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Symposium on "Crop Weather Models in Agriculture"

Chairman	:	Prof. J.S. Rustagi
Convenors	:	Dr. Ranjana Agarwal
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The symposium on Crop Weather Models in Agriculture was held during the 56th Annual Conference of the Indian Society of Agricultural Statistics at College of Agriculture, University of Agricultural Sciences, Krishi Nagar, Dharwad (Karnataka) during 18-20 December, 2002. The symposium was organized on 19 December, 2002. The participating institutions were IMD, Pune; IASRI, New Delhi; UAS, Dharwad; UAS, Bangalore and CRIDA, Hyderabad. Following papers were presented :

1. Forecasting rice and wheat yield over different meteorological sub-divisions of India using statistical models – *Jayanta Sarkar*
2. Weather based forewarning of pests and diseases of some crops - IMD approach – *R.P. Samui*
3. Stocheometric crop weather model for sustainable production of finger millet – *M.B. Rajegowda*
4. Weather based forewarning system for the pest and disease management – *S. Lingappa, S. Yelshetty and H. Venkatesh*
5. Drought preparedness and mitigation – *K.K. Singh*
6. Rice crop simulation model and its application – *K.K. Singh*
7. Modeling crop-weather interactions – *Anil Kumar Singh*
8. Weather based forecasting of crop yields, pests and diseases - IASRI models – *Ranjana Agrawal*

- In all 8 papers were presented, seven dealing with weather based crop yield forecasting and forewarning of pests and diseases, one relating to drought monitoring.
- Most of the papers relating to yield forecasting were based on correlation regression analysis taking weather variables as such as regressors or some derived variables of weather parameters. Some other techniques included water balance technique, dynamic models and discriminant function analysis.

- Pest and disease forewarning mostly were based on empirical thumb rules and correlation regression analysis. Some non-linear models and higher degree polynomials were presented.
- Incidence, spread, intensification and cessation of drought on fortnightly time scale vis-a-vis crop condition with special reference to 2002 has been discussed based on 'Aridity Anomaly Index'.
- Out of presentations and discussions, the following recommendations were emerged.
    - Remote sensing data should also be used along with weather parameters while developing yield forecast models.
    - Some simple thumb rules based on weather may provide forewarning of pests and diseases. Therefore, simple thumb rules may be developed crop wise and agroclimatic zone wise which may provide quick forewarning of pests and diseases. For this purpose, task force may be created in different zones.
    - Interval estimates of forecasts may be given instead of point estimates.
    - There is need to validate region and crop specific weather based models on a larger scale.
    - There is need to establish linkages and collaboration among various institutions involved in developing crop weather models.

Forecasting Rice and Wheat Yield Over Different Meteorological Sub- divisions of India Using Statistical Models

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India Meteorological Department (IMD) has developed empirical-statistical models using correlation and regression technique to forecast rice and wheat yields on operational basis. Since meteorological parameters, particularly the rainfall, are highly variable in space, and because the cultural practices vary from region to region, IMD has developed rice and wheat yield forecasting models for 26 and 16 meteorological sub-divisions of India respectively where these crops are grown on a large scale.

The models use a linear combination of predictors, which include meteorological as well as technological parameters.

The general equation of the model is

$$Y = a_0 + \sum_{i=1}^{n} a_i x_i + \sum_{j=1}^{m} a_j x_j$$

where

Y = Estimated yield, $kg.ha^{-1}$

a_0 = Regression constant

a_i = Estimated regression coefficients for meteorololgical predictor variables

x_i = i^{th} meteorological predictor variable $i = 1, 2, \ldots n$

a_j = Estimated regression coefficients for technological trend variables

x_j = Technological trend variable $j = 1, 2, \ldots m$

For developing forecasting models, long series of actual crop yield data, weather data technological parameters were used. By studying the relationship of yield with different weather elements, predictors are identified. Generally, rainfall, temperature (maximum, minimum and range), humidity, rainy days, dry days, occasions of drought, occasions of tropical storms, cloud amount etc. during critical phases of crop growth fulfill the criteria to be predictors. Besides the meteorological elements, crop yield is dependent on technological advancement like use of high yielding variety seeds, fertilizers, insecticides and pesticides, irrigation etc. which is accounted by using a technological trend variable. The models have been found to perform satisfactorily. Continuous efforts are made to identify new predictor variables and update the models. Newer techniques, like neural network, etc. are being explored which could perform better than linear statistical models.

Weather Based Forewarning of Pests and Diseases of Some Crops - IMD Approach

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There is a sizeable loss of food grains and other cash crops in different regions of the country due to the incidence of pests and diseases. The possibility of reducing such crop due to pests and diseases infestation, based on weather based forewarning system, was explored. The feasibility of meteorological forewarning of stemborer of sugarcane; aphid, jassid and pink bollworm of cotton; gall midge, stemborer, hispa and blast of rice; tikka disease of groundnut; rust of fig; fruit canker of guava and early blight of tomato has been made using graphical superimposition, synoptic and statistical techniques. Graphical superimposition technique was used when data were limited otherwise stepwise multiple regression technique was used for developing forewarning models. The maximum and minimum temperature, morning and afternoon relative humidity and bright sunshine hours have profound effect on the development of stemborer of sugarcane at their successive generations. Decrease in morning relative humidity below 80% was found to increase population of jassid and aphid of cotton at Parbhani and Akola. In addition to this decrease in minimum temperature and sunshine hours, more rainfall increased jassid population of cotton at Parbhani whereas increase in maximum temperature, trace rainfall and more clouding aggravated aphid population of cotton at Akola. Another study revealed that minimum temperature $> 20^{O}$ C, morning relative humidity $> 60\%$, sunshine hours < 6 hours and rainfall > 0.5mm during 42^{nd} and 46^{th} standard week favoured the outbreak of pink bollworm of cotton at Akola and Parbhani. Severe infestation was observed during the month of October and November when the cotton crop was either in flowering or boll formation stage.

A critical analysis of correlation coefficients between the light trap catches of gall midge and stemborer of rice and meteorological parameters showed that there are turning points and epicenters of outbreak for both the pests. The study also revealed that maximum and minimum temperature, morning and afternoon relative humidity, bright sunshine hours and weekly total rainfall have profound effect on the development of gall midge and stemborer at their successive generations. Due to variation in weather parameters within the season and inter season between kharif and rabi the maximum peaks of gall midge and stemborer infestations were observed respectively in kharif and rabi seasons. Favourable weather conditions for the development of gall midge and stemborer at each of the generations were worked out and discussed. A preliminary study also showed that hot and comparatively dry conditions were favourable for rice-hispa incidences while decrease in minimum temperature under humid and cloudy condition caused the incidences of rice blast. Working with tikka disease infestation of groundnut, it is observed that decrease in maximum and minimum temperature below 32^{O}C and 19^{O}C respectively and increase in morning and afternoon relative humidity above 90% and 80% respectively favoured the infestation of tikka disease of groundnut. Similarly increase in maximum temperature was found to increase the infestation of both fruit canker of guava and early blight of tomato. Decrease in afternoon relative humidity favoured the infestation of fruit canker of guava and rust of fig. Fall of minimum temperature and rise in bright hours of sunshine also aggravated the incidence of fruit canker of guava and rust of fig respectively.

Weather based forewarning models/guidelines for the peak infestation period for important pests and diseases of major crops were developed. Pest weather calendars for important pests were also prepared for operational crop protection. These pest weather calendars, present and forecast weather and pest observations from the field would help the Agromet Advisory Units of IMD to issue forewarning of pest and diseases outbreak and also to advise the farming community to decide their spraying and dusting operations. An attempt has been made to use operational pests and diseases management scheme which not only reduce the damage lower than the economic injury level, but also support the growth and survival of its natural enemies. The need to minimize the use of noxious chemicals through proper application of right chemicals at the right time using weather based information has been emphasized.

Stocheometric Crop Weather Model for Sustainable Production of Finger Millet

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Crop weather models have become the modern tools in the field of Agriculture for day to day operation including the estimation of bio-mass and the grain of many crops. In and around the world, many Dynamic and Statistical crop weather models have been generated considering available weather, soil and crop information during the crop growing period. Of the several crop weather models, stocheometric model is one wherein influence of prevailing weather on the performance of crop in each growth stage is considered. As reported information on growth models for finger millet crop is meager, here an attempt is made to develop a Stocheometric crop growth model as influenced by the prevailing weather for finger millet. Here the influence of weather on crop growth starting from sowing to harvest and the grain yield has been studied. The model to predict the biomass accumulated at the end of each phonological stages and the grain yield has been generated. The most important weather parameters having higher degree of influence have been identified and considered as input of the model. Influence of Actual Evapotranspiration (AET), Growing Degree Days (thermal unit i.e. GDD) and Bright Sunshine Hours (SSH) prevailing during each stage of the crop and finally on the grain yield have been studied. The model consist of six multiple linear regression equations relating the GDD, SSH and AET and the total accumulated dry matter in the beginning of each growth stages. The total Dry matter accumulated at the end of each stage could be estimated taking the initial Dry Matter. The coefficient of determinants

indicate that the climatic parameters considered and the initial TDM used to estimate the final TDM in each stage could be able to predict the biomass yield to an extent of 93 per cent to 98 per cent (coefficients of determinants) in different stages. Comparison of the observed and the predicted yields indicate the close agreement between them in all the stages. There is a very good agreement between the observed and the predicted grain yield, which is revealed by the correlation coefficient of 97 per cent. Comparison of the observed and the predicted yields indicate the close agreement between them in all the stages. Considering the observed Total Dry Matter up to the first four stages and the predicted Total Dry Matter at the end of the harvesting stage, the model has been validated for the years 1999 to 2001, and there is very good agreement between the observed and the predicted yield, which is revealed by the regression coefficients of 0.9 and 0.97 for two dates of sowing.

Hence, this Stocheometric crop weather model could be used to predict the grain yield along with their dry matters well before the harvest of crop. This helps the decision making authority in the adverse event of the climate (like drought/flood hit years or areas) to guide the farming community and also the planners for future action.

Weather Based Forewarning System for the Pest and Disease Management

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Forewarning refers to prediction of forthcoming infestation of pest in numbers which would cause economic damage to the crop. It is of foremost importance in integrated pest management programme as it serves as a tool to remain in preparedness to face the exigencies. Weather based pest forecast models are used in crop protection. For the purpose of development and use of these models, both meteorological and biological data are required as input, while the output is the anticipated outbreak of pest or disease.

From operational view point, forecast models could be distinguished as (i) Predictive models, which are used for insurance and (ii) Quantitative models, which are used for good management. From the meteorological point of view,

1. AICRP on Pigeonpea, Gulbarga.
2. AICRP on Agrometeorology, Bijapur.

the models are classified as (a) Analytical bio-physical (b) Statistical and (c) Dynamic simulation. However, most models developed for forewarning of pest and disease outbreaks are of statistical type.

The best known example of a weather based forecasting system of insect pests is for the desert locust. It gives the overall situation of stages of pest from India to Atlanta. The FAO and the WMO do the forecasting on a global scale. Another important forewarning models is the "SIRATAC" which is used in Australia for protecting the cotton crop from bollworms and optimise the yields. This model makes use of maximum temperature, minimum temperature and pest growth stages.

In Karnataka and Andhra Pradesh, forewarning models have been developed against the dreaded polyphagous insect, *Helicoverpa armigera armigera* (Hubner) based on monsoon and October - November rainfall. Prolonged rainfall deficit not only is said to promote growth, but also enhances the chemical cues involved in host selection. A definite trend has been established to predict the level of attack during any year, using surplus or deficit rainfall of different months, and this type of forewarning has justified the severity of *Helicoverpa* attack in different districts of Andhra Pradesh as well as in Gulbarga district of Karnataka. The three types of resultant effects of combination of monsoon (from June to September) and November on pest density are (i) monsoon surplus and November dificit - low pest attack (ii) both monsoon and November either in deficit or excess - moderate pest attack, and (iii) monsoon deficit and November surplus - severe damage. This rule was test verified at 5 locations in Andhra Pradesh in 1997-98, an outburst year. The multiple regression model developed was validated for the same pest which is threatening pigeonpea cultivation in Gulbarga, the pigeonpea bowl of Karnataka. This prediction model was fine tuned by using rainfall data of October instead of November as the lead time in the latter case is extremely short. Based on the model, forecasts are made at the end of October i.e., 15-20 days in advance of anticipated outbreaks.

Similarly, multiple linear regression models for aphids on rabi sorghum and their natural enemies have been sucessfully developed in Karnataka. Temperature at three weeks lead time and relative humidity at one or two weeks lead time are important in influencing the shootfly incidence, another production constraint on rabi sorghum.

Forecast models have also been developed for major crop diseases viz., powdery mildew in grapes and ber, downy mildew in grapes, etc., incorporating weather variables, which are in the stage of field-testing.

Drought Preparedness and Mitigation

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Drought is considered by many to be the most complex but least understood of all natural hazards, affecting more people than any other hazard (Hagman 1984). For example in sub-Saharan Africa, the drought of early to mid 1980s was reported to have adversely affected more than 40 million people. The 1991-92 drought in Southern Africa affected 20 million people and resulted in a deficit of cereal supplies of more than 6.7 million tons (SADCC 1992). Lessons from developed and developing countries demonstrate that drought results in significant impacts, regardless of level of developments although the character of these impacts will differ profoundly (Subbiah 1993; Benson and Clay 1998, 2000; Wilhite 2000; Wilhite and Vanyarkho 2000). Being normal feature of climate its recurrence is inevitable. However, there remains much confusion within the scientific community about its characteristics. It is perhaps this confusion which results into poor drought management in most parts of the globe.

The purpose of this presentation is four fold. First, an overview of the concept and definitions of drought will be provided to help to understand the complexities of the hazard. As drought means different things to different people it has score of definitions and types, therefore its classification will be discussed. Second, techniques to identify and monitor drought will be discussed with some intricacies of drought prediction and analysis of past droughts. Monitoring of drought through remote sensing will also be spelled. Third, aspects related to management of drought and drought preparedness will be discussed. The impact associated with different types of drought and their interacting influence on the society will also be dealt. Finally, drought policy and planning needs will be discussed in the context of a ten-step drought planning process first published in 1991 (Wilhite 1991) and subsequently revised and updated for various users. The goal is to demonstrate how this planning methodology could be employed, with appropriate modifications, to address future drought policy and planning needs in other drought prone regions.

Rice Crop Simulation Model and its Application

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The National Centre for Medium Range Weather Forecasting in collaboration with IMD, ICAR and SAUs is providing experimental agrometeorological advisory service at the scale of agroclimatic zone to the farming community, based on the location specific medium range weather forecast. Presently the service is rendered for 82 agroclimatic zones out of a total of 127 zones in the country. Agriculture scientists at the AAS unit translate the current and forecast weather into management decisions and advise the farmers to adopt them in his farming activities. Adequate technological tools should be available at the AAS unit to achieve the tasks of translation of the weather information into timely profitable agro-management decisions. The crop model based approach to decision-making can be made use of for developing information for real-time weather dependent Agromet. Advisories are disseminated to farmers. Application of crop models provides new and useful information enabling more timely and knowledgeable decisions. In this context, work on dynamic crop simulation modeling for major crops in India is being pursued since more than 10 years.

The work on simulation of rice phenology and growth for different cultivers in the country and its application using CERES - Rice model (DSSATv 3.5) carried out at NCMRWF will be presented.

Modeling Crop-Weather Interactions

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Climatic parameters are the primary variables which define the agricultural productivity of any region and, therefore, the direct effects of climatic factors on crop growth and development have always been a subject of detailed investigations. Attempts have been invariably made through various regression models to predict the relationship between agricultural productivity and climatic components. However, such analysis that includes the effects of some climatic specific factors only excluding the interactions and feedbacks from other controlling elements can often lead to incorrect conclusions. In reality there are a large number of edaphic, hydrologic, biotic, agronomic and socio-economic factors that have a direct bearing on crop growth and productivity in addition to the climatic factors. Therefore, the response to climatic factors will invariably vary in different locations/experiments/years because of genotypic interactions with climatic variability, applications of external inputs such as irrigation and fertilizers, pests and disease incidence, and agronomic management practices. Agro-ecological zoning, which is crucial for planning agricultural development, is based on rainfall statistics and growing days. It may be adequate from a purely ecological point of view but it does not indicate much about the agricultural potential of the region. The growing period need not necessarily have a correlation with crop productivity. For example, it is more than 210 days in Assam and West Bengal, but the yield of principal rainy season rice crop is very low due to limited radiation and input use. On the other hand, the growing period in Punjab is only 90-150 days, yet rice yields are much higher due to significantly higher radiation and input usage.

Dynamic crop growth simulation is a relatively recent technique that facilitates quantitative understanding of the effects of climatic, edaphic and agronomic management factors on crop growth and productivity in varying situations. These process-based explanatory models are quantitative descriptions of the mechanisms and processes that result in growth and development of the crop. These processes could be physiological, physical and chemical. A large number of crop models have been developed during the last two to three decades for all major crops such as wheat, rice, maize, sorghum, millet, chickpea, pigeon pea, groundnut, sunflower, sugarcane, and potato including some plantation and horticultural crops. Crop growth simulation models in conjunction with modern Information Technology tools, Geographical Information System (GIS), databases and optimization techniques, present a new opportunity for assessing potential production in a region and facilitate analysis of the sustainability options for agricultural development including planning of resource allocation. These approaches are being used for evaluating the production potential of a location based on its resource inventory, varieties etc., in matching agro-technology with the farmers resources and identifying the precise reasons for yield gap, forecasting crop yields as well as studying short- and long-term consequences of agricultural practices on crop production. In this paper, an attempt has been made to demonstrate the usefulness of such models to quantify the crop-weather interactions and their applications.

Weather Based Forecasting of Crop Yields, Pests and Diseases - IASRI Models

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Various models were developed using weather parameters for forecasting crop yields. Weekly data on weather parameters for last 20-25 years for the selected districts have been used to develop the models for rice and wheat. For each weather variable, two composite weather variables were developed, one as simple accumulation of weather variable and the other one as weighted accumulation of weekly weather variable, weights being correlation coefficients of weather variable in respective weeks with yield or yield adjusted for trend effect. Similarly, for interaction of weather variables, composite variables were generated using weekly products of weather variables taking two at a time. These models were developed for rainfed district deficient in rainfall (rice - Raipur), rainfed district having adequate rainfall (rice - Puri) and irrigated wheat - Amritsar. These models were also used to study simple and joint effects of weather variables on crop yields. This approach was extended to develop models for agroclimatic zones using weather parameters and agricultural inputs for wheat in Vindhya Plateau zone and rice in Chattisgarh Plain zone and Bastar Plateau zone taken together. Results revealed that reliable forecasts can be obtained around two months before harvest using these models. Similar model was developed for sugarcane in Kolhapur district taking fortnightly weather variables. Reliable forecast using this model can be obtained for sugarcane when the crop is 8-9 months old. In another approach, model was developed for rice in Kolhapur district using discriminant function analysis taking a long series data on weekly weather parameters and corresponding yields. In this approach, years were grouped into three categories - congenial, normal and adverse based on yield adjusted for trend effects. Weather data in these three groups were used to develop weather scores for each year through disciminant function analysis. These weather scores alongwith agricultural inputs and trend were used to develop forecast model through stepwise regression technique. In this approach also, reliable yield forecast of subsequent year could be obtained about 2 months before harvest. Water balance technique has been used to develop models for rainfed crops using weighted stress indices. These models provided forecasts six weeks before harvest for sorghum (Delhi and Parbhani), four weeks before harvest for maize (Delhi) and five weeks before harvest for rice (Raipur).

Methodologies were developed for forecasting aphid population in potato [*myzus persicae* (sulzer)] for Pantnagar (U.P.), Deesa (Gujarat) and Kalyani (West Bengal) using non-linear regression models and GMDH approach. These models provided reliable forewarning in advance of one/two weeks. Forewarning of fruitfly in mango has been attempted by fitting a non-linear model to the natural cycle of fruitfly and then developing regression models relating deviations from natural cycle to weather parameters. Forewarning of powdery mildew in mango has been attempted through logistic models. Forewarning is possible using these approaches one week in advance. Models using composite weather variables were developed for forewarning maximum incidence and age at first appearance of the disease for various diseases, varieties and locations in mustard crop.