Comparison of different models for estimation of net primary productivity in India

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ABSTRACT

Net primary productivity (NPP) and biomass production potential were estimated for 167 stations of India by different models using weather parameters downloaded from CLIMWAT database of FAO. Moisture adequacy index (MAI) as suggested by Hargreaves was calculated. Chikugo model (NPPch), Miami models (NPPmp) and (NPPmt); Thornthwaite (NPPth) and Waginengen, (BIOwag) models were selected for estimating NPP. Correlation and best fit regression equations between MAI and NPP values showed positive relation with Chikugo (NPPch) and Miami based on precipitation (NPPmp) models but negative relation with others. Negative relations of MAI and NPP are not natural therefore the suitability of those models was rejected. The correlation coefficient with MAI to NPPch & NPPmp was 0.76 and 0.71 respectively. Chikugo model (NPPch) was found to be more sensible than Miami model because it estimated NPP in a broader range. The best fit equation developed using NPPch and MAI values showed a logarithmic relation (NPPcheq = 32.6 ln(MAI) + 33.13, R² = 0.788) confirming that the net primary productivity by Chikugo model can also be estimated for the country using this as an alternative equation.

Keywords: Net primary productivity, biomass potential, moisture adequacy index (MAI), Chikugo model, Precipitation.

Net primary productivity (NPP) a key component of biogeochemical cycle is defined as the amount of dry matter produced by plants per unit time and space. NPP reflects the capacity of plants to capture solar radiation for carbon fixation into the ecosystems in the form of organic matter. NPP estimation enables us to identify the gap in the ecosystem potential to the actual NPP, which would give way to carbon sequestration into the ecosystems in the face of climate change. Various models to estimate NPP for diverse climatic conditions such as, Chikugo model (Uchijima and Seino, 1985) for Japanese condition, Miami models (Leith, 1972) for US condition, Thornthwaite model (Leith, 1972) for European condition have been developed to estimate forest yield. The Wageningen model (Doorenbos and Kassam, 1979) has been developed to estimate gross dry matter (GDM) production to estimate crop yield. NPP estimates from different models varied considerably in view of the difference in their input parameters. A suitable procedure to estimate the terrestrial NPP for the territory of the country is not available.

Hargreaves (1971) defined the moisture adequacy index (MAI) as the ratio of rainfall to the estimated potential evapotranspiration for the concerned period. He classified the condition as very deficient (<0.33 MAI), moderately deficient (0.34-0.67 MAI), somewhat deficient (0.68-1.0 MAI), adequate moisture (1.00-1.33 MAI) and excessive moisture (>1.34 MAI). Vegetative growth and forest cover in the moist areas is very high as compared to deficit areas. In view of these facts, the objective of this study is to select out a suitable NPP model for Indian condition using MAI as a scale.

MATERIALS AND METHODS

CLIMWAT 2.0 is a joint publication of the Water Development and Management Unit and the Climate Change and Bioenergy Unit of FAO which offers normal weather data for about 5000 stations across the world. Weather data from the CLIMWAT database was taken to estimate net primary productivity (NPP) and gross dry matter (GDM) production for 167 stations of India. Moisture adequacy index (MAI) as per the procedure suggested by Hargreaves (1971) was calculated for all the stations of the country. Best fit equation and correlation coefficient between MAI and NPP were developed.
Estimation of minimum and maximum air temperature using MODIS data over Gujarat

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ABSTRACT

Minimum and maximum air temperatures are important input parameters for meteorological and agricultural models. Generally minimum and maximum air temperatures are measured at weather stations on the ground. However these measurements are not available with enough spatial density which makes it difficult to be used in real-time applications. Compensation of this lack of information can be achieved by satellite-based methods. The present study investigates the potential of deriving the spatial distribution of minimum and maximum air temperatures with the help of land surface temperature (Ts) and normalized differential vegetation index (NDVI) products from the moderate resolution imaging spectroradiometer (MODIS) sensor and air temperature (Ta) data from automatic weather stations (AWS) over Gujarat region of India. The minimum Ta was successfully retrieved through a regression analysis between night time MODIS Ts and AWS measured minimum Ta over all stations, since the minimum Ta is strongly associated with night time Ts. While, the maximum Ta was retrieved using a method, namely, temperature vegetation index (TVX) approach based on the linear relationship between Ts and NDVI data. Results showed that MODIS estimated minimum Ta were in good agreement with the measured values by mean absolute error (MAE) of 1.49 °C and root mean square error (RMSE) of 1.95 °C. While, maximum Ta retrieved through TVX approach showed a good retrieval accuracy with a MAE of 1.96 °C and RMSE of 2.46 °C.

Keywords: Land surface temperature, NDVI, air temperature, MODIS

Minimum and maximum air temperatures (hereafter called Ta_min and Ta_max) are important climatological variables and accurate mapping its spatial-temporal distribution is useful in wide range of applications in the field of ecology, hydrology and atmospheric sciences. Air temperature (Ta) has been traditionally measured at large number of meteorological stations. However such meteorological measurements are not usually available with enough spatial density for accurate research purposes (Vogt et al., 1997; Willmott et al., 1991). The spatio-temporal pattern of near surface Ta is complex because it is affected by properties that vary greatly in both space and time (Prihodko and Goward, 1997). Satellite-based remote sensing technique is an alternative to provide spatially distributed information, because of its capability of systematic and synoptic coverage over a large geographical area (Czajkowski et al., 1997; Goward et al., 1994). The satellite-derived Land Surface Temperature (Ts) has a significant relationship with the Ta in the boundary layer because of the process of conduction and convection of heat fluxes in the lower atmosphere, resulting from the radiative heating of the earth’s surface (Oke, 1987). This effect will be prominent during clear sky days when land surface characteristics have a major influence on surface energy balance. Under such conditions, it should be possible to map the spatial pattern of the Ta with a higher accuracy, using remotely sensed observation. Satellite derived Ts and Normalized Differential Vegetation Index (NDVI) data provide an opportunity to estimate Ta_min and Ta_max (Nemani and Running, 1989; Goward et al., 1994; Prihodko and Goward, 1997; Florio et al., 2004). Earlier studies have focused basically on five approaches to estimate Ta_min and Ta_max namely; Statistical approach (Davis and Tarpley, 1983; Green and Hay, 2002; Florio et al., 2004; Vancutsem et al., 2010), empirical solar zenith angle approach (Cresswell et al., 1999), energy balance approach (Sun et al., 2005), TVX approach (Nemani and Running, 1989; Goward et al., 1994 and
Climate suitability evaluation for Poplar in Uttarakhand using GIS application

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ABSTRACT

The objective of this study was to evaluate the suitability of climate for poplar in Uttarakhand. The study area located between latitude 28º43’N and 31º27’N and longitude 77º34’E and 81º02’E. and covers approximately 53,485 sq km. The identified theme layers include temperature (maximum, minimum and average temperature), precipitation and soil properties. Those thematic layers with their associated attribute data were encoded in GIS database. Overlay operation was performed on those layers as the suitability model assigned. The model was a result of the crop requirement analysis. Models were applied to the overlay process and to formulate the suitability classes. The result indicated that 41.8%, 26.4%, 10.7%, 1.6% and 19.5% area of the total geographical area of the state, the most suitable, suitable, moderate suitable and less suitable, respectively for poplar plantation. On the basis of the results, it can be recommended that poplar can be grown on the larger area of Uttarakhand state, especially the wastelands can be utilized for cultivation of poplar which will not only be beneficial for socio-economic point of view but also sequester the carbon from the atmosphere.

Key words: Poplar, climate suitability, GIS

Poplar species occupy a unique and important position in the rural economy of India. They are known for their fast growth, easy vegetative propagation, capability to enrich surface soil by adding leaf litter and the ability to provide substantial production (10-30 m³ha⁻¹yr⁻¹) on a short rotation of 6 to 12 years. The tree crown intercept rains, acts as wind breaks and thus checks soil erosion and minimizes the effects of wind on associated crops. Poplar species in India are winter deciduous and remain leafless for 3-4 months, thereby favouring intercultivation of agricultural crops throughout the rotation (Naithani et al. 2001). There are 35 species of poplar currently recognised in the world. Poplar is widely planted above 28 degree N latitude in India. Fast growth rate of poplar, high financial return and multiple utility, have become a very important species for cultivation both in the forest and farms. Poplar wood is widely used in plywood and match splints. Market has been developed for poplar in Haryana, Punjab and Uttar Pradesh (Naithani et al. 2001).

Geo-informatic technology which at present embodies geographic information system (GIS), remote sensing (RS) and global positioning system (GPS) has been further developed to provide greater efficiency. In particular, GIS has been used extensively for spatial analysis and land suitability as GIS functions could be employed for several forms of information including point, line and area. The system, therefore, possesses greater storage capacity for spatial information processed with identical standard. GIS also provides greater reliability with lesser time and cost compared with manual operation (Bera et al., 2003). The geospatial technology can be very efficiently used in analyzing the suitability of agricultural crops, which will not only save the huge cost of experimentation but also save precious time (Harashah, 1994). Several attempts have been done for suitability classification (Al-Mashreki et al. 2011; WeiGuang et al. 2010; Ekanayake et al. 2003, Bhagat et al. 2009). Keeping this in view this study aimed to use GIS to classify the suitability of land with integrated information for poplar plantation. The spatial information resulted from this study could be utilized the wastelands for plantation which not only help to increased income of villages but also minimize environmental problems.

MATERIALS AND METHODS

The area of present study has been considered the state of Uttarakhand which is surrounded by Himachal Pradesh in the north-west and Uttar Pradesh in the south and shares its international borders with Nepal and China. This area is located between latitude 28º43’N and 31º27’N
Determination of crop coefficients and optimum irrigation schedules for bidi tobacco and pearl millet crops in central Gujarat

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ABSTRACT

An attempt was made to determine the rate of ETc and crop coefficients during various growth stages of bidi tobacco and pearl millet crops in central Gujarat by water balance approach. From the crop coefficients and meteorological data, optimum irrigation schedules with furrow and drip irrigations were developed. The duration of various growth stages of bidi tobacco crop identified as 30, 40, 50, 30 days for initial, development, mid season and late season respectively. The crop coefficients for these periods Kc initial, Kc mid, Kc end were found to be 0.42, 0.85 and 0.44 all in respective order. Similarly for the pearl millet crop identified as 15, 25, 30, 15 days for initial, establishment, maturity and late season respectively. The crop coefficients for these periods Kc initial, Kc mid, Kc end were found to be 0.33, 0.73 and 0.42 respectively. The identified duration of crop growth stages and respective derived crop coefficients for various growth stages of bidi tobacco and pearl millet crops will be useful to estimate crop water requirements and further developing optimum irrigation schedules for achieving higher water productivity.

Key words: bidi tobacco, pearl millet, crop coefficients, furrow, drip, irrigation, schedules.

Crop evapotranspiration (ETc) is used to determine the water requirement of the crop and developing irrigation schedules. Measurement of ETc being difficult, the same is commonly estimated using the meteorological data. A common procedure for estimating ETc is to first estimate reference crop evapotranspiration (ETc) from weather data and then to apply empirical crop coefficient (Kc), i.e. the ratio of crop evapotranspiration (ETc) to reference crop evapotranspiration (ETc). Different methods have been attempted by many scientists to estimate the ETc for different crops in different climatic conditions (Khandelwal et al. 1999; Pandey et al. 2008; Gorantiwar et al. 2011). For estimating ET0, Penman- Monteith method is most preferred as it suits a wide variety of climatic conditions (Kashyap and Panda, 2001; Khandelwal & Pandey, 2008; Sahoo et al. 2009). The FAO adopted this method as a global standard (Allen et al. 1998). Sikka et al. (2001) also used this method of computing ET0 because of its better performance in hilly region of Nilgiris. Although crop co-efficient values for different crops grown under different climatic conditions as suggested by Doorenbos and Pruitt (1977) are used where locally measured data are not available; Allen et al. (1998) have suggested that these values need to be derived empirically for each crop based on the local conditions.

In Central Gujarat, the major crops, viz. bidi tobacco (Nicotiana tabaccum), pearl millet (Pennisetum glaucum), cotton (Gossypium sp.), castor (Ricinus communis) are commonly grown both under rainfed and irrigated conditions. Under irrigated conditions, bidi tobacco-pearl millet is the major cropping system, which is practiced by the famers. Mostly, farmers of this zone raise the bidi tobacco seedlings from second fortnight of July to first fortnight of September. Planting is done in second fortnight of September. Tobacco is harvested by the end of February and during first fortnight of March, sowing of pearl millet is completed. This crop continues up to end of May. These crops are growing in post monsoon season (rabi and summer season) and water requirement are completely met from the irrigation. The yield of these crops varies and suffers due to uneven water distribution and improper irrigation scheduling. The study
Evapotranspiration and water use efficiency of hybrid napier + berseem intercropping system under organic and inorganic nutrition

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ABSTRACT

An experiment was conducted during rabi seasons of 2009 and 2010 to assess the crop evapotranspiration of hybrid napier+berseem intercropping system using four weighing lysimeters under organic and inorganic nutrition. The estimated water use efficiency of the system shows that the maximum water use efficiency coincides with the second cutting and it was higher in case of organic as compared to inorganic nutrition. Cut wise water use efficiency of the intercropping system as a function of evapotranspiration under both situations showed a significant (P < 0.05) negative linear relationship. The crop coefficient value at each cutting interval has crossed the unit value (>1) and the highest value coincides with the first cutting in organic as well as inorganic situation.

Key words: Hybrid napier+berseem, evapotranspiration, water use efficiency, crop coefficient, weighing lysimeters

The hybrid napier (Pennisetum purpureum x P. americanum) is highly valued for its abundant quality forage, round the year fodder availability, regenerative ability, and suitability to silage and hay making. It yields upto 110-120 t fresh fodder as sole crop, 90-110 t in intercropping in North and Central India and upto 288 t ha⁻¹ year⁻¹ in Western and coastal regions of the country. Perennial NB hybrid based cropping system registered higher net return in central zone than most adopted sequences (Agrawal et al., 2008). It contains 7.6-8.8% CP, 70-72% neutral detergent fibre, 41-42% acid detergent fibre and 10-11.5% ash on dry matter basis at optimum harvesting stage (Agrawal et al., 2001). The hybrid napier has wider adaptability and grown all over the country, particularly in milk shed area of Gujarat, Maharashtra, Kerala and North and Central India. It is a tropical grass with high water demand. It can withstand drought for a short spell and regenerate with rains. Light showers alternated with bright sunshine are very congenial to the crop.

Berseem (Trifolium alexandrinum L.) is the most forage yielding leguminous crop of Northern and Central India produces 70 to 90 t nutritive, succulent and palatable forage in 4 to 6 cuts. Since hybrid napier remains dormant during winter season, hence, a combination of napier grass with berseem not only improves the quality but also the productivity and sustainability of the system. In multi-locational trials AICRP (FC), berseem + hybrid napier-cowpea sequence has been found highly productive in northern and central zones of the country and produced upto 214.1 t ha⁻¹ year⁻¹ (Agrawal et al., 2008). The use of organics in forage crops is gradually increasing due to realising the importance of organic manure in multicut perennial fodders for good quality forage. The ameliorative effects of organic manures besides improving the chemical and biological properties are also known to influence the water retaining characteristics of soil. Rai et al., (2010) reported markedly higher yields with use of organic nutrient sources in guinea grass in comparison to inorganic sources.

Estimation of evapotranspiration as a function of crop stage is important for determining crop water use and efficient irrigation management. Evapotranspiration loss and rate of evapotranspiration indicate the amount of water required at different growth period for its optimum production. Few measurement of evapotranspiration and water use efficiency of berseem is available (Alvarez and Quiroga 1992; Pradeep Behari and Singh 1998; Pradeep Behari et al., 2003). The effect of crop characteristics on crop water requirement is given by the crop coefficient (Kc). The significance of crop coefficient lies in assessment of crop water requirement for irrigation scheduling. Several workers (Bredero 1991; Chaudhary et al., 1999; Singh et al., 2007) reported the crop coefficients of different crop for Indian region. However, the information on these aspects for hybrid napier + berseem intercropping
Impact of projected climate change on wheat and maize in middle Gujarat agro-climatic zone


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ABSTRACT

The impact of projected climate change on wheat and maize (kharif and rabi) have been studied for Anand and Dahod districts of Gujarat state using PRECIS output of A2 and base line data. Yield simulation study was performed by InfoCrop model. The field experiment data on wheat collected at Anand during 2005-2009 and for maize collected at Dahod during 2004-07 respectively were used for calibration and validation of the model. The simulated yield over projected period (2071-2100) showed that nearly 38 to 43 % yield reduction was noted in both the cultivars as compared to their base yield. However, the yield reduction was lower under late sown condition (30th Nov.) and higher in early sown (1st Nov.).

In case of maize cultivars the percent reduction in yield during kharif season was higher in 15th July sowing as compared to 1st July sowing. Under normal (1st July) sowing nearly 40 % reduction in yield was simulated by model during projected period. During rabi season the yield reduction was less which clearly suggested that rabi sowing of maize found most beneficial under climate change as compared to kharif sowing.

Key words: PRECIS, simulation, InfoCrop, Climate change

MATERIALS AND METHODS

Climate change study

For climate change impact study, weather data for A2 scenario was derived from PRECIS downscaled model output prepared by IITM Pune in a grid size of 0.4 degree. Two periods of 30 years each, one for base line i.e., 1961-1990 (base line period) and another for A2 projected scenario i.e., 2071-2100 (projected scenario) for Anand and Dahod were considered for climate change impact study. There are gross difference between PRECIS base line daily weather data and actual weather data for the same period. Thirty year monthly average of daily weather parameters of base line data was subtracted from corresponding projected A2 scenario data and the difference obtained were used for computing weather data for projected period using actual observed data. In case of rainfall percentage difference on monthly sum of 30 years average data, between projected output and base line output were used as correction factor.
Agrometeorological indices of white clover (Trifolium repens) in western Himalayas

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ABSTRACT

Field experiments were conducted during 2009-2010 and 2010-2011 to study the growth performance of white clover (Trifolium repens L.) under different temperature regimes over the crop growth period. The agroclimatic indices for temperature viz., growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU) were computed for different phenological stages of the crop. Changes in weather parameters concomitant to different sowing time caused significant variation in the performance of the crop. The results indicated that the early sown crop had longer crop span (205 days) than the late sown (142 days). From emergence to seed maturity, white clover accumulated GDD of 2314±72 °C days, HTU of 17791±409 °C days hour and PTU of 29412±742 °C days hour, respectively. Positive correlations were found between fresh leaf weight, fresh stem weight and fresh root weight for GDD, HTU and PTU.

Key words: White clover, phenophases, heat units, heliothermal unit, photothermal unit.

Of the 250-300 odd species of genus Trifolium (family Fabaceae) (Anonymous, 2008), white clover (Trifolium repens L.) is the most important species in the temperate region of the world. The high forage quality and yield, besides its role in symbiotic N₂ fixation, make it a valuable forage crop. Owing to its wide adaptability under changing conditions of soil, and environmental variables, the species response to changing environmental variables has been used in several climate change models. T. repens is grown as a winter crop in northern India. Temperature is one of the most important climatic events that affect the growth, phenology and development of winter crop (Kalra, 2008).

Plants have a definite temperature requirement before they attain certain phenological stages. A change in optimum temperature during different phenological stages of a crop adversely affects the initiation and duration of different phenophases and finally economic yield of the crop. It is therefore indispensable to have knowledge of exact duration of phenophases in a particular environment and their association with yield attributes for achieving high yields (Kumari et al., 2009). Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat unit system (Haider et al., 2003 and Pandey et al., 2010). Air temperature based agromet indices viz., growing degree days (GDD), photothermal units (PTU), heliothermal units (HTU), have been used to describe changes in phenological behaviour and growth parameters (Singh et al., 2007; Kumar et al., 2008; Kumar et al., 2010). GDD or a similar linear unit system is widely used to predict crop development with air temperature. Similarly, attempts have been made to correlate phenology (Dhaliwal et al., 2007; Hundal et al., 1997) to total dry matter, growth and yield (Hundal et al., 2003; Murty et al., 2008). The selection of an appropriate base temperature is critical to the GDD or any heat unit model. The present study has been done to determine the phenological stages and heat unit requirement of T. repens under varied microclimate conditions.

MATERIALS AND METHODS

Field experiment

Field experiments were conducted during 2009-10 and 2010-11 in the experimental farm of CSIR- Institute of Himalayan Bioresource Technology, Palampur (1325 m amsl altitude, 32°06′05″N latitude, 76°34′10″E longitude), India. The treatment comprised of seven dates
Thermal time requirement and energy use efficiency for single cross hybrid maize in south Telangana agro climatic zone of Andhra Pradesh

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ABSTRACT

Field experiment was conducted during kharif seasons of 2009 and 2010 at Agricultural Research Institute, A.N.G.R. Agricultural University, Rajendranagar, Hyderabad to study heat and radiation use efficiency of maize crop. The experiment was in four dates of sowing (7 July, 21 July, 6 August and 22 August in 2009 and 18 June, 02 July, 17 July and 02 August in 2010) with recommended dose of fertilizer (200 kg ha⁻¹). Results revealed that the mean AGDD, AHTU and APTU were 1740±29, 9025±1477 and 21155±812, respectively from emergence to physiological maturity. Crop took 110±4 calender days from emergence to physiological maturity. Progressive delay in sowing caused a decrease in AGDD i.e., 1754 to 1717 in 2009 and 1788 to 1746 in 2010. Higher heat use efficiency of 8.44 and 8.42 kg °C day⁻¹ for biomass and 4.93 and 4.68 kg °C day⁻¹ for grain and radiation use efficiency of 7.99 and 8.19 kg MJ⁻¹ for biomass and for grain 4.55 and 4.57 kg MJ⁻¹ were obtained in crop sown on 21 July in 2009 and 18 June in 2010 respectively.

Keywords: Hybrid maize, GDD, Phenology, HUE, RUE

The critical agrometeorological variables associated with agricultural production are precipitation, air temperature and solar radiation (Hoogenboom, 2000). By relating and comparing the agro-climatological requirements of the crop with the existing agro-climatic conditions in an area, one can find the extent to which the requirements are satisfied during the different phases of the crop growth and development (Todorov, 1981). The growth rate and development of crops from planting to maturity is dependent mainly upon temperature. The effect of temperature on crop is accounted through the concept of heat unit, which is based on the fact that crops need certain amount of temperature requirement for the completion of each stage of its ontogeny. The seasonal variation of crops and varieties can be effectively answered through its heat unit requirements. According to Schulze et al. (1997), 1500 to 1700 growing degree days (GDD) are required for growing maize for grain, but can vary according to cultivar. As per Dahiya and Narwal (1989), the GDD requirement of maize cultivars showed variation with sowing dates depending upon temperature during each growth phase and also the cultivar.

In maize variation in sowing date modifies the radiative and thermal conditions during its growth. In the maize crop grown under well-supplied water and nutrient conditions, the temperature and solar radiation are reported to have greater effect on growth and development of crop. Shift in sowing dates directly influence both thermo and photoperiod, and consequently a great bearing on the phasic development and partitioning of drymatter. Quantification of these effects may help in the choice of sowing time and match phenology of crop in specific environment to achieve higher heat and radiation use efficiency.

Heat and radiation use efficiencies in terms of drymatter or yield are important aspects, which have great practical application. The total heat and radiant energy available to any crop is never completely converted to drymatter under even the most favourable agroclimatic conditions. Efficiency of conversion of heat and radiant energy into drymatter and grain yield depends upon genetic factors, sowing time and crop type (Rao et al., 1999). Maximum heat use efficiency and of 49.76 g°C⁻¹ day⁻¹ was obtained when the corn crop was sown on 15 June and the crop was fertilized with 120 kg N ha⁻¹ during Kharif season on alluvium soils during Kharif season in the Tarai region, (Kushwaha et al., 2010).

By keeping above facts a field investigation was carried out to generate information on phenophase wise thermal requirement and, heat and radiation use efficiency in Kharif maize of South Telangana agro climatic zone of Andhra Pradesh.
Accumulated heat unit requirement and yield of irrigated wheat (*Triticum aestivum* L.) varieties under different crop growing environment in central Punjab

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**ABSTRACT**

Field experiment was conducted during *rabi* seasons of 2009-10 and 2010-11 to study the phenology, accumulation of growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU), pheno-thermal index (PTI) and performance of wheat (*Triticum aestivum* L.) varieties grown under different sowing dates. The crop sown on October 25 took maximum calendar days, growing degree days, photo-thermal unit and helio-thermal unit for 75% earing and maturity which got reduced significantly with subsequent delay in sowing time. The grain yield recorded in October 25 was statistically at par with November 5. The significant reduction in grain yield of timely sown varieties was recorded when sowing was delayed beyond November 15. Among the varieties ‘PBW 621’ recorded the highest grain yield which was statistically on par with ‘PBW 550’. The timely sown wheat varieties like ‘PBW 621’, ‘PBW 343’, ‘DBW 17’ and ‘WH 542’ took highest calendar days, GDD, HTU, PTU and PTI for earing and maturity. However, in medium duration varieties like ‘PBW 550’ the significant reduction was noticed when sowing was delayed beyond November 25. The variety ‘PBW 550’ recorded the highest grain yield at November 15 sowing as compared to all other sowing dates.

**Key words:** Wheat, GDD, PTU, HTU, PTI, Grain yield

Wheat (*Triticum aestivum* L.) is an important *rabi* crop of North-western plains of India. It is the second most important cereal crop after rice. Wheat is a widely adapted crop it is grown from temperate irrigated to dry and high rainfall areas, and from warm humid to dry cold environments. Undoubtedly this wide adaptation has been possible due to the complex nature of its genome, which provides a fantastic plasticity to the crop. Wheat is a C₃ plant and as such it thrives in cool environments. It is grown under diverse agro-climatic conditions on 29.2 million hectares area in India with a production of 85.9 million tonnes during the season 2010-11 (Anonymous, 2011).

Sowing time of wheat is one of the most important factors that governs the crop phonological development and efficient conversion of biomass into economic yield. Normal sowing has longer growth duration which consequently provides an opportunity to accumulate more biomass as compared to late sowing and henceforth manifested in higher grain and biological yield (Singh and Pal, 2003). Whereas in case of delayed sowing, the wheat crop is exposed to sub-optimal temperatures at establishment and supra-optimal temperature at reproductive phases that leads to forced maturity and reduction in grain yield (Sardana et al., 1999). Growing of suitable variety at an appropriate time is essential for ensuring optimum productivity. Being a thermo-sensitive crop, choice of suitable variety for different seeding time further gets prime importance. Temperature is an important environmental factor influencing the growth and development of crop plants. Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Bishnoi et al., 1995). Plants have a definite temperature requirement before they attain certain phenological stages. Though accumulation of degree-days for each development stage is relatively constant and independent of sowing date, crop variety may modify it considerably. Under North Indian condition, the maturity of wheat hastened due to gradual rise in ambient temperature under delayed planting. Hence, it becomes imperative to have knowledge of exact duration of phenological stages in a particular crop-growing environment and their impact on yield of crop. Therefore, an experiment was planned to determine the phenology and heat unit requirement of promising wheat varieties under different crop growing environment of central Punjab.
Validation of CROPGRO-peanut model in middle Gujarat agroclimatic region

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ABSTRACT

A field experiment was conducted during the kharif seasons of 2009 and 2010 to evaluate the CROPGRO-Peanut model for phenological and yield attributes of three groundnut cultivars V₁-M 335 (Virginia spreading type), V₂-GG 20 (Virginia semi-spreading type) and V₃-GG 5 (Spanish bunch type) sown under three environments. Model output showed that the simulated values of phenology, growth parameters and pod yield of the groundnut cultivars were close to the corresponding observed values.

Keywords: Glue cultivar coefficient estimator, DSSAT v. 4.5, CROPGRO- Peanut.em

India is a world leader in groundnut farming and cultivates around 7.74 million hectares and produces 7.61 million tones of groundnut with the productivity level of 991 kg ha⁻¹, with an increase in groundnut cultivation from 6.8 million hectares from 1980-81 to 8 million hectares, from 1993-94 onwards the production of groundnut is fluctuating between 7 to 9 million tones indicating the fluidity of production trend in groundnut in the recent years. Among oilseed crops, groundnut is the single largest source of edible oils in India, constituting about 50% of area and 45% of oil production. In India, about 80% of the groundnut area lies in a low to moderate rainfall zone (parts of peninsular region and western and central regions) with a short period of duration (90-120 days). Most of the groundnut production is concentrated in five states viz. Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, and Maharashtra. These five states account for about 86% of the total area under peanut cultivation, amongst these states Gujarat and Andhra Pradesh account for more than half of the cultivated area. Gujarat state alone occupies 1.95 million hectares (28.9%) of the total area of the country producing 3.39 million tones (42.4%) of the total production of the country with a productivity of 1777 kg ha⁻¹ (Anonymous, 2010). Nevertheless, there are constraints about substantial yield gaps between yields realized by farmers and those recorded from research stations or potential yield estimations. Yield fluctuates strongly due to climate variation and uneven adoption of improved technology. The objectives of the study were to quantify the production potential of groundnut in middle Gujarat Agroclimatic condition with special regard to dates of sowing to varying rainfall distribution during the growing season. Water deficit is a major constrain in groundnut production, especially during the critical period of pod set which results in reduced pegging. For the purpose, the Decision Support System for Agrotechnology Transfer (DSSAT) crop growth model Vs. 4.5 was evaluated and validated using two years of observed phenological growth and yield data.

MATERIALS AND METHODS

For evaluation and validation of the CROPGRO-Peanut model, data on plant growth and development, soil characteristics, weather and crop management were collected as required for determining the cultivar coefficients of V₁-M 335 (Virginia spreading type), V₂-GG 20 (Virginia semi-spreading type) and V₃-GG 5 (Spanish bunch type), following the procedures described in IBSNAT and Hoogenboom et al., (1999). The data were collected by conducting field experiments laid out at the Agronomy farm, B. A. College of Agriculture, AAU, Anand (22°35” N of latitude and 72°55” E longitude, elevation of 45.1 m) during the kharif seasons of 2009 and 2010 at the onset of monsoon followed by successive interval of 15 days in sowing environments during kharif 2009 2nd July (D₁), 17th July (D₂), 1st August (D₃) and kharif 2010 15th June (D₁), 30th June (D₂), 14th July (D₃). The cultivar coefficients were estimated by repeated iterations by running the GLUE coefficient estimator using the observed phenology, yield and yield attributes for all the sowing environments during both the years until a close match between simulated and observed phenology, growth and yield was obtained as presented in Table. 1. Validation of accuracy of the procedure used to estimate the cultivar coefficients of each peanut cultivar was determined by...
Sequential simulation of wheat and urd using DSSAT model in mollisol of Uttrakhand

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ABSTRACT

CERES wheat and CROPGRO urd model were used for sequential simulation to examine the stability of urd-wheat crop rotation as influenced by the interaction between environment and nutrient status. The results revealed that the CERES wheat and CROPGRO urd model satisfactorily simulated the growth and yield in sequential run. Therefore, the validated model can be further used for applications such as sequential study, crop growth, phenology, potential and actual yields etc. The effects of one crop on soil, water, and nutrient status are carried over to the next crop in the sequence or rotation. These sequences can be efficiently studied by the sequence analysis program of DSSAT.

Key words: CERES model, CROPGRO model, sequential simulation, wheat, urd

The DSSAT, developed by International Benchmark Sites for Agrotechnology Transfer (Tsuji. et al. 1994), contains crop simulation model; database for weather, soil crop; and strategy evaluation programs integrated with a user friendly interface. For simulating wheat development needs CERES model and for Urd CROPGRO model can be used meaningfully toward reducing additional experimentation and decision making to increase yield. The effects of one crop on soil, water, and nutrient status are carried over to the next crop in the sequence or rotation. These sequences can be efficiently studied by the sequence analysis program of DSSAT.

MATERIALS AND METHODS

Pantnagar is situated at Tarai belt, foothills of the Shivalic range of Himalayas at 29°1′N, latitude, 79.28°E longitude and at an altitude of 215.00 m above the mean sea level. The climate of Pantnagar is temperate with severe cold winter and hot summer. The CERES-Wheat model (Godwin et al., 1990; Ritchie and Otter, 1985) was used for simulation of daily phenological development and growth in response to environmental factors (soils, weather and management). CROPGRO version v4.5 was used for Urd in this study. Sequence analysis program was run to simulate the combined situation of the experiment involving crop rotation for urd-wheat rotation. The data base included all relevant information including the different management practices adopted, location specific soil and weather conditions obtained from field experiment conducted during kharif and rabi seasons of 2007 and 2008 at Crop Research Center, GBPUAT Pantnagar, Uttraknad. In the present study replicated data were used in the model calibration and validation process. Urd (Vigna mungo L. Hepper) variety Pant Urd-31 and Wheat (Triticum aestivum L.) UP-2565 were used in this study. The wheat crop was fertilized at the rate of 100 and 150 kg ha$^{-1}$ N levels, 60 kg ha$^{-1}$ P$_2$O$_5$, 40 kg ha$^{-1}$ K$_2$O of which one third of nitrogen and whole phosphorus and potash were applied uniformly as basal dressing and incorporated in surface soil.

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Response of wheat to temperatures as simulated with CERES-wheat model in Tarai region

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ABSTRACT

The present investigation was carried out to quantify the impact of change in minimum and maximum temperatures on wheat production in Uttarakhand using CERES-wheat model. Grain and biomass yields as simulated by the CERES-wheat (cv. BPW-343) model were found to have increased significantly due to decrease minimum (Tmin) and maximum (Tmax) temperature units from 1 to 3°C and vice-versa. Generally, minimum temperature has more significant effect than maximum temperature.

Key words: CERES-wheat, simulation, Tmin, Tmax and sowing dates.

Wheat (Triticum aestivum L.) is very important crop in Tarai region of Uttarakhand, which is sown during November/December and harvested during March/April. The total area under wheat in Uttarakhand is 0.4 m ha, with a total production of 0.8 mt and productivity of 2.0 t ha-1 (DES, 2010). The wheat production in the country is highly variable due to inter-seasonal weather variability. Using HADCM3 model, an analysis made by Tripathi et al. (2006) indicated that the projected increase in average temperature will be 3-4°C by 2080 AD for eastern U.P. Hence, winter production will be adversely affected due to high temperature. Wheat is sensitive to high temperature (during early and late stages of the crop) but magnitude of damage depends on the variations of ambient temperature, stage of development and varieties (Asseng et al. 2011; Modarresi et al. 2010). Extreme temperatures at sensitive developmental stages are especially detrimental.

The Decision Support System for Agro-technology Transfer (DSSAT) (Version 4.0) is an application software program that includes crop simulation models for more than 25 crops to make more reliable predictions (Jones et al. 2003). DSSAT and its crop simulation models have been used for a wide range of applications, including on-farm and precision management to regional assessments of the impact due to climate change. Crop simulation models are principal tools that can successfully apply to assess the effect of changes due to temperature on wheat yields (Matthews et al., 2002; Nain et al., 2002) and also helpful to assess the impact of climate change on the stability of crop production under different management options (Hoogenboom et al., 1995). Crop Environment Resources Synthesis (CERES)-wheat model is a process based management-oriented model that can simulate the growth and development of wheat crop (Ritchie et al., 1998). The model can identify gaps between potential and on-station farm yield and yield contributing characters etc. The main goal of this study is to quantify the impact of change in minimum and maximum temperature on the level of wheat production in Uttarakhand.

MATERIALS AND METHODS

The present experiments were conducted in split plot design with three dates of sowing i.e. November 20, December 15 and January 09 during rabi seasons of 2007-2008 and 2008-2009 at the Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar (29°N, 79.29°E with 243.80 m above msl). The CERES-wheat model for the genotype PBW-343 was well calibrated (Table 1) based on field experiment data, soil data and the actual weather parameters (i.e. minimum & maximum temperature, rainfall and bright sunshine hours). CERES-wheat model was used to simulate the biomass and grain yield of wheat using changes in temperature (Tmin & Tmax) from +1 to +3°C and -1 to -3°C under different sowing environments and percent change was calculated.
Effect of weather parameters on the incidence of stripe rust in Punjab

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ABSTRACT

To identify the meteorological factors which favour the development of stripe rust disease in wheat correlation and regression analysis was carried out by using 7 years (2004-11) data. In order to evaluate the reasons for the same an effort has been made to short list the weather parameters responsible for this wide variation in the occurrence of the disease. The maximum temperature for 48th and 49th standard meteorological weeks (SMW) were positively correlated while sunshine duration for 49th to 50th SMWs were negatively related. On the other hand, minimum temperature, rainfall and RH during 2nd and 3rd SMWs were positively correlated with the disease intensity. As such the disease will be higher in those years, when temperature will be higher than normal coupled with high relative humidity during December and January.

Key words: Stripe rust, Puccinia striiformis, wheat, climate change, meteorological elements

Stripe rust commonly known as yellow rust is primarily a foliar fungal disease of wheat. Under severe infection conditions, it can infect glumes resulting in grain shrivilage. The disease is caused by the fungus *Puccinia striiformis* f. *sp. tritici*. The fungus can only survive and reproduce on wheat. The pathotype survives during hot summer seasons in north hilly regions on self sown wheat plants or collateral plants. In Punjab, the losses due to this disease vary from 2 to 68% depending upon crop growth stage when it is affected, severity of the disease and variety grown (Jindal and Sharma, 2010). Under low temperatures the latent periods increase and the mild winters and cooler wet weather favour the development of the disease (Zadoks 1961). Yellow rust needs free moisture (high humidity, rainfall or dew) for infection. The optimal temperature ranges for stripe rust disease varies from around 10 to 15°C. As weather factors are driving forces in plant disease development, they are essential in plant disease prediction including the effect of weather on different parts of the disease cycle – dormancy, reproduction, dispersal and pathogenesis and also effect yield (Thomas *et al*, 1989., Pietravalle *et al*.) The aim of this paper is to analyze disease severity in relation to weather parameters throughout the season and to develop quantitative forecasting model for yellow rust under Punjab conditions.

MATERIALS AND METHODS

Historical data pertaining to meteorological elements and percent disease severity were collected for Ludhiana for 7 years period (2004-2011) from departments of Agricultural Meteorology and Plant Breeding & Genetics, PAU, Ludhiana. The weekly weather data i.e. maximum (Tmax) and minimum (Tmin) temperature, morning (RH1) and evening (RH2) relative humidity, rainfall (mm), number of rainy days (RD), sunshine hours (BSS) and wind speed (WS). The weekly parameters were calculated corresponding to standard meteorological weeks (SMW) as demonstrated by Mavi *et al* (1992).

The data on stripe rust was collected from surveys carried out at 7-10 days interval in Ludhiana district of Punjab starting from January to March since 2004-05 to 2010-11. Randomly fields were observed for the rust prevalence at 5-6 spots after every 20 km distance by moving 500 m area on both sides of road. The fields were observed for disease prevalence and severity. The susceptible wheat variety PBW 343 occupied large area and observations were mainly recorded on this variety. Based on these observations every year was given following rating for the disease depending upon the stripe prevalence and its intensity.
Sucking pest population dynamics of cotton crop in relation to agrometeorological parameters and spectral indices

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ABSTRACT

Present study was designed to reveal the impact of different meteorological factors on sucking pest population dynamics and to work out multiple regression equations using different weather parameters and spectral indices. Leafhopper population was positively correlated with \( T_{\text{max}} \) (Maximum temperature), \( T_{\text{min}} \) (Minimum temperature), \( R_{\text{H}}^\text{M} \) (Morning RH) and \( R_{\text{H}}^\text{E} \) (Evening RH) and negatively associated with VPD (Vapour pressure deficit). However, whitefly population was negatively correlated with \( T_{\text{max}}, T_{\text{min}} \) and VPD and positively related with \( R_{\text{H}}^\text{M} \) and \( R_{\text{H}}^\text{E} \). In case of leafhopper, regression equation consisting all the weather variables were more suitable to predict their population \( (R^2 = 0.79) \). But for whitefly population, equation with only temperature variables explained more variability \( (R^2 = 0.89) \). Multiple regression analysis with spectral indices showed variable performance for these pests.

Key words: Cotton, leafhopper, whitefly, correlation, weather, multiple regressions

Cotton (Gossypium Spp.) being the king of natural fiber is grown in 111 countries all over the world. In India it is cultivated in 8.97 million ha with a production of 21.3 million bales of seed cotton (Anon., 2005). The average productivity of cotton in India is 463 kg per ha (Anon., 2006) as compared to world average of 621 kg per ha. India occupies 26 per cent of global cotton area contributing 18.3 per cent of world production (Anon., 2007). Thus India ranks first in area and fourth in production on global basis. Despite the large area, the productivity in India is very low. In Karnataka, cotton is being grown in an area of 5.50 lakh ha with a productivity of 248 kg per ha (Anon., 2005). Cotton fiber is an important raw material to the textile industries and plays a key role in national economy in terms of employment generation and foreign exchange.

Among the insect pests, a complex of sucking pests viz., leafhopper, Amrasca biguttula biguttula (Ishida), whitefly, Bemisia tabaci (Gennadius) occupy major pest status and cause considerable damage in cotton. Information on seasonal activity of sucking pests on cotton helps to take up effective management strategies. Keeping this in view present study was undertaken to develop regression models for sucking pests based on weather and spectral indices.

MATERIALS AND METHODS

Present study was carried out during Kharif 2007 and 2008 at the Research Farm of the Department of Entomology, CCS Haryana Agricultural University, Hisar under irrigated condition. Two cotton cultivars HS-6 and H-1226 having different growth habit were sown with row to row spacing of 60 cm. Thinning was done one month after sowing maintaining plant to plant spacing of 30 cm. The experiment was laid out in a split plot design with three replications. Three different dates of sowing viz. 15 April, 1 May and 15 May were kept as main plot treatments and varieties as subplot treatments. Fertilization and irrigation were applied as per the recommended package of practices released by CCS HAU, Hisar.

Pest population assessment: Top three leaves of a branch were selected for population study of sucking pests because of their tender and succulent nature. Randomly three branches were selected from each cotton plant to count leafhopper nymphs and whitefly adults. Likewise, ten plants were observed randomly from each plot. Observations were recorded on population build up of sucking pests at 15 days interval starting from vegetative phase to 50% boll formation for each date of sowing. Therefore, mean population of the sucking pests were calculated as:

\[
\text{Mean leafhopper population per leaf=} \frac{\text{Total nymphs on 10 plants at each level of row crop}}{30}
\]

\[
\text{Mean whitefly population per leaf=} \frac{\text{Total adults on 10 plants at each level of row crop}}{30}
\]
Short Communication

Yield prediction of sugarcane and paddy for districts of Uttar Pradesh

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Reliable and well-timed forecasts are essential for appropriate agriculture planning which is full of uncertainties. Well-timed and accurate crop yield forecasting is essential for crop production, marketing, storage, and transportation decisions and also helps managing the risk associated with these activities (Bannayan and Crout, 1999, Potgieter et al., 2005). Weather plays an important role in crop growth as well as crop development. Therefore, models based on weather parameters can provide reliable forecast of crop yield in advance of harvest. A number of yield forecasting models have been developed for various crops. Yield forecasting regression models utilise data on yield and weather variables for past several years pertaining to locations under consideration. By studying the relationship of yield with different weather elements, predictors are identified. Generally, rainfall, temperature, humidity, rainy days, dry days and cloud amount etc. during critical phases of crop growth fulfill the criteria to be predictors (Jayanta Sarkar, 2003). Crop yield in different years is affected by technological change and weather variability. The technological factors will increase yield smoothly through time and therefore, year-number can be used to study the overall effect of technology on yield. The weather variability both within and between seasons is unmanageable source of variability in yield. The weather variables affect the crop differently during various stages of development. Thus, extent of weather influence on crop yield depends not only on the magnitude but also on the distribution pattern of weather variables over the crop season.

Thus, there is a need of dividing the crop season into different intervals. Thus, a technique based on relatively smaller number of manageable variables and at the same time taking care of entire weather distribution may solve the problem. The regression model which was used for yield forecasting is weather indices based model which is modified Hendricks and Scholl method at IASRI (Agrawal and Mehta, 2007).

The model is given below:

\[ Y = A_0 + \sum_{i=1}^{p} \sum_{j=0}^{l} a_{ij} Z_{ij} + \sum_{i=1}^{p} \sum_{i=1}^{p} \sum_{j=0}^{l} a_{ij'} Z_{ij'} + cT + e \]

Where,

\[ Z_{ij} = \sum_{w=1}^{m} r_{iw} X_{iw} \quad \text{and} \quad Z_{ij'} = \sum_{w=1}^{m} r_{i'w} X_{iw} X_{i'w} \]

Where,

- \( r_{iw} \) is correlation coefficient of yield with i-th weather variable in w-th week
- \( r_{i'w} \) is correlation coefficient of yield with product of i-th and i'-th weather variables in w-th week
- \( m \) is week of forecast
- \( p \) is number of weather variables used
- \( e \) is random error distributed as N \( (0, s^2) \).

In this model, for each weather variable, two types of indices were developed, one as simple total of values of weather variable in different periods (un-weighted index - \( Z_w \)) and the other one is weighted accumulation of weekly weather variable, weights being correlation coefficients of weather variable in respective weeks with yield (weighted index - \( Z_w \)). Similarly, for interaction of weather variables, indices were generated using weekly products of weather variables taking two at a time. Stepwise regression technique was used to select the important weather indices (Agrawal et al. 2001; Mehta et al. 2000).

Sugarcane yield prediction

Yield forecasting models of sugarcane are presented for 8 districts viz. Meerut, Bareilly, Allahabad, Kaushambi, Fatehpur, Bahraich, Varanasi and Gorakhpur districts in the Table 1. The weather data for maximum temperature (Tmax), minimum temperature (Tmin), relative humidity at 8:30 IST (RH I), relative humidity at 17:30 IST (RH II) and daily rainfall values were collected for the period of
Effect of weather parameters on population dynamics of mustard aphid (*Lipaphis erysimi* Kalt) in Tarai region of Uttarakhand

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Pest and diseases are foremost cause of reduction in crop yield. To reduce the yield loss timely application of remedial measures is essential which is feasible with prior knowledge of the time and severity of outbreak of the pests and diseases. Among different insect pests attacking mustard, the mustard aphid (*Lipaphis erysimi*, Kalt) is the most serious and destructive pest and a major limiting factor for its cultivation. The rate of reproduction varies from 5 to 9 youngs in a single day by a single female. The incidence and spread of aphid is largely influenced by weather conditions. The temperature range of 16.5 to 20.6 °C seems to have favoured the pest multiplication (Talpur and Khuhro, 2003). Weather information can provide a reliable forewarning of pests and diseases attack, therefore, suitable plant protection measures could be taken timely (Agrawal and Mehta, 2007).

The experiment was conducted at Crop Research Centre (CRC) of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Lat. 29°N, Long. 79.3°E, Alt. 243.8 m above the m. s. l.) district Udham Singh Nagar, Uttarakhand. Eight varieties of mustard *BSH-1, YST-151, Euraca sativa* (Mill CV, T-27, Taramira), *Brassica alba* (White mustard), *Brassica napus* (Gobhi sarson, sheetal), *Brassica carinata* (Ethiopian mustard), *Brassica juncea* (Indian mustard, Varuna) and *B. nigra* (Banarasi rai) were sown on 5/11/2009 and 9/11/2010 in randomized block design (RBD) with three replications.

Observations were taken on ten plants selected randomly and tagged in each replication at weekly interval. The numbers of aphids were counted on a 10 cm apical central shoot of inflorescence. Correlation coefficients were worked out between aphid population between dependent variables under study with the respective weather parameter in different meteorological weeks obtained from Agrometeorological observatory located at the centre.

During 2009-10, the population of mustard aphid (*L. erysimi*) across all varieties started building up in 1st std. week (Table 1) and reached its peak (146.7 aphids) in 4th std week. Thereafter it decreased to 21.5 during 9th std week.

During 2010-11, the aphid attack was two week early and started in 51st week and reached to its peak value of 514.6 in std week 1st. During subsequent weeks its population remained high (>225) upto 7th std week. Thus between years aphid population was higher in 2010-11 than 2009-10.

A perusal of two years of weather data (Table 1) shows that the maximum temperature during 2009-10 (14.7 to 24.0 °C) was lower than that during 2010-11 (16.5 to 25.5 °C) while the aphid population was higher in 2010-11 than that during 2009-10. Thus higher maximum temperature (> 15 °C) favoured population build up of aphid in mustard. However, maximum temperature alone may not be the only criteria for aphid population as negative correlation was found with it. It seems that higher maximum temperature in association with higher morning relative humidity (> 90 %) seems to be most favourable for aphid population dynamics.

Similarly, the minimum temperature varied considerably during both the years 3.0 to 11.0 °C with mean value of 5.4 °C during 2009-10 and 4.2 to 10.4 °C with mean value of 6.6 °C during 2010-11. Thus higher minimum temperature also accelerated the aphid build up during 2010-11. Wind speed did not affect the aphid population during that year. Relative humidity showed a negative correlation with aphid population in most of the germplasm except the *B. napus* and *B. juncea*. The aphids disappeared after 1st week of March which was due to unfavourable weather and host plant conditions. The observations are in confirmity with the studies of Singh and Malik (1998) and Ansari *et al* (2007). Correlation
Evaluation of weather generators in foothills of western Himalayas

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Weather generators are statistical models used to generate near real daily sequences of meteorological variables—precipitation, maximum and minimum temperature, humidity etc. These are used for gap filling of missing data or for incorporation in long-term simulation models (Ray and Turakhia, 2008). The WGEN (Richardson and Wright, 1984) model is designed for use in generating daily values of precipitation, maximum temperature, minimum temperature and solar radiation that represents the weather at a specific site. The model is based on the procedure described by Richardson (1981); however, several assumptions have been made to simplify the use of the model. ClimGen (Arnold and Elliot, 1996), which includes some generation concepts adopted from WGEN, is a weather generation program with novel features and friendly and effective user interface. ClimGen has been evaluated and found to perform reasonably for a number of world locations. ClimGen generates precipitation, daily maximum temperature (Tmax) and minimum temperature (Tmin), solar radiation (SRAD), air humidity, and wind speed.

In this present work the weather generators, WGEN and ClimGen were used to generate weather parameters for Pantnagar (29° N latitude, 79.3° E longitude and 243.8 m MSL). This area lies in the ‘Tarai’ belt located in the foot hills of Himalayas with annual rainfall of about 1400 mm, out of which 80 percent is received from mid June to September during SW monsoon. Daily data of weather parameters viz. maximum temperature (Tmax), minimum temperature (Tmin), rainfall (RF), number of rainy days (RD) and solar radiation (SR) from 1998 to 2006 of Pantnagar (Uttarakhand) were used to generate daily weather scenario for the years 2007, 2008 and 2009. Detailed procedure of generating daily values of weather parameters by WGEN is explained in Richardson and Wright (1984) and by ClimGen in Arnold and Elliot (1996).

Performance of weather generators

Comparisons between observed weather and generated (from WGEN and ClimGen) weather parameters for different years have been presented in Table 1. The values of Tmax, Tmin, total rainfall and solar radiation generated by WGEN were very close to the values of observed weather parameters than ClimGen in the year 2008 and 2009. In the year 2007, close values of weather parameters, generated by ClimGen, for Tmax and Tmin were found to be nearer to the mean of observed values, while SR and RF generated by WGEN was close to observed mean. Number of rainy days generated by WGEN (71 in 2008 and 41 in 2009) was found closer to observed (71 in 2008 and 41 in 2009) than ClimGen (68 in 2008 and 74 in 2009) in the years 2008 and 2009, while close prediction for number of rainy days, in the year 2007 showed by ClimGen (Table 1).

Based on the pooled data of three years weather parameters generated by WGEN was found higher correlation ($R^2$) values than ClimGen. Due to high interannual variability of the rainfall both the weather generators were unable to generate total rainfall precisely (Fig. 4). In spite of that, $T_{max}$ (Fig. 2) and $T_{min}$ (Fig. 3) were highly correlated between observed and generated parameters by both the weather generators followed by solar radiation (Fig. 1).

It is therefore, concluded that the values of different weather parameters i.e. maximum temperature ($^\circ C$), minimum temperature ($^\circ C$), total rainfall (mm), number of rainy days and solar radiation (MJ m$^{-2}$ d$^{-1}$) generated by WGEN were very close to values of observed weather parameters than ClimGen. Weather parameters i.e. $T_{max}$, $T_{min}$, RF, SR and RD generated by WGEN were found almost higher correlation than ClimGen. Hence, it can be adopted for generation of substituting missing data and also can be used for climate change study in the ‘Tarai’ belt of the foot hills of Himalayas.
Comparative study of estimated and simulated reference evapotranspiration of black gram and wheat crops in mollisol of Uttrakhand

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Evapotranspiration is the combination of soil evaporation and crop transpiration. Weather parameters, crop characters, management and environmental factors affect evapotranspiration. Reference evapotranspiration ($ET_0$) is an important agrometeorological parameter for climatological and hydrological studies. The reference evapotranspiration concept has been gaining significant acceptance by scientists throughout the world since its introduction. $ET_0$ can also be estimated from pan evaporation. Pans have proved their practical value and have been used successfully to estimate $ET_0$ by observing the water loss from the pan and using empirical coefficients to relate pan evaporation (FAO-24 pan method). The rate of evapotranspiration is usually expressed in millimetres per unit time. Estimates of evapotranspiration from cropped land surfaces are vital for agricultural water management. $ET_0$ values estimated or calculated at different locations or in different seasons are comparable as they refer to the evapotranspiration from the same reference surface. $ET_0$ is an agro-climatic parameter and can be computed form the weather data. $ET_0$ express evaporating power of the atmosphere at specific location and time (Allen et al., 1989). Through crop models, it became possible to simulate a living plant through the mathematical and conceptual relationship which governs its growth in the soil atmospheric continuum (Thornley 1976). Crop models can help researchers, policymakers, and farmers to make correct decisions on crop management practices, and also for marketing strategies and food security of a country with a deterministic view on the import-export market.

Pantnagar is situated at Tarai belt, foothills of the Shivalic range of Himalayas at 29°1’N, latitude, 79.28°E longitude and at an altitude of 215.00 m above the mean sea level. The climate of Pantnagar is temperate with severe cold winter and hot summer. Generally, the monsoon sets around the third week of June and last up to September end. Regarding spatial variability annual rainfall varies between 1200-1500mm and distribution over 55 to 60 rainy days.

Estimation of reference ET through USWB pan evaporation (FAO-24 pan method)

Pan evaporation data were used to estimate reference evapotranspiration ($ET_0$).

Reference evapotranspiration obtained by the application of FAO-24 pan method from the following equation:

$$ET_0 = K_p \cdot E_{pan}$$

where $ET_0$ = reference evapotranspiration (mm day$^{-1}$), $K_p$ = pan coefficient, $E_{pan}$ = pan evaporation (mm day$^{-1}$).

Values of the pan coefficient for the class A pan are presented in Allen et al. (1997).

CERES wheat and CROPGRO urd model (DSSAT model v4.5) were used in this study for assessment of $ET_0$. The model requires a set of minimum data pertaining to daily weather, soil genotype characters and crop management details. These data are provided to the model through different data file. The data base included all relevant information including the different management practices adopted, location specific soil and weather conditions obtained from field experiment conducted during kharif and rabi seasons at N.E. Borlaug, Crop Research Center, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttrakhand. In the present study replicated data of 2007-08 and 2008-09 of wheat and blackgram were used in the model calibration and validation processes. In the present study replicated data were used in the model calibration and validation process.

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**Cotton yield prediction for Punjab using weather based statistical models**

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Variation in crop yield over years has two components. One is the more or less systematic rise in yield derived from improved cultivars, better crop management, and the interaction between cultivars and management (Bolton, 1981). The second component is erratic and mostly related to meteorological variables. Evaluation of crop responses to management practices needs therefore to consider these sources of interannual variation in yield. Interannual variation in yield can be analysed using several tools including multivariate analysis and crop simulation models. Even powerful standard statistics may be limited in biological meaning, however, while crop simulation models have their own problems (Monteith, 1996; Passioura, 1996; Sinclair and Seligman, 1996; Sadras and Trapani, 1999). An alternative approach uses simple, agronomically meaningful models based upon few, key environmental variables.

The study was conducted using the dataset of 1980-2010. The weather data for the period under study for four locations of Punjab namely Amritsar, Ludhiana, Patiala and Bhatinda, well representing the state were collected from the meteorological observatories of IMD. The average drawn from these four stations were used as average weather data of Punjab. The weather data of crop season i.e. kharif season were taken into consideration (from 16\(^{th}\) to 45\(^{th}\) SMWs).

The cotton crop yield data for Punjab state as a whole for american cotton (*Gossypium hirsutum*) as well as total cotton which includes american cotton and Desi cotton (*Gossypium arboretum*) were collected from State Agriculture Department of Punjab for last 31 years (1980-2010). The year wise yield variations in american as well as total cotton are presented in Fig. 1. The variation in yield from 1980 to 2003 was very low and this is because of the corresponding area under each crop. The total cotton comprises of american as well as desi cotton and the share of american cotton to the total cotton was very high as compared to the desi cotton which in turn reduced the gap between two cottons. During 2004 and onwards the Bt cotton was introduced which replaced the desi cotton and the increased share of Bt cotton to the total cotton contributed higher yields to the total cotton which reproduced the large variations between yields of american and total cotton.

Simple statistics were used to the draw inferences by correlating weather parameters with cotton yield and the weather parameters significantly effecting the yield were worked out separately for american as well as total cotton yield. The statistically significant weather parameters were then regressed with yield and simple regression models for american and total cotton yield prediction were developed. The models were developed using dataset of 1980-2008 and the model prediction were validated with the independent dataset of 2009 and 2010.

The different weather parameters which significantly (at p< 0.05) influenced the yield were worked out. The different variables used are described in Table 1. The yield of cotton was influenced differently by different weather parameters at different time of crop stage. The maximum temperature during 45\(^{th}\) SMW showed a significantly +ve correlation. In case of rainfall the significant -ve correlation were found and the rainfall of 16\(^{th}\), 42\(^{nd}\) and 45\(^{th}\) SMWs were with significant correlation with yield and the average of theses three weeks were...
Short Communication

Effect of meteorological parameters on growth and sporulation of alternaria alternata causing alternaria fruit rot of brinjal

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Brinjal (Solanum melongena L.) is a major solanaceous vegetable crop of India. It contributes about 12.47 per cent of the total production of vegetables in India. In Rajasthan, it is grown in all districts in an area of 5738 hectares with 37253 metric tonnes production and productivity of 6.49 metric tonnes per hectare (Anonymous, 2007-08). A heavy infection of Alternaria fruit rot of brinjal caused by A. alternata (Fr.) Keissler was observed in the vicinity of Jobner (Jaipur). In India, the disease Alternaria fruit rot of brinjal was first reported from IARI, New Delhi. This disease is severe and appears regularly, causing heavy losses in fruit yield. The disease appear in two phases, leaf spot and fruit rot. The disease first makes its appearance in young seedling during the rainy season (July-August) which is blighted. They give a cherry appearance and finally die out. In September, it attacks on leaves and then spread to fruits which rot and become unfit for consumption. Lesions of fruits are first observed during February. They start as small (above 1/2 cm in size), concentric, dark brown and sunken spots. Colour of the lesions become olivaceous dark brown due to spore formation. Several lesions may coalesce and cover the entire surface of the fruit (Kapoor and Hingorani, 1958). Fungus produces muriform conidia and usually formed in chains (Fig. 1 & 2). To find out the role of environmental factors such as temperature, relative humidity and light/darkness on the disease development, in vitro studies were conducted at Department of Plant Pathology, SKN, College of agriculture, Jobner during 2009-10.

To study the effect of temperature on mycelial growth and sporulation the pathogen, 20 ml of sterilized PDA medium was poured in sterilized Petri-plates. Inoculation was made with 5 mm disc from 7 days old pure fungal culture and incubated at 5 different temperatures viz., 15, 20, 25, 30 and 35°C. Observations were recorded at 4th and 7th days after incubation. Each treatment was replicated four times.

To study the effect of relative humidity on mycelial growth and sporulation, the pathogen on PDA medium was inoculated similar to the previous experiment and incubated at 60, 70, 80, 90 and 100 per cent relative humidity. The different relative humidity levels were maintained by the method suggested by Buxton and Mellanby (1934). Composition of the acid solution used was as follows.

<table>
<thead>
<tr>
<th>Relative humidity (%)</th>
<th>Stock solution (ml)*</th>
<th>Distilled water (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>374.0</td>
<td>396.0</td>
</tr>
<tr>
<td>70</td>
<td>348.0</td>
<td>510.3</td>
</tr>
<tr>
<td>80</td>
<td>294.0</td>
<td>640.0</td>
</tr>
<tr>
<td>90</td>
<td>161.0</td>
<td>712.0</td>
</tr>
<tr>
<td>100</td>
<td>0.00</td>
<td>Only distilled water</td>
</tr>
</tbody>
</table>

* 50 % v/v solution of concentrate sulphuric acid

Observations and treatments were similar to the previous experiment.

To study the effect of light / darkness on mycelial growth and sporulation of A. alternata, the fungus was grown in four different growth chambers set at different light/dark cycles viz., 24 hrs light/0 hrs darkness, 16 hrs light/ 8 hrs darkness, 8 hrs light/ 16 hrs darkness, 0 hrs light/ 24 hrs darkness. Observations were recorded at 4th and 7th days after incubation.

The temperature for the radial growth of fungus varied for all treatments. It is evident from the data (Table 1 and Fig. 3) that the pathogen grew at all the temperature i.e. 15, 20, 25, 30, and 35°C both at 4th and 7th days after incubation. Maximum mycelial growth 86.00 mm and excellent sporulation was observed at 25°C. A gradual decrease in mycelial growth and sporulation was observed at 30°C and 35°C. However the temperature 20°C and 30°C favoured good mycelial growth and sporulation of A. alternata but differ significantly from the growth at 25°C. Minimum mycelial growth i.e. 10.00 and 16.00 mm and fair sporulation was observed at 15°C temperature at 4th
Short Communication

Influence of weather factors on the development of leaf spot of betel vine caused by 
Colletotrichum capsici

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Betel vine (Piper betle L.) is an important cash crop in India, Bangladesh, Malaysia, Sri Lanka, Pakistan, Mauritius and Myanmar. Plants of betel vine are cultivated in conservatories under shady and humid condition that favours the development of many diseases (Chattopadhayay and Maiti, 1990). Leaf spot caused by Colletotrichum capsici is one of the major disease of the crop (Bhale et al. 1987) that in severe condition lead to death of the plants producing up to 25-90 percent losses of the crop in different parts of India (Dastur, 1935; Chattopadhayay and Maiti, 1990). This disease of betel vine was first identified by (Roy, 1948) and it is also known as anthracnose of ‘Pan’ (vernacularly called as ‘Jhalma’). The epidemic form of the disease in the country has also been reported by (Basak et al. 1992) and (Hossain et al. 1986), causing 10-60 percent yield loss (Singh and Joshi 1971, Maiti and Sen 1982). It reduces market value of the crop (Maiti and Sen, 1971). Environmental factors play an important role on the development of disease as they help the pathogen for growth, dissemination and infection as well as influences on expression of susceptibility/resistance of the host plant after infection (Walker, 1965). Among the environmental factors, temperature, humidity and rainfall are the most crucial for the development of leaf spot of betel vine (Maiti and Sen 1982). So, the present study was undertaken to find the effect of weather factors on the development of the disease severity and to formulate suitable prediction equation.

The field experiment on betel vine was conducted in the betel vine garden during the year 2009, 2010 and 2011 at Baliapal block of Balasore district in coastal belt of Odisha. Five betel vine cultivars viz. Bangla, Chandrakona, Balipan, Aima Bangla and Sanchi were planted in the garden. Young cuttings of vines of each cultivar were used as planting materials. The cuttings were planted in 3.0 x 3.0 m plots maintaining 45 cm (R×R), 15 cm (P×P) and 1.0 m plot to plot distance. After establishment of the cutting the field was fertilized with only mustard oil cake and neem cake @ 16q ha⁻¹ per year. The oil cake was applied in equal splits during the months of May and September. All the agronomic and cultural practices such as weeding, watering, earthing up, pruning, tying, vine lowering and other operations were done as and when necessary to maintain congenial environment for proper growth and development of the plants. Shed was provided with a thin roof made of straw and bamboo sticks. Normally betel vine growers of Balasore district raise their betel vine garden exclusion of chemical fertilizers. So, no chemical fertilizers were used in experimental field. The experiment was laid out in a 4x3 factorial in randomized complete block design with three replications. To study the development of leaf spot observations were taken in betel vine garden during three consecutive years viz. 2009, 2010 and 2011. Every year plants of all five cultivars were checked regularly with 10 days interval during January to December to record severity of the disease. Severity was indexed on a subjective scale based on leaf area diseased. The severity of the disease was computed following a modified 0-5 rating scale (Basak et al. 1992), where 0= healthy, 1= up to 5%, 2= 6-15%, 3= 16-30%, 4= 31-50% and 5=>50% diseased leaf area. It was expressed as Percent Disease Index (PDI), which was computed using a standard formula (Basak et al. 1992) as shown below:

\[
PDI = \frac{\text{Sum of all numerical ratings}}{\text{Total numbers of leaves counted} \times \text{Maximum rating}} \times 100
\]

For studying the multiple effects on the dependent variables the multiple regression analysis was done. The monthly average temperature (X₁), average relative humidity (X₂) and total rainfall (X₃) were recorded every month during the study period. The meteorological data was collected from ‘Meteorological office, Chandannahal, Sunhat, Baleswar’. Before analysis the data, square root transformation of PDI value was calculated. To predict the disease development, multiple regression equations were computed for each cultivar by using SPSS computer