence of Alternaria leaf spot on safflower could be predicted with an accuracy of 85 % to 91 % under different sowing conditions.

Key words: Safflower, Alternaria leaf spot, correlation, environmental factors, crop age, PDI

The leaf spot disease caused by Alternaria carthami is a major and destructive disease of safflower (Carthamus tinctorius L.) grown in India. The disease is endemic in most of the safflower growing areas of Southern Telangana Zone of Andhra Pradesh. The pathogen infects leaves, stem, head, seed and causes severe seed yield loss and also deterioration in the quality of the seed. Under severe infection, the disease has been reported to cause 50 per cent loss in seed yield (Indi et al., 1986). Weather conditions play a predominant role in determining the cause and severity of epidemics. Along with the weather factors, age of the crop also contributes to the disease incidence and spread significantly (Ojiambo et al., 1999). Hence, an attempt was made to study the role of different weather parameters viz., rainfall, relative humidity and temperature along with the crop age on infection and development of Alternaria leaf spot and secondly to develop forecasting models for predicting disease incidence in advance.

MATERIALS AND METHODS

A field experiment was conducted for five consecutive years from 2006-07 to 2010-11 during post-rainy seasons on medium black soil with three sowing dates. The cultivar Manjira was sown in three plots measuring 100 m² each at 15 to 20 days interval i.e. second fortnight of August (early), first fortnight of September (normal) and first or second fortnight of October (late). The crop was fertilized at the rate of 50 kg N and 25 kg P₂O₅ hectare⁻¹ at the time of sowing. Recommended agronomic practices were followed as per the crop requirement. The crop was protected against aphids by spraying Dimethoate 30 EC at the rate of 0.05 %, twice during the crop growth. Twenty plants each from early, normal and late sown crop were tagged and scored for the Alternaria leaf spot disease at four days interval using 0-9 scale (DOR, 2011). The details of scales are as shown below.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No symptoms on leaf.</td>
</tr>
<tr>
<td>1</td>
<td>Small brown spots covering &gt;1% or less of the leaf area.</td>
</tr>
<tr>
<td>3</td>
<td>Lesions small, scattered, brown to black with concentric rings covering 1-10% of the leaf area.</td>
</tr>
<tr>
<td>5</td>
<td>11-25% leaf area affected.</td>
</tr>
<tr>
<td>7</td>
<td>26-50 % of leaf area affected with lesions enlarging, slightly sunken in the center with concentric rings.</td>
</tr>
<tr>
<td>9</td>
<td>Lesions enlarging up to 10 mm coalescing to form bigger patches covering &gt;50% area.</td>
</tr>
</tbody>
</table>

The per cent disease intensity (PDI) was calculated by using the formula given by Mayee and Datar (1986).

\[ PDI = \frac{(\text{Sum of individual rating})}{(\text{No. of leaves examined} \times \text{Maximum disease grade})} \times 100 \]
Management of intermittent droughts through on-farm generation of organic matter: Participatory experiences from rainfed tribal districts of Andhra Pradesh

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ABSTRACT

Soil organic matter (SOM) content and composition affect both soil structure and adsorption properties; therefore, water retention is affected by SOM. Low and erratic rainfall, intermittent droughts, high temperature, degraded soils with low profile moisture storage limit crop productivity in rainfed drylands. Present study examines the effect of increase of soil organic carbon (SOC) on improvement in water retention in soil profile; thereby crops could be protected from intermittent droughts from moisture stress in degraded soils. Such improvements in SOC were attempted through on-farm generation with crop management interventions implemented in 54 villages in eight rainfed tribal districts of Andhra Pradesh. These strategies are crop residue recycling, farm yard manure (FYM) additions, inclusion of legumes in the system, legume cover crops, growing green manure crops (dhaincha, sunhemp), green leaf manures (gliricidia), composting, vermicomposting and tank silt application. Crop residues of rainfed crops such as cotton, castor, pigeonpea, maize etc were chopped and left on the surface of soil to act as a mulch-cum-manuring. SOC improvement in farmer’s fields registered with continuous carbon management practices, resulted in increase available soil moisture retention by 2-3 per cent in the soil. Thus, improved SOC mediated in higher water retention.

Key words: Intermittent droughts, soil moisture storage, soil organic carbon, on-farm generation, rainfed tribal districts

Major part of the country’s rainfed agriculture is fed by the southwest monsoon. Hence, its onset, continuity, intensity and withdrawal patterns have a tremendous influence on the agricultural production. High intensity rains produce volumes of water beyond the intake capacity of the soil and may leave the soil dry at lower depths. Intermittent long dry spells affect rainfed crops adversely, even in areas with moderate to high rainfall. Drylands farmers have very less option for irrigation/life saving irrigation due to scarcity of water. Soil profile recharge through conservation practices or improvement of available water content through increase in soil organic carbon (SOC) are few alternatives to the farmers to cope up with intermittent drought and increasing the production with better water nutrient synergy.

SOC is a function of organic matter inputs (residues and roots) and litter decomposition. Composition and decomposition rate of SOC influences the soil structure and porosity; the water infiltration rate and moisture holding capacity of soils; the diversity and biological activity of soil organisms; and plant nutrient availability. Many common agricultural practices, especially ploughing, disc-tillage and vegetation burning, accelerate the decomposition of SOM and results in leaving the soil susceptible to wind and water erosion (FAO, 2005). However, recommended management practices (RMPs) that enhance soil health and allow sustained agricultural productivity need to be promoted (Srinivasarao et al., 2011a).

MATERIALS AND METHODS

In some villages, community nursery of gliricidia (Gliricidia sepium) was taken under shade net facility provided under National Agricultural Innovation Project (NAIP) led by Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad. Training was also given on propagation of gliricidia through stem cuttings. Initially about 120 farmers were trained in on-farm generation of gliricidia leaf manuring in terms of selecting good seed material, soaking, filling of polythene bags with soil and vermicompost, sowing the seed, planting of seedlings. Planting was taken up on the field boundaries, common lands, around water harvesting ponds and also as live fencing. Gliricidia plantations were initiated on the field boundaries of cotton-pigeonpea (Adilabad, Andhra Pradesh), groundnut and chickpea (Anantapur, Andhra Pradesh). One year after planting, harvesting was done by lopping the plants at 75 cm to 1 m above the ground. For good management, plants were...
Impact of temperature variability on physiological, hematological and biochemical profile of growing and adult Murrah buffaloes

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ABSTRACT

Temperature variability impact on physiological, hematological and biochemical profile of growing (n= 6) and adult Murrah buffaloes (n= 6) were studied during hot humid (32.0±0.3 °C and RH 86.3%), winter (11.0±0.3 °C and RH 85.0%), thermo neutral (23.0±0.5 °C and RH 45.0%) and summer (39.0±0.6 °C and RH 37.7%) seasons. The rectal temperature (RT) and skin temperature (ST) increased significantly (P<0.05) during summer and hot humid season over TN conditions. Hematological parameters viz., packed cell volume (PCV) and hemoglobin (Hb) content were higher during winter over TN conditions and summer season, whereas WBC levels were lower during winter compared to TN conditions. Significantly (P<0.05) higher levels of cortisol was found during summer compared to TN conditions. The plasma enzymes viz; ALT, AST, ALP and LDH increased significantly (P<0.05) during summer compared to TN conditions in both the groups of buffaloes. Physiological and biochemical parameters showed positive correlation (P<0.05), whereas hematological parameters showed negative correlation (P<0.05) with Tmax and temperature humidity index (THI). Results of the present study showed significant deviations in different physiological, hematological and biochemical profile during summer, hot humid and winter season from baseline data (TN conditions). Therefore, these animals need to be protected from extreme thermal stress (summer, hot humid and winter) for sustained productivity.

Key words: Murrah buffalo, physiological, hematological, biochemical profile, temperature

MATERIALS AND METHODS

India has the largest population of buffaloes which constitutes around 54.4% of total world population and contributes substantially to national economy by producing over 59.2 million tones of milk. Buffaloes are homeotherms and can maintain their body temperature within a relatively narrow range. Due to poor heat tolerance capacity of buffaloes, any deviation in ambient temperature from the normal comfortable range may lead to changes in physiological, hematological and biochemical parameters. Changes in physiological parameters due to climatic variability may be helpful to understand the physiological functions of the animals and to design strategies for combating stress and maximizing production. Hematological picture represents the health status of the animals and can be used to evaluate herd health. Reference values are of great importance for the correct interpretation of biochemical data. In animals, a large number of factors such as species, type, sex, age, season, physiological stages such as those in pregnancy and lactation, nutritional and health status can affect blood biochemistry. No systematic information is available on physiological, biochemical and hormonal profile of growing and adult Murrah buffaloes during different variable temperature, hence, the present study was undertaken.

Six each of growing (8-12 months) and adult (>2.5 years) Murrah buffaloes were selected from the National Dairy Research Institute, Karnal herd. All the animals were maintained as per standard feeding and management practices followed at farm. The concentrate mixture was fed @ 1-2 kg/animal/day as per the age and body weight for maintenance. The meteorological parameters viz., dry and wet bulb temperature (°C), relative humidity (%) was recorded between 8.0-9.0 AM in the morning and 2.0-3.0 PM in afternoon during different months. Physiological parameters viz., respiration rate (RR), pulse rate (PR), rectal temperature (RT) and skin temperature (ST) were recorded between 8.0-9.0AM and 2.0-3.0 PM during hot humid (32.0±0.3 °C and RH 86.3%), winter (11.0±0.3 °C and RH 85.0%), thermo neutral (23.0±0.5 °C and RH 45.0%) and summer (39.0±0.6 °C and RH 37.7%) seasons. Blood samples were also collected from both the groups of animals at the similar interval during all the seasons for assessment of hematological parameters viz., haemoglobin (Hb), packed cell volume (PCV), red blood corpuscles (RBC) white blood corpuscles (WBC) and biochemical parameters viz., Aspartate Aminotransferase (AST), Alanine Aminotransferase (ALT), Alkaline Phosphatase (ALP), Lactate dehydrogenase (LDH) activity and Cortisol hormone.
Detecting motion of insects in varied environments using digital image analysis

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ABSTRACT

Motion detection is the process of locating moving object(s) in time, using a camera, for providing artificial intelligence to the machines. Inexpensive camera equipment was used and statistical analysis of optical flow patterns were computed to analyse the behaviour of larva and parasitoid when parasitoid was interacting. The optical flow measures described here did not track individual insect, but characterized the overall movement of whole interaction between insect and parasitoid. This could be important in the development of new ways of assessing and managing insect pest and potentially has wide application to the study of an alternative to other more intrusive or invasive methods. The developed optical flow digital image processing tool helps in understanding the dynamics of insect motion in an image sequence at different environments. This approach of motion analysis provides clear results to demonstrate the interaction of insects and behavior in different conditions and behaviour can be quantified prior to the field trials. This will greatly help in understanding and formulating biological pest control programs and developing an Integrated Pest Control Strategy for different environmental conditions.

Key words : Motion detection, optical flow, abnormal behavior, larva, parasitoid

Motion detection is the process of locating moving object(s) in time, using a camera, for providing artificial intelligence to the machines. Several tasks relate to motion estimation, in which an image sequence is processed to produce an estimate of the velocity at each pixel in the image. This allows pattern analysis to be carried out on video images and so yields quantitative measurements of the observed insects' behavior in different environmental conditions. The movement is then calculated for a small image block, by searching the next image from the sequence for a similar block. The observer can note certain behavior patterns of insects/animals down. But fatigue factor sets in and crucial information may be lost in this mode of recording. For some behaviour, where it may be the only way to detect and record their occurrence, automated observation can provide significant advantages. Automatic video tracking systems enable insect behaviour to be studied in consistent way and over longer time periods than if it is manually recorded. The behaviours are recorded more reliably because the computer algorithm always works in the same way, and the system does not suffer from observer fatigue or drift. While techniques are readily available for static visual patterns and ornaments (Endler, 1990), this is less so with dynamic sequences of visual signals (motion displays) (Zanker and Zeil, 2001). There is now an inexpensive camera/video system for observing and recording animal behaviour, from tiny cameras that can be put onto moving insects to video surveillance that enable constant monitoring of its behaviour. But collecting data is only the first step. Without the ability to sift and analyse the vast quantities of data that can now be collected, the information revolution that the new technology promises is incomplete.

An extensive literature exists on the study of motion as it pertains to neural processing, navigation and the extraction of motion information from visual scenes (reviewed in Barron et al., 1994; Zanker and Zeil, 2001). Such techniques could, in principle, provide extensive information on motion signals. Peters et al. (2002) described powerful techniques for the analysis of visual motion as optical flow patterns in an attempt to demonstrate that signals are conspicuous against background motion noise (Peters and Evans 2003a, b). Damian et al. (2006) build upon these pioneering techniques by making use of these previous algorithms to develop another depiction of visual signals and use these to analyse courtship displays of jumping spiders from the genus Habronattus. In addition, it was showed that optical flow approaches are suitable for quantification and classification by methods equivalent to audio analysis (Cortopassi and Bradbury, 2000). For motion estimation of biological structures from a subcellular, cellular to a supracellular level, optical flow vector fields have become increasingly important (Baaren et al., 2006, Roberts et al., 2010). At this time point we have carried out research work to develop and demonstrate optical flow Digital Image Processing System to find interaction between larva and its
A model based approach for predicting Karnal Bunt disease of wheat under Punjab conditions

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ABSTRACT

Karnal Bunt (KB) of wheat caused by Tilletia indica, infects the developing ovaries and is a disease of importance. It is very difficult to control once infections occur as the popular varieties lack reliable resistance. Bivariate probability density analysis helped to identify the appropriate range of different agrometeorological factors that governed development of KB in the field. Day temperature between 25-30 °C and night time temperature between 10-15 °C showed higher probability density asserting good association with sporidial showering. However, separately, RH morning or evening did not show such good association. But the diurnal range was important as RH morning > 90 % and RH evening between 40 and 60% gave the maximum combined probability density with daily sporidial showering. A predictive regression model for inoculum load (with lowest AIC value of 11.68) was constituted with a adjusted $R^2$ value of 0.885 and could explain maximum variance in the response variable.

Key words: Karnal bunt, predictive model, Punjab, probability analysis

Plant diseases are responsible for at least 10% of crop losses throughout the globe, sometimes threatening our food security. There are certain types of plant diseases very difficult to control if once appear in the field. Karnal Bunt (KB) of wheat caused by Tilletia indica is very difficult to control once infection of wheat ovaries occur. Moreover, it can only be recognized after harvesting of the crop. Records emphasize that the disease was prevalent in the continent since long, infecting native wheat grown over North-eastern parts of India (Gill et al., 1993) but it never caused serious yield reduction. It became a serious yield limiting factor in the early 1970s as a consequence of introduction of dwarf Mexican wheat varieties into India and Pakistan (Swaminathan et al., 1971; Hassan 1973). Gradually it became a non-tariff trade barrier for India. Its consistent occurrence was also reported (Kaur et al., 2005). Most of the commercial HYVs developed in India in the post green revolution era were susceptible to KB (Kaur et al., 2006).

The primary inoculum of Tilletia indica, the thick walled teliospores, is soil borne. They remain dormant during the hot summer and germinate in the last week of September to produce secondary sporidia, which are air borne and infect the developing wheat ovaries. However, secondary sporidia are short lived and are affected adversely when RH reduces to <76% and temperature rises above 24° C. Such condition is common during wheat growing season in Punjab, thus, affects the available load of the infective inoculum, even if the soil inoculum load of the teliospores is adequate. Modelling the relationship of the infective stage of the pathogen in the endemic areas, where telitial inoculum is prevalent in the soil, will help in the effective proactive management of the disease as well as in the judicious use of recommended fungicides. Investigations revealed that congenial weather is responsible for regular incidence of KB year after year (Singh et al., 1990; Nagarajan, 1991; Singh 1993; Sidhartha et al., 1996). The infection gets established when maximum and minimum temperatures are in the range of 19-23° C and 8-10° C, respectively, followed by high humidity and intermittent rains (Joshi et al., 1981). The effects of environmental conditions on the survival and growth of T. indica have also been studied in the laboratory (Smilanick et al., 1989) and several climate models have been developed to simulate meteorological factors suitable for establishment and spread of the disease (Jhorar et al., 1992; Mavi et al., 1992; Kaur et al., 2000). Numerous attempts have also been made to model KB forecasting in Indian conditions (Srinivasan 1980; Jhorar et al., 1992; Mavi et al., 1992; Singh et al., 1996) but all the models could not be validated in Punjab, India (Kaur et al., 2006).

The earlier investigations established that some meteorological factors are regulating endemic occurrence of this disease in Punjab and other wheat growing regions of India. But subsequent failure of the models developed using those findings raised the question of re-investigation into factors of that are actually governing KB. To provide more appropriate prediction for the management of KB in the field,
Thermotolerance of sheep in relation to coat colour

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ABSTRACT

The present investigation was conducted to study the influence of the coat colour on thermal susceptibility of sheep in terms of performance and blood protein level under three different Temperature Humidity Index (THI) conditions between May to July 2012. Plasma total protein, albumin, globulin and creatinine were determined under these conditions at Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture. THI varied at 87.6 ± 0.57 in May, 84.7 ± 0.41 in June and 81.4 ± 0.32 in July. Eighteen male and female sheep of three different breeds in the age group of 9-10 months with average body weight 16.6-17.0 kg, six animals each from Deccani (black color with long coarse carpet wool), Nellore (dark brown color with little wool) and Deccani x Nellore Crossbred (light brown color with long coarse carpet wool) were selected for the study. Immediate indicators of stress (respiratory rate and rectal temperature) varied significantly (p<0.05) in three breeds under different THIs. There was significant variation (p<0.05) in the feed intake of three groups and Deccani sheep was the worst affected. However, body weight change under these extreme circumstances was not significantly differed in three groups. The level of total plasma protein was significantly decreased (p<0.05) with increase in the THI in all the three breeds. However, the plasma protein (g/l) levels declined more in Deccani (8.70 vs. 5.73) followed by crossbred (8.20 vs. 6.02) and Nellore (7.48 vs 6.35). Similarly significant decrease (p<0.05) was observed in plasma albumin and globulin levels in all the three breeds. Serum cortisol and creatinine level was high under hot climatic condition in all the three breeds but no significant difference was observed between the breeds. The results obtained in this study clearly indicated that all three breeds of sheep are thermally stressed during the month of May as compared to July, while dark colored sheep (Deccani) were under more stress compared to the rest. This study suggests a relationship between the coat color and thermotolerance of sheep.

Key words: Temperature-humidity index, stress hormones, small ruminants, plasma protein, heat stress

Ruminants are least tolerant to the heat stress because the ruminal fermentation produces excessive heat in addition to the environmental factors (ambient temperatures, relative humidity, solar radiation and air movement). This excess heat needs to be efficiently dissipated in order to maintain the constant body temperature especially in grazing animals. Increase in solar radiation considerably increases the thermal load on the grazing animals like sheep and goat during the day, particularly in summer. Susceptibility of sheep to heat stress is associated with several factors like species, colour, condition score or finish, temperament, sex, coat thickness and previous exposure to heat stress (Brown Brandl, 2009). Among these, coat colour is very important as it determines (partly) the amount of radiant heat absorbed by the animal’s coat, along with length and condition of its hair. Studies have shown that animals with dark coat colour absorb more solar radiation and therefore are more susceptible to thermal radiation, compared to those with light coat colour (Silva, 1998).

The physiological responses of livestock to heat stress have been well described (Ominski et al., 2002), and include increased body temperature (Bernabucci et al., 1999), increased respiratory rate (Collier et al., 2006), decreased feed intake (West, 1999) and increased water intake (Mader et al., 2006). These responses have detrimental effect on production, reproduction and health in ruminants. Likewise, sheep productivity is also affected adversely by the extreme climatic conditions. Excessive heat stress causes hyperthermia and potentially has several physiological side effects. Thus, present investigation has been carried out to suggest thermotolerant breed of sheep with respect to coat colour.

MATERIALS AND METHODS

Six animals (three male and three female) each from Deccani (Black colour with long coarse carpet wool), Nellore (dark brown colour with little wool) and crossbred (Light brown colour with long coarse carpet wool) of Deccani and Nellore were selected from the herd maintained at Hayathnagar Research Farm, Central Research Institute for Dryland Agriculture (17°27′N latitude and 78°35′E longitude and altitude 515m), Hyderabad. The animals were in the age group of 9-10 months and average body weight was 16.6-17.0 Kg. The experimental animals were maintained as per standard managerial and feeding practices.
Effect of long-term tillage and sources of nitrogen on crop yields of sorghum-sunflower rotation and soil carbon sequestration in rainfed vertisols

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ABSTRACT

Reducing tillage intensity and addition/recycling of organic matter are two important components of conservation agriculture which contributes towards the buildup of soil organic carbon (SOC) but their impact on crop yields and extent of SOC buildup is not known under rainfed conditions in tropical regions. A long-term (10 years) experiment was conducted to study the impact of reduced tillage systems and addition of organic matter on sorghum – sunflower yields and organic carbon buildup. Split-plot design was used, in which the main factor was different tillage systems and sub plots consists of addition of organic matter ranging from 2.5 to 5 t-1 ha-1 year compared with that of farmers’ practice of application of chemical fertilizers. Sorghum yields were higher by 10% in conventional tillage over minimum tillage but the differences were not significant between the three tillage systems. Grain yields of sorghum (14.3 q ha-1) and sunflower (9.1 q ha-1) were highest with 100% recommended dose of fertilizers. Differences in total carbon (TC), inorganic carbon (TIC) and organic carbon (TOC) levels between tillage treatments and organic matter additions after 10 years of cropping were not significant, but higher in comparison to the fallow land use. Improvement in the SOC level in 0 - 20 cm depth ranged from 1.60 to 3.56 Mg C ha-1 due to various tillage treatments and organic matter additions after 10 years resulting in C sequestration rates of 160 to 356 kg C ha-1 yr-1. Reducing the tillage intensity did not have a significant influence on crop yields and application of recommended dose of nitrogen either through organic or chemical fertilizers contributed to carbon sequestration.

Key words: Carbon pools, carbon sequestration, crop yields, organic matter, tillage

Enhancing the soil carbon sequestration has been considered as one of the important strategies for mitigating the threat of global warming and climate change. Improvement in quality and quantity of the SOC can also contribute towards improvement in crop productivity, reduces the erosion besides favorably influencing several other soil processes such as water availability, soil tilth, nutrient availability, microbial activity, etc. which are critical for stabilizing the productivity of rainfed systems. There is a need to increase the SOC density in the soil, improve its depth distribution and stabilize SOC within stable aggregates so that carbon is protected from microbial processes as organic carbon storage in agricultural soils affects global climatic change and crop productivity (Lal, 2004; Srinivasarao et al., 2012a).

In recent years, resource conservation has assumed importance for stabilising productivity in rainfed systems in view of the widespread natural resource degradation and the need to reduce production costs and to make agriculture profitable for small farmers (Jat et al., 2012). Conservation agriculture systems consisting of reduced tillage intensity, recycling of crop residues/application of organic matter and crop rotation, which are also called as the essential principles of conservation agriculture (Erenstein, 2011), has assumed importance as a solution to these problems. Several studies have reported improvement in soil carbon stocks in many parts of the world with the adoption of reduced tillage systems and recycling of crop residues (West and Post, 2002; Machado and Silva, 2001). However, the extent of improvement in soil carbon is being dependent on several factors such as the antecedent level of SOC, climate, extent of recycling of crop residues and duration of the practice (Srinivasarao et al., 2012b). In India, the introduction of reduced tillage systems is of recent origin and much of the adoption has been confined to the Indo-Gangetic region under irrigated conditions. The information on the influence of reduced tillage and recycling or application of organic matter on the extent of soil carbon sequestration is limited particularly under the rainfed conditions. Concerns have been raised about the decline in crop yields mainly during the initial years in such systems (Jat et al., 2012).

Crop residues, particularly for some of the crops such as sorghum, finger millet, pearl millet, etc. have fodder value and fetches market price in rainfed regions as the biomass
Recent and future weather and climate trends of Kancheepuram, Tamil Nadu and their possible impacts on agriculture

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ABSTRACT

PRECIS, a Regional Climate Model developed by Hadley Centre, UK Met office has been used in the present study to predict the future climate change scenarios by using the output of Global Climate Model HADCM3Q. The projections of maximum annual temperature over Kancheepuram district for the period 2010-2040, 2040-2070, 2070-2100 with reference to the base line year (1970-2000) indicated an average increase of 1.2 °C, 2.4 °C, and 3.3 °C, respectively. The projections of the annual minimum temperature showed an average increase of 1 °C, for 2010-2040, 2.2 °C for 2040-70, and 3.3 °C for the period 2070-2100. Projections on the annual precipitation also showed a decreasing trend, with a range of 700-1200 mm/year over the western and interior north western parts of the district during the period 2040-2070. Projections of soil moisture showed a decreasing trend for the period 2040-2070. The possible impacts like changing cropping patterns, hampering crop productivity, increasing pests and insect attack may threaten the agro biodiversity and food security.

Key words: PRECIS, climate change, future projections, agricultural impacts

The Intergovernmental Panel on Climate Change reported that global surface temperature has increased by 0.74 °C during the last hundred years ending in 2005 (IPCC, 2007). Global Climate Models project a rise in global temperature by 1.8 to 4 °C with equally increasing atmospheric carbon dioxide by the year 2100 due to the increase in greenhouse gases in the atmosphere based on different emission scenarios. This may result in significant regional consequences on the hydrological cycle, runoff, evapotranspiration, soil moisture content and their spatial and temporal re-distributions. This will seriously affect the suitability and productivity of current and future agriculture.

Climate change will have significant interactions with crop growth, different developmental stages, water use efficiency, and productivity. In many tropical and sub tropical regions, the potential yields are predicted to decrease for projected increase in temperature (Houghton et al., 2001). Studies done by several other authors also reveals that agriculture production could suffer yield losses in the next hundred years (Challinor et al., 2009, 2010; Lobel et al., 2008; IPCC, 2007). The increased levels of CO2 could increase the yield of major crops, but the beneficial effects can be negated by the declining photo synthetically active radiation (Hume and Cattle, 1990). Forced maturity and poor harvest index due to shortage in water supply are the other major consequences of increased temperature. Analysis of the long term monthly rainfall data of 1200 stations for the period from 1871-2004 for rainfed areas of India indicated negative trends in the annual rainfall over some parts of Tamil Nadu (Singh, 2010).

Higher temperature during march 2004, in the Indo-Gangetic Plains, caused the wheat crop to mature earlier by 10-20 days, this resulted in the drop of wheat production by more than 4 million tones, significant losses were also observed in crops like mustard, peas, tomatoes, onion, garlic, vegetables and fruit crops (Samra and Singh, 2004). The yields of wheat, soybean, mustard, groundnut, and potato are expected to decline by 3-7% for every one degree increase in temperature (Aggarwal, 2009). One degree increase in temperature can impact insect physiology and development directly or indirectly through the physiology or existence of hosts. Depending on the development “strategy” of an insect species, temperature can exert different effects (Bale et al., 2002). For every 1°C increase in temperature, the productivity of rice yield may decline by 6% (Saseendran et al., 2000). Studies on sorghum indicated that, productivity loss due to the rise in temperature may likely to be offset by projected increase in rainfall in some parts, but complete adjustment of yield loss beyond 2°C rise may not be attained even after doubling of rainfall (Srivastava et al., 2010). Results from the Free Air Carbon Enrichment (FACE) experiments cast uncertainties on the CO2 fertilization effects on offsetting yield losses resulting from increased heat stress and soil moisture deficit under changed climatic situation (Gobin, 2010; Ewert et al., 2002; Kimball et al., 2002; Long et al., 2006). The increased temperature will lead to forced maturity of the crops and poor harvest index due to limited water supply (Yadav et al., 1987). A research carried out by CRIDA using HADCM3 model, on the crops such as groundnut, mustard, wheat, and
Adaptation to climate change: Integrated nutrient use in cotton

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ABSTRACT

A field experiment was conducted at Agricultural College Farm, Bapatla during kharif, 2011 to study the influence of organics along with Phosphorus Solubilizing Bacteria (PSB) at different levels of phosphorus on soil health and yield of cotton under the prevailing climate. The mean maximum temperature of the current season was found to be more while the minimum temperature, relative humidity and rainfall were less than the normal. The FYM treated plots recorded significantly high organic carbon. Highest available phosphorus was recorded on integration of maximum dose of phosphorus with PSB and FYM. Application of FYM and PSB either individually or in combination showed significant influence on bacterial population. An increase of 32, 25 and 8 per cent seed cotton yield was recorded by the treatments that received maximum inorganic phosphorus (60 kg P₂O₅ ha⁻¹) along with PSB and FYM, with FYM and with PSB, respectively over only inorganic treatment. The study revealed that use of organics can improve organic carbon, which is considered as one of the climate change indicators in soils there by sustaining their health.

Key words: FYM, phosphorus solubilizing bacteria, bacterial population

Soils are non renewable finite support of primary production systems. Therefore, sustaining soil health is a critical factor to ensure increasing food demand. The organic carbon is intimately linked with the natural fertility and productivity of soils. The increase in temperatures and changes in rainfall patterns due to climate change may depreciate the carbon content of soil, which in turn deprive it of physical, chemical and biological health. Owing to deterioration of soil health, the response of crops to the applied fertilizers would decrease. Indeed, more fossil fuel combustion for production and transportation of fertilizers results in the formation of nitrous oxide, which apart from contributing directly to the range of environmental problems, also constitutes a powerful greenhouse gas. Hence to meet the food and fiber needs of the increasing population on a sustained manner, the strategies involving addition of carbon from organic soil amendments (farm yard manure, compost, crop residues, sewage sludge) along with bio-fertilizers, which add to nutrient transformations, are required. These measures would reduce the dependence on fertilizers over a period of time. Approximately 90% of the technical potential to reduce emissions from agricultural production lies in carbon sequestration in the soil. Improved carbon sequestration and reductions in industrial emissions are mainly achieved through organic farming or integrated nutrient management involving use of inputs by incorporating organic components.

In view of this, an experiment was conducted to study the influence of organic manures and bio-fertilizers on soil health and carbon sequestration under the prevailing conditions.

MATERIALS AND METHODS

The experiment was carried out at the Agricultural College Farm, Bapatla, Andhra pradesh, during kharif 2011 with 10 treatments replicated thrice in a randomized block design in Bt cotton. The treatments comprised of T₁ = RDP (60 kg P₂O₅ ha⁻¹); T₂ = RDP+PSB; T₃ = 50% RDP+PSB; T₄ = PSB; T₅ = RDP+FYM; T₆ = 50% RDP+FYM; T₇ = FYM; T₈ = RDP+PSB+FYM; T₉ = 50% RDP+FYM and T₁₀ = PSB + FYM. FYM and PSB were applied @10 t ha⁻¹ and 5 kg ha⁻¹ respectively. Prior to the experiment the bacterial population was 1.3 X 10⁶ colony forming units (CFU) g⁻¹ soil.
Spatial and temporal assessment of net primary productivity for Andhra Pradesh using MODIS data

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ABSTRACT

The performance of monsoon is a critical factor in Indian agriculture as it is the most important factor effecting agriculture productivity. Present study covers spatial and temporal assessment of agricultural Net Primary Productivity (NPP) for Andhra Pradesh and its response to precipitation for cropping seasons viz., winter crop (January-February), summer crop (March-May), kharif (Jun-September), rabi (October-December), extended kharif (June-December), and annual for the period 2001 to 2010 using Production Efficiency Model (PEM). The study showed that agricultural NPP values are higher (0.9 kg cm−2) after northeast and southwest monsoons, comparatively lower during winter and lowest (0.3 kg cm−2) during summer season. It also showed that spatial distribution of NPP was mainly effected by rainfall. Comparative assessment of NPP was made for drought and normal years. Variability in NPP for different districts was also worked out for different years. However, human interventions may have also played a key role in agricultural NPP growth, which is largely driven by increase in irrigated area and fertilizer use.

Key words: NPP, MODIS, PEM, NDVI, Andhra Pradesh

Many studies have been conducted on possible climate change impacts on ecosystem. The continuing rise in atmospheric CO2 is considered to be the main cause for future changes in global climate. Predicted climate changes includes increase in mean annual temperature and alterations in precipitation pattern and cloud cover. Net primary productivity (NPP) measures the major economic and social importance, such as agricultural crop yield and forest production (Zhiqiang Gao et al., 2012). NPP is a key component of the carbon budgeting in the event of the global climate change. NPP estimates vary from regional to global scale, as the carbon storage by terrestrial ecosystem plays an important role in limiting the increasing rate of atmospheric CO2 (Nethaji, 2010) In mid-latitudes, productivity is obviously linked to seasonal change, with productivity peaking in each hemisphere during summer. The boreal forests of Canada and Russia experience high productivity in June and July and then a slow decline during winter. Year-round, tropical forests in South America, Africa, Southeast Asia, and Indonesia have high productivity, not surprising with the abundant sunlight, warmth and rainfall. However, even in the tropics; there are variations in productivity over the course of year. For example, in the Amazon, productivity is especially high from August to October, which is the dry season. The reason is that the trees have access to a plenty of ground water that builds up in the rainy season and they actually grow better when the rainy skies clear and allow more sunlight to reach the forest.

In situ NPP ground measurements are costly, involves more time, labour intensive, tedious and therefore available ground measurements are insufficient to account for spatio temporal variability of NPP at regional and meso-scales (Nethaji, 2010). Hence it is, necessary to calibrate and derive NPP estimates in combination with remote sensing and other datasets to quantify the spatio-temporal variability.

Production Efficiency Model (PEM) was used to estimate agricultural NPP, which uses remote sensing data as input. This model has been successfully used for estimation of global NPP at annual scale (Prince et al., 1995), but the estimate for agricultural NPP is not attempted even in regional and global scale and on a seasonal basis. Therefore, agricultural NPP estimation was taken up in this study for Andhra Pradesh using existing PEM algorithms.

Productivity is the rate of atmospheric carbon uptake by vegetation through the process of photosynthesis. Built up of productivity is a complex phenomenon, which is a culmination of many temporal plant processes. Recent methods to evaluate NPP involve decomposition of productivity into independent parameters such as incoming solar radiation, radiation absorption efficiency and conversion efficiency of absorbed radiation into organic matter (Kumar et al., 1981). Goward et.al. (1985) showed that vegetation indices, such as Normalized Difference Vegetative Index (NDVI) is related to NPP. Monteith (1977) suggested that NPP under non-stressed conditions is linearly related to the
Effect of temperature on grain protein content of wheat

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ABSTRACT
To investigate the effects of temperatures during different phases of growth on grain protein, field experiment with eight dates of sowing at weekly interval was conducted during 2008-09 and 2009-10. Grain protein content increased with delay in sowing. It varied from 8.8 % in 4th November sown crop to 12.4 % in 21st December. Protein content exhibited significant negative association with grain yield (r=-0.79, p<0.01). There existed an inverse relationship between duration of grain filling and grain protein content (r=-0.863, p<0.01). Correlation coefficients between protein content and mean maximum, minimum, and mean temperatures, and photo- and nycto-temperatures prevailing during reproductive, post-heading, and grain filling phases demonstrated significant positive correlation with protein content. Values of these weather parameters were more during grain filling phase than those occurring during vegetative and reproductive phases. As values of these weather parameters increased with delay in sowing dates, protein contents also increased, and in turn they exhibited significant positive correlation values. Stepwise regression equation, developed for prediction of protein content, accounted for 94 % of the total variation in the protein content by a linear function, involving mean minimum and maximum temperatures during 100 % anthesis to physiological maturity.

Key words: Wheat, grain protein, temperature, correlation, regression

Temperature plays a dominant role in growth, development and yield of wheat in West Bengal where the winter is short and mild. Rice-wheat sequence is one of the dominant cropping systems in the state. Sowing of wheat in this cropping system is often delayed due to late harvesting of the preceding rice crop and thus a reduction in the grain yield of wheat is inevitable. The loss in the grain yield due to late sowing is because of poor grain yield components, out of which maximum loss is incurred in 1000-seed weight. However, there have been meagre studies in India as to how the variation in sowing dates affects the grain protein content. Proteins are the most important components of wheat grains governing its quality. Variations in both protein content and composition significantly modify flour quality for bread-making (Weegels et al., 1996). Although the grain protein composition largely depends on the genotype, however there are reports to the effect that it is also significantly affected by the environmental factors (Graybosch et al., 1996; Zhu and Khan, 2001). Many researchers observed increased crude protein content with delayed sowing dates (Reents et al., 1997; Schemitt and Dewes, 1997; Yadava and Singh, 2003). Higher grain crude protein content but lower grain sizes were obtained with delayed sowing (Patil et al., 2000). Daniel and Triboï (2002) reported that the percentage of proteins in the flour increased with the increase of temperature and nitrogen supply, whereas the quantity of proteins per grain was affected negatively by high temperatures and affected positively by N fertilization. Although it is established that late-sown wheat in W. Bengal is vulnerable to produce lower grain yield (Khan and Chatterjee, 1981; Khan et al., 2010), effects of weather factors on grain protein content have not yet been studied. The present study is aimed to understand the effects of temperatures, mainly air and soil temperatures, and photo- and nycto-temperatures during different growth phases, on crude protein content in grains of wheat grown under different dates of sowing.

MATERIALS AND METHODS
Field experiment was conducted with wheat (Triticum aestivum L. emend. Thell) during winter seasons of 2008-09 and 2009-10 with eight dates of sowing, viz., 4 November, 11 November, 18 November, 25 November, 2 December, 9 December, 15 December and 21 December, replicated four times, and designed in randomized complete block design at the Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur (22°56’N; 88°32’E; 9.75 m AMSL) located in the New Alluvial agroclimatic zone of West Bengal. The soil of the experimental site is upland well-drained sandy loam in texture with neutral in reaction (6.8 pH), organic carbon (0.54 %), total nitrogen (0.053 %), available P2O5 (15 kg ha-1) and available K2O (154 kg ha-1). ‘UP-262’ a recommended variety for Gangetic Plains of West Bengal was sown during both years in rows 22.5 cm apart. The crop was fertilized with 100, 50 and 50 kg of N, P2O5 and K2O ha-1, respectively. Half of the N and all P2O5 and K2O were applied as basal dose before sowing and 25% N at
Microclimate, gas exchange, canopy architecture and photosystem II (PSII) photochemistry as influenced by spacing in *Pongamia pinnata*

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**ABSTRACT**

The pongam tree (*Pongamia pinnata* (L.) Pierre) is a medium sized evergreen tree with a spreading crown and a short bole. A single tree can yield 9–90 kg seed per tree, indicating a yield potential of 900—9000 kg seed ha\(^{-1}\), 25% of which might be rendered as oil (assuming 100 trees ha\(^{-1}\)). In general, Indian mills extract 24–27.5% oil, village crushers 18–22% oil. Recently the potential of the oil has been rediscovered as an effective alternative/additive for fossil derived diesel. This has fuelled research in the area of cultivation aspects of the tree to increase economic yield. In a study in CRIDA (Central Research Institute for Dryland Agriculture) it was found that microclimate in terms of reduced rate of transpiration with a concomitant increase in resistance to water flow in stomata, increase in relative humidity under tree canopy and effective utilization of photosynthetically active radiation for sufficient photosynthate production was influenced by spacing in pongamia viz., 6m x 4m, 6m x 6m and 8m x 6m. In addition photosystem II (PSII) photochemistry, Non photochemical quenching and OJIP (Chlorophyll a fluorescence induction kinetics) were also influenced by spacing. In our study we found that microclimate was significantly influenced by spacing in terms of gas exchange parameters. Our results indicate that the optimum spacing for pongamia considering the parameters studies is 6m x 6m.

**Key words:** Pongamia, microclimate, tree spacing, gas exchange
Farmers perception of climate change impact and its mitigation in Golaghat district of Assam

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ABSTRACT

A study was conducted in Golaghat district of Assam to assess the perception of farmers to climate change impact over specified time periods viz., 1991-2005 (first 15 years) and 2006-2010 (recent 5 years). A total of 120 respondents were selected from two villages and their perceptions on impact of climate change based on weather parameters like rainfall, temperature and vulnerability of agricultural crops was recorded. Adaptation and mitigation strategies adopted by the farmers were also documented. Observed rainfall and temperature data of the study area did not show much variation for the mentioned time period. Under this study it was observed that an increase in the number of rainy days (70.8%) and on timely onset of rainfall (75.4%) was perceived by the farmers during 1991-2005. However, during the period from 2006-2010 less number of rainy days (81.7%), low rainfall (68.3%), irregular onset of rainfall (68.8%), longer dry spells (62.5%), high variation in changes of rainfall pattern (71.7%) and reduced crop growing period (68.8%) was perceived by the farmers. Changes in temperature were also perceived by the farmers during the recent 5 years. Crop adaptation strategies viz., changes from long to short duration varieties (75%), changes in planting dates (85%), changes in quantity of seeds, fertilizer application, number of irrigation and spacing was adopted by majority (73%) of the farmers. Farmers (>90 numbers) have stressed on provision for early warning system, awareness creation among farmers about climate change, timely supply of inputs and provision of financial support for soil nutrient enrichment.

Key words : Climate change, farmers’ perception, Assam, adaptation strategies

Today, the commonly used term climate change represents any change in climate over time, either due to natural or anthropogenic causes (NRC, 2010). Extreme events like droughts, floods, cyclones and hurricanes have become synonymous to climate change (IPCC, 2012). Climate change will have common and differentiated impacts. For example, countries in the northern latitude may benefit from a higher temperature due to longer growing season of crops (Water Aid, 2007). In contrast, North east India in general and Assam in particular, the crop growing period especially of rice will get shortened thereby, reducing yield (Swaminathan and Keshavan, 2012). The climate change manifestation in terms of recurrent floods due to heavy downpour has resulted in damage to crops and villages (DES, 2010) in the state, Assam, due to its unique geo-physiographic settings, low socio economic index, illiteracy, agrarian economy etc is vulnerable to the vagaries of climate change and variability. All these factors supersede the interventions attempted by the policy forming institutions to address the adverse impact of climate change. Hence, it becomes important to make aware the farmers on problems of climate change that is creeping in slowly but steadily. For this purpose, it is important to know the farmers perception on changing climate scenario and related problems. This study attempts to present the perception of farmers of Golaghat district of Assam and relate it to scientific meteorological data and thus bring into forefront the adaptation measures to address the problems of adverse impact of climate change.

MATERIALS AND METHODS

The study was carried out in two villages namely Thengal Gaon and Kochupothar of Central Development Block, Kothalguri of Golaghat district of Upper Brahmaputra Valley Zone of Assam. Both the villages are situated at 26°35’N latitude and 93°52’E longitude with altitude varying from 83 to 90 m AMSL indicating availability of different land situations in the two villages. Farmers mainly grow rice as the main crop during kharif and rapeseed & mustard, potato, vegetables during rabi season. The climate of the study area is characterized by hot and humid summer and dry and cool winter. Total cultivable land area of the Thengal Gaon is 50.7 ha of which about 60% had irrigation facility. On the other hand, total cultivable land area of the Kachupathar village is 175 ha, and only 20% of land is under irrigation. A total of 120 farmers were selected with 60 respondents from each village. Meteorological data during pre monsoon (March-May), monsoon (June-September), post monsoon (October and November) and winter (December-February) for rainfall, maximum and minimum temperature, as recorded at Agromet Observatory, Sugarcane Research Station, Buralikson, Golaghat were collected and analyzed. Perception of farmers was recorded on impact of climate
Impact of weather factors on incidence of leaf miner Aproaerema modicella, (Gelechiidae: Lepidoptera) on kharif groundnut in Chittoor district of Andhra Pradesh

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ABSTRACT

Groundnut leaf miner (GLM), Aproaerema modicella Deventer is a major pest on groundnut and soybean causing economic loss to groundnut. Field experiments were conducted at Regional Agricultural Research Station, Tirupati during 2006-2011 to study the influence of various weather parameters on the pheromone trap catches of groundnut leaf miner. Correlation studies indicated a positive association between maximum temperature, minimum temperature, sunshine hours and wind velocity with moth catches. Whereas negative association was observed with morning and evening relative humidity, rainfall and rainy days. Maximum temperature ($r=+0.59$), minimum temperature ($r=+0.65$) showed significant positive influence, morning relative humidity ($r=-0.39$) and evening relative humidity ($r=-0.33$) showed significant negative association with leaf miner moth catches. Forward step down regression analysis showed that minimum temperature, sunshine hours, rainy days, evening relative humidity and wind velocity together influenced the leaf miner incidence to extent of 61.59 per cent.

Key words: Groundnut leaf miner, Aproaerema modicella, weather parameters, correlation, regression

Groundnut is an important oilseed crop grown worldwide and India is a major groundnut growing country in the world. Groundnut productivity is influenced by degree of insect pest infestation and drought stress. Groundnut crop is attacked by about 90 species of insects and among them nine are considered to be economically important. Major insect pests of groundnut are termites (Odontotermes), whitegrubs (Lachnosterna consanguinea), thrips, leaf hoppers (Empoasca kerri), aphids (Aphis craccivora), leaf miners (Aproaerema modicella), tobacco caterpillars (Spodoptera litura) and red hairy caterpillar (Amsacta albistriga).

Aproaerema modicella Dev. ‘a gelechiid moth’ commonly called as groundnut leaf miner (GLM) is a serious oligophagous insect pest on groundnut, soybean and other few legume crops in South and South East Asia. Narahari Rao et al. (2000) reported that in Anantapur region of south India leaf miners emerge during drought periods with no rainy days for more than 21 days during 35-110 days of the cropping period. Ranga Rao et al. (1997) also reported similar phenomenon during moisture stress conditions. Three to four overlapping GLM generations in groundnut crop per season was noticed, although five generations have been reported during the rainy season in south India. Leaf miner is considered to be a major pest both in kharif and rabi seasons in Chittoor district of Andhra Pradesh. In recent years, some of the seasons were most favouring in build-up of leaf miner resulted in severe outbreak particularly during rainy season in eastern part of Chittoor district. Muralikrishna et al. (2009) reported severe incidence of GLM during 2008 summer and Kharif groundnut grown in Chittoor district of Andhra Pradesh. Rainfall pattern influencing parasitism level of braconid parasites on GLM was to the extent of 5.5 to 57.14 per cent during kharif 2008 at RARS, Tirupati (Anonymous, 2008). Hence studies are needed on GLM population dynamics through pheromone traps in relation to changing weather to forewarn the incidence of leaf miner to initiate timely control measures.

MATERIALS AND METHODS

Field experiments were conducted at Regional Agricultural Research Station, Tirupati during kharif, 2006 to 2011. Groundnut variety Narayani was sown during first week of July as normal sown crop. The crop was raised duly following normal agronomic practices developed by ANGRAU. Wota-T traps @ 4 No/acre were installed in the field and provided with a GLM lure. The trap was smeared with castor oil to avoid the escape of trapped moths. The moth caches in pheromone trap was counted daily and along weather parameters like maximum temperature, minimum temperature, morning RH, evening RH, rainfall, rainy days, sunshine hours and wind velocity were recorded. GLM moth catches and weather data were compiled meteorological standard week-wise for studying the dynamics of moth catches in each season and influence of weather factors on moth catches of GLM using statistical package SAS EG 4.3.
Studies on the irrigation scheduling in low chilling cultivars of peach under subtropical conditions

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ABSTRACT

The study was carried out during 2009-10 to 2010-11 seasons to estimate water requirement of subtropical peach cultivars (viz., Florida Prince, Shan-e-Punjab and Early Grande). Different irrigation intervals based on 20 mm, 30 mm, 40 mm and 50 mm evapotranspiration (Et) and crop coefficient (Kc = 0.7) were used. The average total Reference Crop Evapotranspiration (ET0) varied from 288-309 mm for 20 mm ET0, 240-244 for 30 mm ET0, 181-226 mm for 50 mm ET0 and 173-217 mm for 40 mm ET0 during the both seasons of study. In first season, yield and the number of fruits increased in all cultivars, but during second season the number of fruits increased in Shan-e-Punjab, while decreased in Florida Prince and Early Grande, with respect to the irrigation treatments. Rainfall pattern in the season is an important contributor.

Key words: Peach, evapotranspiration, water requirement, yield

Peach (Prunus persica L.) an important cash crop of Jammu subtropics, belonging to family Rosaceae is being grown on area of 2238 ha with an annual production of 2375 metric tons (Anon., 2007). Though, the peaches are commercially grown all over the world between 25°-45° latitude, with the introduction of low-chilling peach cultivars, it is now grown successfully in the sub mountain regions of Punjab, Delhi, Haryana, Western Uttar Pradesh and Jammu province of Jammu and Kashmir State. Peach requires frequent irrigation during fruit development and lack of water supply to peach trees at critical stages leads to fruit drop, reduced fruit size and quality. Level of irrigation depends on the environment factors that drive evaporative demand and transpiration, the resistance of soil to root penetration, moisture transport, and soil aeration and the tree hydraulic architecture (Noar, 2006).

Evapotranspiration is a key factor in irrigation scheduling as a management tool (Villar, 2001). The meteorological-based irrigation scheduling approach of the FAO is being adopted in order to estimate irrigation amount of the intensive and hyper-intensive orchards. Wiegand and Swanon (1982) reported that the total evapotranspiration of grapefruit varies from 840 to 1220 mm. Bielorai and Levy (1978) observed that maximum grapefruit yield required 9 to 12 irrigations during the growing season. Indeed, the main purpose of the experiment is to determine the water requirement of peach cultivars and to identify the yield response of the crop to different irrigation intervals.

MATERIALS AND METHODS

The experiment was carried out since 2009-10 to 2010-11 with the peach cultivars viz; Shan-i-Punjab, Florida Prince, Early Grand growing in a well-maintained Experimental orchard of Division of Fruit Science, Faculty of Agriculture, Sher-e-Kashmir University of Agriculture Sciences and Technology of Jammu at Main campus Chatha. Climate is humid with an average of 1200 mm rainfall. Summer months are hot with temperature and humidity ranging from 23.5 °C to 35.5 °C and 53.0% to 73.5%, respectively. The winter months experience mild to severe cold conditions with an average temperature ranging from 6.5 °C to 21.7 °C. December is the coldest month, when minimum temperature touches 4 °C. The highest temperature is recorded in the month of June (45 °C). Daily maximum and minimum temperature, evaporation rate rises from February onwards.

Irrigation treatment
\[
\begin{align*}
I_1 & \text{ - after 20 mm evapotranspiration} \\
I_2 & \text{ - after 30 mm evapotranspiration} \\
I_3 & \text{ - after 40 mm evapotranspiration} \\
I_4 & \text{ - after 50 mm evapotranspiration}
\end{align*}
\]

The optimal level of irrigation was calculated with CROPWAT (CROPWAT is a computer program for irrigation planning and management, developed by the Land and Water Development, Division of Food and Agriculture Organisation of United Nations, Rome, Italy) based on the Penman-Monteith equation for calculation of reference crop evapotranspiration, ET0 (FAO, 1992).
Impact assessment of climate resilient technology on carbon balance using EX-ACT model: A case study in three rainfed tribal villages of Andhra Pradesh

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ABSTRACT

EX-Ante Carbon-balance Tool (EX-ACT), developed by FAO provides ex-ante measurements of the impact of agriculture (and forestry) development projects on GHG emissions and C sequestration. Under National Initiative on Climate Resilient Agriculture (NICRA) project, various climate resilient farm technologies were demonstrated during 2012-13 in 125 villages in 100 climatically vulnerable districts. Out of this, carbon balance was studied with EX-ACT model for 3 rainfed and tribal dominant villages in Nalgonda and Khammam districts in Andhra Pradesh. Interventions in Nandyalagudem (Nalgonda) showed that the project activities represent a sink of 3854 t CO₂ e (CO₂ equivalents). The project was able to sequester 5712 t CO₂ e while emitting 1857 t CO₂ e so that the net effect of project activities created a sink of 3854 t CO₂ e. In Boringthanda village, the results of EX-ACT model showed that the interventions can mitigate a net balance of 2410 t CO₂ e, corresponding to a mitigation potential of 12.5 t CO₂ e. In Nacharam village of Khammam district, the project is being implemented in 1273 ha of area. All interventions of the project together have a potential to sink of 6176 t of CO₂ e during 20 years. The modules of inputs, livestock and nonforest land use changes showed sources of 6908 t CO₂ e. The annual crops due to improved management practices show a net sink of 9726 t CO₂ e.

Key words: EX-ACT model, carbon balance, green house gas emission, mitigation

Following the unprecedented expansion and intensification of agriculture in India, there is clear evidence of a decline in the soil organic carbon (SOC) contents in many soils as a consequence; while on the other hand it has been reported that good farming practices such as balanced fertilization and addition of crop residues either maintains or results build up or depletion of SOC stock (Srinivasarao et al., 2012). The process of decline of soil organic matter is accelerated by the process of nutrient depletion (Lal, 2002), soil erosion and other forces of land degradation (Lal, 1999). Carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) are the key greenhouse gases (GHG) that contribute towards the global warming at 60, 15 and 5%, respectively (Watson et al., 1996). The CO₂ in the atmosphere has increased from 280 ppm in 1850 to 393 ppm in 2012 (WMO, 2012; CDIAC, 2012). There has been increase in the atmospheric CH₄ and N₂O concentrations over the same period resulting in increase in the radiative forcing leading to global warming (IPCC, 2007). Apart from causing global warming, N₂O is also responsible for the destruction of the stratospheric ozone (Li et al., 2004). Quantification of GHG emissions from soil is needed for global modelling studies in the context of ecosystem modification and climate change (Li et al., 1997).

Global warming potential (GWP) is used to compare the effectiveness of each GHG to trap heat in the atmosphere relative to some standard gas, by convention CO₂. The GWP of CH₄ and N₂O are 21 and 310 times of CO₂, respectively.

Estimates of GHG emissions from the agriculture sector arise from enteric fermentation in livestock, manure management, paddy cultivation and agricultural soils and on field burning of crop residues. The emissions cover all forms of water management practices followed in the country for rice cultivation, namely, irrigated, rainfed, deep water and upland rice. EX-Ante Carbon-balance Tool (EX-ACT), developed by FAO provides ex-ante measurements of the impact of agriculture (and forestry) development projects on GHG emissions and C sequestration. The project “National Initiative on Climate Resilient Agriculture” (NICRA) was initiated during 2010-11 and one of the objectives of the project was to demonstrate site specific technology packages on farmers’ fields for adapting to current climate risks. Under this, carbon balance studies were initiated in about 125 villages in 100 climate vulnerable districts of India in association of respective Zonal Project Directorates (ZPD) and Krishi Vigyan Kendra (KVK) to evaluate the impact of climate resilient technologies implemented in these model
Simulation of phenology, growth and yield of maize in a humid sub-tropical region of India using CERES-Maize model

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ABSTRACT

Crop simulation models are often used to characterize, develop and assess field crop production practices under alternate management scenarios. In this study, CERES-Maize model was employed to characterize maize phenology, growth and yield. A three year study was conducted with maize c.v. Ganga Safed-2 under different microclimatic conditions such as two dates (D1-10th June and D2-25th June), two moisture regimes (W0-rainfed and W1-irrigated) and three spacings (S1-60 x 20 cm, S2-75 x 20 cm and S3-Broadcasting). The model predictions for flowering and physiological maturity were close to observed with a variation of -4.8 to 1.8 per cent. Maximum LAI was over estimated by model under different treatments with a difference of 0.3 to 0.9. The estimation of number of grains ear-1 by the model was slightly higher than observed with a deviation of 2 to 4.24 per cent. The model predicted biomass with fair accuracy and deviation varied from -12.33 to 4.12 per cent. Prediction of grain yield by model under irrigated conditions was close to observed yield under rainfed conditions. Similarly, the simulated grain yield was close to observed with the variation of 8.9 per cent under first date of sowing, however, it was overestimated under late sown conditions. Overall, the yield predictions by the model were fairly close to the observed. Thus, CERES-Maize model could be used as a research tool to predict phenology, growth and grain yield of maize.

Key words: CERES-Maize model, sowing date, spacing, rainfed, irrigated

Crop simulation models deal with interactions of plant growth with climatic factors, soil characteristics and agronomic management (Jones et al., 2000; Hammer et al., 2002) and thus provide useful insights about the functioning of crops in agricultural systems. Several authors have made efforts to enumerate yield potential and its variation at a regional scale using both observed and modeled data (Loffler et al., 2005; Grassini et al., 2009; Liu et al., 2012). Crop models, when well calibrated and validated, are able to integrate soil and weather conditions and management decisions to predict crop development and yield under alternative scenarios.

Maize is one of the world’s most important cereal crops after rice and wheat (Azam et al., 2006), and because of increasing global demand for stock feed it is predicted that maize demand will continue to rise. In Jammu and Kashmir, the maize is grown on the area of 0.3 million hectares with productivity about 17.12 q ha-1 (Anonymous, 2010). Maize productivity is directly related to its light and water use efficiencies to generate biomass (Liu et al., 2010). The maize responds to these factors differently mainly due to differences in leaf area index (Azadgoleh and Kazmi, 2007), intraspecific competition in maize plants (Maddonni and Otegui, 2006) and dry matter accumulation (Monneveux et al., 2005; Brenda et al., 2006). The study of relationships between potential maize yields and diverse environmental factors due to different sowing time have shown that light, temperature and water availability are necessary yield determinants (Cardoso and Soccol, 2008). Grain yield increases with the plant density until some competitive effects become apparent (Abolhassan et al., 2005; Singh and Choudhry, 2008; Lashkari et al., 2011). However, monitoring all this on a real time basis is not always possible, necessitating the adoption of an integrated approach using a crop growth simulation model for which CERES-Maize model is probably conceptually appropriate for researcher and planner to give reasonable predictions with crop management practices.

The objective of this study was to compare the prediction of CERES-Maize model with observed data generated from field experiments laid out under microclimatic conditions which will allow us to evaluate model under different crop management practices and identify model subroutines that can be modified to improve it better in humid sub-tropical conditions.
Short Communication

Evaluating canopy temperature based indices for irrigation scheduling and yield prediction in wheat

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Wheat is an important cereal crop and is adapted to a wide range of climatic conditions. However, in arid and semi-arid areas, its yield is severely limited by water-deficit stress. Water deficit is one of the most important factors limiting crop yield, and the monitoring of crop water status is important for reasonable irrigation and water saving cultivation. Using crop canopy temperature to characterize crop water status is a new method for the monitoring (Wen-zhong et al., 2007). The canopy temperature has long been recognized as an indicator of water availability. Crop canopy temperature reflect the interactions among plants, soil and atmosphere. The canopy temperature provides an efficient method for rapid, non-destructive monitoring of whole plant response to water stress (Idso et al., 1981). Along with the development of the techniques and equipments for the measurement of canopy temperature with infra-red technology, crop canopy temperature has been used in studies of water status and metabolic functions of crops (Zhang, 1990). It had been reported in several studies that there widely exists a difference of canopy temperature among different wheat genotypes under the identical climatic, soil and farming conditions (Zhang, 1990). Several canopy temperature based indices such as canopy-air temperature difference (Tc–Ta), stress degree days (SDD), crop water stress index (CWSI) have been used in grain yield prediction. These provide useful tools in managing irrigation water (Idso et al., 1977). So an attempt was made to develop the models for explaining the yield variation in wheat with canopy temperature based indices.

A factorial experiment comprising three dates of sowing in main plot (November 15, November 25 and December 5), four irrigation levels in sub-plot I1 (irrigation at CRI, Jointing and Milking), I2 (irrigation at CRI, Tillering, Booting and Milking), I3 (irrigation at CRI, Jointing, Booting and Milking) and I4 (irrigation according to weather forecast) and two wheat varieties in sub-sub plot (PBW 343 and PBW 621) was laid as split-split plot design at Research Farm, School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana in the winter season 2011-12. The study was conducted to observe the canopy temperature of wheat crop under different sowing environments and moisture levels in two cultivars and also to evaluate the relationship between the grain yield and canopy temperature based indices in winter wheat. The measurement of canopy temperature was initiated after the crop attained full canopy cover from 70 days till the harvest of crop. The canopy temperature and canopy-air temperature differential were recorded in all treatments at 14:30 hrs under clear sky conditions with the help of infrared thermometer (FLUKE 574) by inclining at an angle of 45° holding 1m above the crop canopy. The average canopy temperature and canopy-air temperature difference for a particular phenophase were calculated as (Singh and Kanemasu 1983):

\[
\text{Average canopy temperature (Tc)} = \frac{\sum_{i=1}^{n} T_i}{n}
\]

Where,
- \( T_c \) = canopy temperature
- \( n \) = number of days

\[
\text{Average canopy air temperature difference (CATD)} = \frac{\sum_{i=1}^{n} (T_c - T_a)}{n}
\]

Where,
- \( T_c - T_a \) = canopy-air temperature difference
- \( n \) = number of days

The canopy air temperature difference \((T_c - T_a)\) values were used to determine the accumulated stress degree days (SDD) and crop water stress index (CWSI) by using following formula Jackson et al., (1977):

\[
\text{Accumulated SDD} = \sum_{i=1}^{n} (T_c - T_a)
\]

\[
\text{CWSI} = \frac{(T_c - T_a)_m - (T_c - T_a)_min}{(T_c - T_a)_max - (T_c - T_a)_min}
\]

where,
- CWSI = crop water stress index
- \((T_c - T_a)_m\) = measured canopy air temperature difference
- \((T_c - T_a)_max\) = maximum canopy air temperature difference
- \((T_c - T_a)_min\) = minimum canopy air temperature difference
Short Communication

Long-term rainfall analysis of Ranga Reddy district of Andhra Pradesh using GIS

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Being a tropical country, India mainly depends upon the rainfall for the water resources. More than 80% of the annual rainfall occurs during the monsoon periods in Andhra Pradesh. Intensity of monsoon rainfall is uneven and erratic both in space and time (Vennila, 2007). One of the sources of information on climatic-scale is rain gauge observation, which has advantages and shortcomings. Long-term gauge data of particular region can be important source to understand the nature variation of monsoon. Knowledge and understanding of such variability can lead to improved risk management practices in agriculture and other industries. Thus it is essential to analyse the occurrence of rainfall during various seasons for evolving a system to manage the water resources effectively.

Blanford (1886) was the first meteorologist who made extensive studies of Indian rainfall. Sir Gillbert Walker (1910, 1914, 1922) examined the south-west monsoon rainfall of British India (the whole country as one unit) by considering all available rain gauge data for the period off 1841-1908. After walker’s studies, little work was done during next 50 years. Later, analysis of average rainfall of India (as one unit) was done by Parthasarathy and Dhar (1976), Parthasarathy and Mooley (1978) and Mooley and Parthasarathy (1979) with variable number of rain gauge stations. Jagannadha Sarma (2005) has analysed the rainfall pattern of the coastal zone of Krishna-Godavari River Basin of Andhra Pradesh, India. He analyzed the annual, monsoon and non-monsoon rainfall and spatial and frequency distribution of rainfall intensity and Venila (2007) analyzed rainfall variation analysis of Vattamalaikarai sub-basin, Tamil Nadu, India. Ishappa (2010) has studied the rainfall characteristics of the Coimbatore District, which include the spatial distribution and variability through different seasons. However detailed study on the occurrence and distribution of rainfall in Ranga Reddy District has not been done. The present paper analyses the pattern of rainfall distribution over space and time. These results were taken to Geographical Information System (GIS) platform to prepare spatial distribution maps. GIS provides greater reliability with lesser time and cost compared with manual operation (Bera et al., 2003). Keeping this in view this study aimed to use GIS for spatial analysis of rainfall variation in Ranga reddy district of Andhra Pradesh.

Study area

The Ranga Reddy district is located in Central part of Deccan plateau of Andhra Pradesh and lies between 16° 30’ and 18° 20’ of North Latitude and 77° 30’ and 79° 30’ of East Longitudes. The district covers an area of 7493 Sq. Kms. The district is bounded on the North by Medak District, East by Nalgonda District, South by Mahaboobnagar District, and West by Gulbarga District & North West of Bidar District of Karnataka State. There are 37 mandals, 3 Revenue divisions and 12 Muncipalities in the district. Study Area is shown in Fig. 1.
Regional climate variability analysis and impact assessment on wheat productivity: 
A case study in Haryana

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Although meteorological data compiled over the past century suggest that the earth is warming, there are significant differences at regional levels. The IPCC's fourth assessment report concludes that it is extremely likely that the rise in global atmospheric temperature that has taken place since the mid-nineteenth century has been caused by human activities (IPCC, 2007). Almost all the years in the recent past recorded extreme weather events, and the year 2011 was found to be among 10 warmest years on record. The climate projections over India indicate that temperature rise is likely to be around 3°C and rainfall increase is expected by 10-20 per cent over central part of India by the end of this century. A likely impact of climate change on agricultural productivity in India is causing a great concern to the scientists and planners as it can hinder their attempts for achieving household food security. Food grain requirements in the country would reach about 345 million tonnes in 2030 (ICAR, 2011). The wheat production in the country since last few years was not been encouraging due to increase in temperature across the wheat growing regions during the reproductive phase of the crop. Year to year variations in climate and sudden departure from normal weather features have deleterious effects on crops and keep the food production highly fluctuating (Attri and Rathore, 2003). The climate of Haryana is strongly influenced by north-westerly cold and south-westerly monsoon winds. Scanty rains, excess and untimely rains, heat waves, cold waves, fog, frost and hails are important weather abnormalities occurring in the region and adversely affect the crop production (Singh et al., 2010). An attempt has been made here, to document and understand the observed climate variability and its impact on wheat productivity on regional scale in Haryana. For climate variability analysis, the study was undertaken using the data recorded at Agrometeorological Observatory at Research Farm of CCS Haryana Agricultural University, Hisar, (Latitude 29°17' N; Longitude 75°68' E, altitude 214.25 meters above mean sea level). Rainfall, maximum and minimum temperature (1971-2010) data were analyzed following standard statistical procedures. The wheat variety PBW-343 was grown in 2010-11 and 2011-12 with recommended package and practices to see the effect of temperature variations on performance of crop.

Change in rainfall pattern

Climate is one of the important agricultural resource which has not been exploited to its full for increasing the productivity. While analyzing the rainfall pattern, on an average Hisar region received annual rainfall of 460 mm spread over 27 rainy days during the period under report. The season-wise rainfall distribution indicated that 78% of annual rainfall is confined within the four monsoon months (June to September). Summer and winter contribute about 11.8 and 6.2%, respectively whereas the least rainfall is received in post monsoon (4%). Variation in annual as well as seasonal rainfall may be considered as a measure to examine climate variability/change over the region. Inter and

Table 1: Decadal variability in annual and seasonal rainfall at Hisar

<table>
<thead>
<tr>
<th>Seasons</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual</td>
<td>448.4 (34)</td>
</tr>
<tr>
<td>Winter</td>
<td>25.3 (89)</td>
</tr>
<tr>
<td>Summer</td>
<td>45.5 (84)</td>
</tr>
<tr>
<td>Monsoon</td>
<td>359.5 (44)</td>
</tr>
<tr>
<td>Post monsoon</td>
<td>18.1 (120)</td>
</tr>
</tbody>
</table>

Values in parentheses are CV (%)
**Short Communication**

**Heat unit requirement of different rice varieties in Chhattisgarh plain zone**

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India is the second largest producer of rice after China has an area of over 43.77 million ha with the production of 96.43 million tonnes (Anon, 2009). Rice is the backbone of the Indian agriculture. Chhattisgarh popularly known as “Rice Bowl of India” occupies an area around 3610.47 thousand hectares with the production of 5.48 Mt and productivity of 1517 kg ha⁻¹ (Anon, 2010). Farmers of Chhattisgarh are mainly depends on climate for rice cultivation. The radiation in crop production provides the necessary energy for all the phenomena concerning biomass production. Photosynthetically active radiation (PAR) is the real source of energy for photosynthesis process. Plants are the efficient biological converters of solar energy into biomass. Radiation defines the yield of crop in a particular region. It also provides the energy for the physical processes taking place in plants, soil and atmosphere. The present study is aimed to find out the heat unit requirement of different rice varieties.

The experiment was set at Research and Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur situated in eastern central part of Chhattisgarh at latitude of 21°16' N, longitude 81°36' E and altitude 289.5 m above mean sea level. The present experiment was conducted during the *Kharif* season of 2010. Three rice cultivars, *viz.*, Karma Mahsuri, Mahamaya and MTU-1010 were cultivated in a factorial Randomized Block Design (RBD) with three sowing dates. The unit plot size was 7 m X 4.4 m (30.8 m²) having a plot to plot and block to block distance of 0.5 m and 1.0 m, respectively. There were 27 plots in the experiment. A fertilizer dose of 100:60:60 kg ha⁻¹ was applied as N, P₂O₅ and K₂O, respectively in the form of urea, DAP and MOP, respectively. The half dose of N was applied as basal dressing and the rest half N was applied in two split doses at 30 and 50 days after transplanting. The whole amount of phosphorus and potash was applied as basal during transplanting. The grain yield and straw yield were computed in kg ha⁻¹. The accumulated heat unit system is based on the idea that plants have definite temperature requirements to attain certain phenological stage.

**Yield (kg ha⁻¹)**

Highest grain yield of 5170 kg ha⁻¹ was obtained with variety Karma Mahsuri when the crop was sown on 10th June but it was statistically at par with that of Mahamaya (4726 and 5156 kg ha⁻¹) sown on 10th and 20th June and MTU-1010 (4789 kg ha⁻¹) sown on 10th June. The highest grain yield of 5170 kg ha⁻¹ was at par with the grain yield of 4870 kg ha⁻¹ obtained with variety Karma Mahsuri sown on 20th June. On an average rice variety Mahamayaj produced higher grain yield (4744 kg ha⁻¹) which was comparable with grain yield of Karma Mahsuri (4460 kg ha⁻¹).

**Table 1**: Yield (kg ha⁻¹) of rice varieties under different sowing dates

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>Straw yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D₁-10 June</td>
<td>D₂-20 June</td>
</tr>
<tr>
<td>V₁-Karma Mahsuri</td>
<td>5170</td>
<td>4870</td>
</tr>
<tr>
<td>V₂-Mahamaya</td>
<td>4726</td>
<td>5156</td>
</tr>
<tr>
<td>V₃-MTU-1010</td>
<td>4789</td>
<td>4167</td>
</tr>
<tr>
<td>Mean</td>
<td>4895</td>
<td>4731</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S Ems± CD (P=0.05) CV (%)</th>
<th>S Ems± CD (P=0.05) CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>116 348 7.89</td>
<td>223 NS 10.06</td>
</tr>
<tr>
<td>116 348</td>
<td>223 NS</td>
</tr>
<tr>
<td>201 603</td>
<td>387 NS</td>
</tr>
</tbody>
</table>
Short Communication

Assessing the impact of change in climate on the water use index (WUI) and nitrogen use efficiency (NUE) of rice

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It is expected that the evapotranspiration and in turn Water Use Index (WUI) of the crop will get altered to change in climate owing to the future warming. It is important to understand the impact of change in climate on the Water Use Index (WUI) and Nitrogen Use Efficiency (NUE), to device adaptation strategies and hence a study has been undertaken at Tamil Nadu Agricultural University. The Cauvery Delta Zone of Tamilnadu, which is contributing the major share of rice production for the state pool was chosen for the study. The A1B scenario outputs of the two Regional Climate Models (RCM) viz., PRECIS and RegCM3 were used to run the DSSAT crop simulation model. The simulations were made for 128 years from 1971-2098 with two ruling varieties (ADT 43 and CR 1009) of the zone with and without CO2 enrichment. The predictions from both RCMs showed a declining trend for WUI and NUE under controlled (330 ppm) CO2 simulation while its enrichment likely to increase the WUI and NUE up to 2060 and thereafter the same is declining because of the increased warming. Both varieties showed similar trends in simulating the WUI and NUE except for the change in their magnitude.

Climate change is an important factor in policy agenda as it is no more a future threat but a facing reality around the world. Increase in greenhouse gas concentration (GHG) in the atmosphere is the major contributor to recent climate change, which is evident from the 0.74° C increase in observed temperature in the last 100 years (IPCC, 2007). Atmospheric carbon dioxide concentration has also increased dramatically since the pre-industrial era and will increase in the future with other GHGs. These changes in climate (increased temperature, change in rainfall pattern, sea level rise) and GHGs will have different impact on varied ecosystems. To combat these changes it is necessary for us to have future insight into the changing climate. For this purpose climate models are being used to obtain the future projections as per the Special Report on Emission Scenarios given by the IPCC.

Agriculture is the predominant user of water and is likely to be a major constraint on future productivity due to changes in rainfall pattern. These changes will have greater impact on agriculture factors like Water Use Index (WUI) and Nitrogen Use Efficiency (NUE), as large population will demand for more food production with limited area and soil nutrients. Rice is one of the major crop in the world and staple food of the Asian continent. Hence in the present study, rice is considered for assessing the WUI and NUE influenced under A1B scenario over the Cauvery Delta Zone (CDZ), the major rice growing tract of Tamilnadu.

The climate change data for the future were obtained by running PRECIS (Providing Regional Climates for Impact Studies) and RegCM3 regional climate models at 25 km resolution by ingesting HadCM3Q0 and ECHAM5 global climate models as inputs, respectively. The extracted outputs (maximum temperature, minimum temperature, solar radiation and rainfall) from the two RCMs were used as weather inputs in the DSSAT crop simulation model. The simulations were run with the CDZ predominant varieties viz., ADT 43 and CR 1009 for the period from 1971-2098. Besides to understand the effect of enrichment of CO2, runs were made with a base level of CO2 at 330 ppm and with a gradual increment of CO2 over the years (Table 1).

Table 1: CO2 increments (ppm) over base of 330 ppm over decades

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<tbody>
<tr>
<td>CO2 increment (ppm)</td>
<td>8</td>
<td>24</td>
<td>38</td>
<td>62</td>
<td>113</td>
<td>165</td>
<td>216</td>
</tr>
<tr>
<td>CO2 (ppm)</td>
<td>338</td>
<td>354</td>
<td>368</td>
<td>392</td>
<td>443</td>
<td>495</td>
<td>546</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>2041-50</th>
<th>2051-60</th>
<th>2061-70</th>
<th>2071-80</th>
<th>2081-90</th>
<th>2091-2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 increment (ppm)</td>
<td>268</td>
<td>319</td>
<td>371</td>
<td>422</td>
<td>474</td>
<td>525</td>
</tr>
<tr>
<td>CO2 (ppm)</td>
<td>598</td>
<td>649</td>
<td>701</td>
<td>752</td>
<td>804</td>
<td>855</td>
</tr>
</tbody>
</table>
Projected boro rice yields for different locations of West Bengal using DSSAT model

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With the ongoing consciousness and worry about climate change, it is important to assess the associated impacts on agricultural production. The annual global temperature has increased by 0.74 °C in the past 100 years (IPCC, 2007) and it is projected that increase of temperature by 2100 may be 2.4 °C to 5.8 °C. The recent IPCC report and other worldwide studies show a probability of 10-30% loss in crop production in India with increase in temperature around 2050. The long term future climatic projections have been generated by various global circulation models (GCMs) and regional circulation models (RCMs). Simulation model becomes a very essential tool to predict the future yield of a crop and the possible adaptation measure against that (Aggarwal and Mall, 2002).

The field study was carried out at the C Block Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani under New Alluvial Zone of West Bengal. Required date for validation of the DSSAT Crop Growth model were collected. After validation, the model was used to study the impact of climate change at ten different stations covering five agro-climatic zones of West Bengal. Data on growth parameters, like LAI, biomass, plant height and number of tillers and the meteorological data on radiation, temperature were measured as per model input requirement. Phenological observation on plant emergence, 50% flowering, tillering, grain filling, anthesis, maturity and harvesting were also recorded.

To work with the model, we collected weather data from PRECIS (Providing Regional Climates for Impact Studies) output. Details of the projected climatic scenario up to the year 2053 are arranged within PRECIS (Wilson et al., 2005) output. Soil data of selected districts were used in DSSAT model. Through an iteration method the genetic coefficients of three varieties viz, IR-36, Satabdi, and Khitish was worked out and presented in Table 1.

The model predictions revealed that the rice yield at Kalyani may decline by 181 kg ha⁻¹ (-6.38%) and 374 kg ha⁻¹ (13.18%) from the present level (2836 kg ha⁻¹) for the year 2030 and 2050 respectively. A decreasing trend though of varying magnitude was predicted for other locations that included Krisnanagar, Bankura and Purulia. On the other hand increasing trend of yields were observed at locations of Maldah and Balurghat located in the old Alluvial regions. At Coochbehar the yield increment for 2030 and 2050 may be to the tune of 427 kg ha⁻¹ and 339 kg ha⁻¹ compared with the present yield whereas the respective increases may be of the order of 343 kg ha⁻¹ and 397 kg ha⁻¹ at Jalpaiguri. At Diamond Harbour although yield will be slightly increased by 0.17% in 2030 but it may decrease by 3.24% by 2050. The yield will remain more or less stable at Canning.

It is therefore, concluded the decrement of future yield of rice at Kalyani, Bankura, Purulia, Krisnanagar, Canning may probably be attributed to the increasing temperature in the future.

Table 1: Genetic coefficients for rice cv. IR-36, Khitish and Satabdi at Kalyani

<table>
<thead>
<tr>
<th>Variety</th>
<th>P1</th>
<th>P2R</th>
<th>P5</th>
<th>P2O</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR 36</td>
<td>590.0</td>
<td>149.0</td>
<td>430.0</td>
<td>11.7</td>
<td>68.0</td>
<td>0.0230</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Khitish</td>
<td>700.0</td>
<td>100.0</td>
<td>490.0</td>
<td>11.4</td>
<td>48.0</td>
<td>0.0220</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Satabdi</td>
<td>660.0</td>
<td>90.0</td>
<td>480.0</td>
<td>12.1</td>
<td>56.0</td>
<td>0.0235</td>
<td>0.80</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Here, P1: Time period (expressed as growing degree days, GDD), P2R: Extent to which phasic development leading to panicle initiation is delayed (expressed as GDD °C), P5: Time period (in GDD °C), P2O: Critical photoperiod or the longest day length (hours), G1: Potential spikelet number coefficient, G2: Single grain weight (g), G3: Tilling coefficient (scalar value), G4: Temperature tolerance coefficient (Usually 1.0 for variety, grown in normal environment).

REFERENCES


**Effect of rainfall on cotton yield in Yavatmal District**

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Rainfall plays an important role in agricultural production and thereby influence economy of farmers. Decreasing trend in monsoon rainfall was reported over some parts of country. Effect of drought is accentuated by the higher coefficient of variability over region of low seasonal rainfall (Parthasarathy, 1984). Analysis of the observed climate records globally revealed increase in temperature, both night and day temperatures. At all India level, there is no trend in monsoon rainfall during last 100 years, but there are some regional patterns. Areas of increasing trend in monsoon rainfall were also found (Sharma, 2008).

In Vidarbha region, cotton is the most important cash crop grown on an area of 13 lakh ha with production of 27 lakh bales of cotton (2008-09). The productivity of cotton in Vidarbha is dependent on monsoon rain and about 95 to 98 per cent area is under rainfed cultivation. The Yavatmal District is predominately cotton growing district in the state. The impact of global warming on rainfall and cotton lint in Vidarbha revealed inverse relation with rainfall and cotton lint yield in four out of five districts in Vidarbha (Deshmukh, and Lunge, 2012).

In view of the above, an attempt has been made to study the impact of rainfall on cotton yield in Yavatmal District, with the objective to study the rainfall pattern during study period, to find out rainfall at various levels of probability and to study effect of rainfall on cotton yield.

The data on weekly rainfall for the period 1990 to 2011 was recorded from Meteorological observatory, Agricultural Research Station, Yavatmal and data on average yield (lint) kg per hectare from Epitome of Agriculture published by Government of Maharashtra.

The statistical analysis was done to workout variability in rainfall, the probabilities of seasonal rainfall for deficit rainfall, excess rainfall and the effect of rainfall on cotton yield by calculating different descriptive viz. Coefficient of Variation (%), Coppock’s instability index, gamma distribution and regression analysis.

**Rainfall pattern**

The performance of rainfall pattern during cotton growing period in the Yavatmal District was studied by using coefficient of variation and Coppocks instability index and the results are presented in Table 1.

<table>
<thead>
<tr>
<th>Metrological Week</th>
<th>Mean (mm)</th>
<th>CV (%)</th>
<th>CII (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>1.7</td>
<td>289.</td>
<td>240</td>
</tr>
<tr>
<td>23</td>
<td>21.7</td>
<td>171</td>
<td>97</td>
</tr>
<tr>
<td>24</td>
<td>72.8</td>
<td>127</td>
<td>47</td>
</tr>
<tr>
<td>25</td>
<td>59.2</td>
<td>96</td>
<td>79</td>
</tr>
<tr>
<td>26</td>
<td>64.4</td>
<td>105</td>
<td>62</td>
</tr>
<tr>
<td>27</td>
<td>62.9</td>
<td>87</td>
<td>81</td>
</tr>
<tr>
<td>28</td>
<td>60.5</td>
<td>89</td>
<td>63</td>
</tr>
<tr>
<td>29</td>
<td>84.8</td>
<td>79</td>
<td>38</td>
</tr>
<tr>
<td>30</td>
<td>80.6</td>
<td>83</td>
<td>47</td>
</tr>
<tr>
<td>31</td>
<td>87.7</td>
<td>73</td>
<td>45</td>
</tr>
<tr>
<td>32</td>
<td>76.1</td>
<td>73</td>
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</tr>
<tr>
<td>33</td>
<td>43.5</td>
<td>106</td>
<td>79</td>
</tr>
<tr>
<td>34</td>
<td>51.9</td>
<td>101</td>
<td>62</td>
</tr>
<tr>
<td>35</td>
<td>64.0</td>
<td>105</td>
<td>34</td>
</tr>
<tr>
<td>36</td>
<td>44.4</td>
<td>93</td>
<td>96</td>
</tr>
<tr>
<td>37</td>
<td>32.3</td>
<td>107</td>
<td>91</td>
</tr>
<tr>
<td>38</td>
<td>33.9</td>
<td>110</td>
<td>76</td>
</tr>
<tr>
<td>39</td>
<td>21.4</td>
<td>110</td>
<td>84</td>
</tr>
<tr>
<td>40</td>
<td>24.9</td>
<td>143</td>
<td>41</td>
</tr>
<tr>
<td>41</td>
<td>14.9</td>
<td>134</td>
<td>100</td>
</tr>
</tbody>
</table>

It is revealed from the Table 1 that inconsistency in rainfall was recorded in almost all the weeks during study period. However, the meteorological weeks 22nd, 23rd, 24th, 38th, 40th and 41st recorded highest inconsistency in rainfall and the same was confirmed by Coppock's instability index indicating that the rainfall behavior during these weeks is erratic in nature. The meteorological weeks 29th, 30th, 31st and 32nd are of assured rainfall with minimum variability.
Rainfall probability analysis of Lakhimpur, Assam

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Rice, wheat, oil seeds and vegetables are the principal crops of Lakhimpur occupu major portions of the gross cropped area. Agriculture is mostly dependent on the monsoon. Drought constitutes a major hazard in the district. Intermittent gaps in precipitation and moisture stress during the monsoon season gives rise to serious setback in production during the kharif season, which is the main stay of agriculture in the district. Several rainfall related risk analysis have been reported by several authors (Chakraborty et al., 1990; Chakraborty and Chakraborty, 1991; Rai et al., 2009; Singh et al., 2009; Mukherjee et al., 2012) for different agro-climatic zones of India with the help of incomplete gamma distribution (Thom, 1958) as well as Markov chain method. In most of the studies, the scientists have suggested cropping pattern considering the rainfall amount at different probability levels. Keeping this in view, agricultural drought, meteorological drought, seasonal rainfall and rainfall probability of Lakhimpur were analyzed using Markov-chain model.

The daily rainfall data for the period 1985-2011 (27 years) at Lakhimpur district (27°17’ N latitude, 94°10’ E longitude and 87 AMSL altitude) of North Bank Plain Zone of Assam have been used for analysis.

Agricultural drought is the period of four consecutive weeks (of severe meteorological drought) with a rainfall deficiency of more than 50 per cent of the Long Period Average (LPA) or with a weekly rainfall of 5 cm or less during the period from mid-May to mid- October (kharif season) when 80 percent of the country’s total crop is planted, or six such consecutive weeks during the rabi season.

According to India Meteorological Department, meteorological drought is subdivided into following three categories based on rainfall deficit from normal:

1. Mild : 0-25% deficit
2. Moderate : 26-50% deficit
3. Severe : > 50% deficit

The average rainfall, rainy days, standard deviation and coefficient of variation was calculated for the four seasons separately viz winter (Jan-Feb), summer (Mar-May), Southwest (June-Sept) and Northeast (Oct-Dec). Probability of getting certain amount of rainfall (30, 40 and 50 mm) in a particular week or consecutive weeks was analyzed using Markov-chain model and incomplete gamma distribution through Weather Cock (v 1.0) software developed at CRIDA.

Analysis of 27 years weather data of Lakhimpur showed that kharif season-drought was observed during the study years. Only in the year of 2000, the agricultural drought was found and it also prolonged for 4 weeks. The occurrence of rabi season drought was more than the kharif season-drought. In rabi season, the agricultural drought was mostly prolonged for 5 weeks except in the year of 1987 and 2011. During 1987 and 2000, it continued for 10 weeks and 11 weeks respectively. During rabi season of 1987-88, the agricultural drought was prolonged up to 1st January to 25th February of 1988. Likewise, agricultural drought during rabi season of 2000-01 was prolonged up to 1st January to 25th February of 2001.

Meteorological drought analysis

The average rainfall of the district is 2949 mm. It was observed that, among twenty seven years, the average annual rainfall was below normal rainfall for 12 years. Out of the 12 years, 3 years (1987, 2002 and 2010) was in moderate drought situation and the extent of deficiency was to the tune of 25.7% to 30.1%. Other 9 years (1988, 1993, 1996, 2001, 2003, 2004, 2006, 2007 and 2011), the extent of deficiency was to the tune of 0.7% to 24.0% causing mild drought situation. During rest of the years the annual rainfall received by Lakhimpur was 0.3-28.7% higher over normal annual rainfall. Thus, during the study period, mild drought occurred in 33% years, moderate drought occurred in 11% years and remaining of the 56% years there was normal or above normal.
Crop evapotranspiration can be estimated by direct measurements of the water loss from a soil (using lysimeters) and vegetation samples or can be estimated by using the reference crop evapotranspiration (ET$_0$) and crop coefficient ($K_c$) (Doorenbos and Pruitt, 1977; Kang, 1986 and Kerr et al., 1993). Accurate measurement of crop evapotranspiration is difficult since specific devices and measurements of various physical parameters or the soil water balance or lysimeters are required. These methods are often expensive and can accurately be determined only by well-trained research personnel.

Crop coefficients also serve as an aggregation of the physical and physiological differences between crops (Allen, 1994). Although $K_c$ values are suggested by various researchers for a number of crops grown under different climatic conditions (Doorenbos and Pruitt, 1977), these values are general estimates and can only be used at locations where local data are not available. For a more accurate estimate on crop water requirements, $K_c$ values need to be derived empirically for each crop based on lysimetric data and local climatic conditions (Allen et al., 1998). Studies on crop coefficients for soybean are very limited and are not well documented for semi-arid region of Marathwada. Keeping this in view, a study was conducted to estimate crop evapotranspiration in soybean through lysimeter, develop $K_c$ values for different phenophases and compare with empirical estimates using different approaches.

A field experiment was conducted at Experimental Farm, Department of Agricultural Meteorology, Marathwada Agricultural University, Parbhani during kharif season of 2007 and soybean cv. MAUS – 71 was sown in the field as well as in two weighing type lysimeters. Crop was raised in both the seasons with all recommended package of practices and the crop in the lysimeters was kept weed free. Daily actual crop evapotranspiration (ET$_c$) was derived from the difference in weight of two lysimeters in 24 hours, which was recorded daily at 8.30 am. The mean of the two lysimeters was considered as the daily ET$_c$ and phenophase-wise ET$_c$ values were deduced from the daily data. Weather data required for the computation of ET$_0$ by different methods were collected from the Meteorological Observatory, Marathwada Agricultural University, Parbhani. Daily values of ET$_c$ were estimated by using the Blanney-Criddle, Thornthwaite, Pan evaporation and modified Penman as given in Doorenbos and Pruitt (1977).

Crop coefficients ($K_c$) on daily time step were calculated as:

$$K_c = \frac{ET_c}{ET_0}$$

where, ET$_c$ is the actual crop evapotranspiration mm day$^{-1}$ measured from lysimeter and ET$_0$ estimated by the Blanney-Criddle / Thornthwaite / Pan evaporation / modified Penman methods.

Water requirements of soybean for maximum production generally vary between 450 and 700 mm depending on climate and length of growing period (FAO, 2013). Actual AET observed in the present study was 354 mm. The $K_c$ values reported by FAO (2013) for soybean for different stages are 0.3-0.4 during the initial stage (20 to 25 days), for the development stage 0.7-0.8 (25 to 35 days), the mid-season stage 1.0-1.15 (45 to 65 days), the late-season stage 0.7-0.8 (20 to 30 days) and at harvest 0.4-0.5.

Crop coefficients derived from various ET$_0$ approaches

Phenophase wise $K_c$ values deduced by employing Eq.1 with ET$_0$ values estimated by different approaches are presented in Table 1. The $K_c$ values ranged from 0.34 - 1.07 during P$_1$ phenophase to 0.56 - 1.52 during P$_4$. It could be noticed that $K_c$ values estimated by Blanney-Criddle as well as pan evaporation methods were close to unity for majority of the phenophases. A $K_c$ value close to unity indicates that ET$_0$ estimated by the method in question is close to AET of soybean. $K_c$ values deduced using modified Penman during majority of the phenophases were the lowest indicating that ET$_0$ estimated by modified Penman were relatively on higher side compared to other three methods. Thornthwaite’s based $K_c$ values were the second lowest in that order. The mean $K_c$ values for the entire crop season were of the order of 1.08, 0.54, 0.70 and 1.11 for the ET$_0$ estimated by Blanney-Criddle,
Rainfall variability and its impact on kharif rice in Nalanda district of Bihar

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Rainfall is a very important natural resource, which plays a pivotal role in the success or failure of agricultural crop production in an area. In the recent years, successful and profitable production of kharif rice, which is a very important crop in Bihar, has been a gamble with erratic monsoon system. Thus, study of rainfall variability during kharif crop growing season assumes significance for evolving better crop management strategy under rainfed condition. As Nalanda district is situated in Zone IIIB (south Bihar alluvial plains) where average rainfall is relatively less than other zones of Bihar and most of the annual rainfall is received during monsoon season, there is ample scope of rain water harvesting for supplemental irrigation and pre-sowing irrigation for subsequent rabi crops. Several authors have carried out rainfall analysis for crop planning at district level (Ramana Rao et al., 1979; Gupta et al., 2010). But variability of rainfall within a district is too large. The variability of rainfall at block level plays important role in crop planning. Kothari et al., (2008) opined that district crop planning was required at micro (tehsil) level for efficient utilization of natural resources. Swaminathan (2005) suggested for developing contingency crop planning to suit different rainfall patterns and work out comprehensive production programme down to village level for proactive monsoon management. Keeping this mind, an attempt has been made in this paper to study the rainfall variability down to block level of Nalanda district for better rice crop planning. Probability analysis of rainfall, identifying the moisture stress condition during the growing season of rice crop and the effect of monsoon rainfall on rice productivity have also been studied.

Daily rainfall data for the period from 1974 to 2010 of four blocks viz. Biharsarif, Asthawan, Nursarai and Rahui of Nalanda district in the Zone IIIB of Bihar were collected from the Directorate of Statistics and Evaluation, Government of Bihar. The growing season of rice crop was divided into three growth phases viz. vegetative phase ( transplanting to 50% booting stage) during 28 standard meteorological weeks (SMW) [9-15 July] to 38 SMW (17-23 September), reproductive phase (50% booting to 50% flowering stage) during 38 SMW (17-23 September) to 41 SMW (8-14 October) and ripening phase (50% flowering to maturity stage) during 41 SMW (8-14 October) to 44 SMW (29 October – 4 November). Daily rainfall data for the period from 1974 to 2010 of the four blocks of the district were analyzed to obtain annual, seasonal and monthly rainfall, rainy days, expected weekly rainfall at different probability levels and accumulated rainfall during different phases of growth of kharif rice pertaining to four blocks were computed. Agricultural droughts of these blocks during the period from 1974 to 2010 were also characterized. Length of growing period (LGP) was worked out for efficient crop planning for growing kharif rice in the district. Conditional probabilities of occurring two consecutive wet weeks with 30 mm threshold rainfall per week during kharif season in different blocks have been computed for working out moisture stress period during growing season of rainfed rice. Daily rainfall data were summed up over different growth phases. Simple correlation coefficient values between kharif rice productivity and accumulated rainfall prevailing at different phases of growth were computed.

Variation in agroclimatic environment

The mean annual rainfall varied from 777.1 mm received in 39 rainy days in Rahui block to 926.1 mm in 45 rainy days in Biharsarif block. The C.V. of annual rainfall and rainy days were highest (34.2% and 32.3%, respectively) at Rahui, whereas the lowest C.V. values were recorded at Biharsarif (28.1% and 19%, respectively) followed by Nursarai (30.8% and 26.3% respectively). It is evident that annual rainfall and rainy days were more variable at Rahui than those in remaining blocks. Results further revealed that the C. V. of monsoon season rainfall ranged between 27.5% at Biharsarif and 37.0% at Rahui, indicating more stable monsoon rainfall at Biharsarif. However, the highest C.V. of rainy days during monsoon season (28.2%) was observed at Rahui and the lowest C. V. (17.6%) was recorded at Biharsarif implying better distribution of monsoon rainfall for kharif rice in Biharsarif block in the district. Monsoon rainfall contributed 87.3 to 89.5% of the total annual rainfall over different blocks under study, signifying ample scope