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Pre-harvest estimation of wheat yield for NW India using climate and weather forecast

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सार – किसी भी स्थान के खेतिहरों की फसल अपने जीवन चक्र में मौसम पर मुख्य रूप से निर्भर होने के साथ–साथ पोषण, मृदा आर्द्रता और प्रबंधन कार्यों पर निर्भर करती है। मौसम का सही पूर्वानुमान, किसानों को उपयुक्त मौसम में पूँजी लगाने और फसल को खराब मौसम से बचाने के लिए सही कदम उठाने में सहायता प्रदान कर सकता है। यह कार्य जलवायु और मौसम पूर्वानुमान से जुड़े फसल अनुकरण निदर्शों का उपयोग करते हुए पूरा किया जा सकता है। किंतु उपयोग के लिए इन्हें अपनाने से पहले विभिन्न कृषि जलवायविक क्षेत्रों में मौसम पूर्वानुमान की विश्वस्नीयता की जाँच अवश्य कर लेनी चाहिए।

इस कार्य के लिए उत्तरी पश्चिमी भारत में दीर्घ अवधि मौसम रिकार्डों का उपयोग करते हुए फसल के मौसम के दौरान विभिन्न स्तरों पर गेहूँ की प्रचलित किस्म की समजातियों के लिए श्रेष्ठ पूर्वानुमान के द्वारा उपज और मात्रात्मक मान को आकलित करने के लिए आकलित सेरस–गेहूँ निदर्श V 3.5 का इस्तेमाल किया गया है। विभिन्न खादों, फसल की बुवाई की तारीखों और नमी वाले स्थानों में मौसम पूर्वानुमान की यथार्थता (मध्यम अवधि) की भी जाँच पड़ताल की गई है। इस जाँच से प्राप्त हुए परिणामों से फसल के उगने के मौसम के दौरान अनुकूल नीति की योजना उपज आकलन और यथेष्ठ निर्णयों के लिए निदर्श की उपयुक्तता का पता चलता है।

ABSTRACT . The yield of a cultivar at any given location depends highly on weather experienced during its life cycle interalia nutrition, soil moisture and management practices. Accurate weather prediction may help farmers to capitalise on benevolent weather and to take adequate steps to protect crops from adverse weather events. This task may be accomplished using crop simulation models linked with climate and weather forecast. But, reliability of weather forecast must be assessed in various agroclimatic zones before their adoption on operational basis.

For this purpose, evaluated CERES-Wheat model V3.5 was utilised to estimate yield and quantify value of perfect forecast for popular wheat genotypes at various steps during crop season using long term weather records in NW India. Accuracy of weather forecast (medium range) was also tested under different fertiliser, dates of sowing and moisture scenarios. Results indicate the suitability of the model for strategic planning, yield estimation and tactical decisions during crop growth season.

Key words – Forecast, Simulation, Yield, Growth, Genotype.

1. Introduction

In many countries, losses due to weather sometimes reach as much as 30% of the annual agricultural production. According to an estimate, at least 8% of these losses could be avoided by proper use of weather forecast and climatological information. In fact, for subsistence of small and marginal farmers, weather forecast based farm management may prove crucial during critical crop as well as weather conditions. Newly framed Agriculture Policy by the Government of India has projected 4% growth rate in agriculture sector by introducing 'rainbow revolution' in next two decades and due focus on accurate weather forecast and agro meteorological aspects has been spelt in the policy. It also emphasises on long term development of the farm sector on the basis of efficient use of scientific, economic and environmental resources.

An estimate of crop yield is essential for maintaining food storages/supplies and to assess the relative economic situation well in advance, at national and international levels. In India, the estimates of crop production are obtained by multiplication of area estimates by corresponding yield estimates. The yield estimates are obtained through analysis of crop cutting experiments (CCE) conducted under General Crop Estimation Surveys (GCES). The CSE is a cumbersome method as it involves identification and marking of experimental plots of a specified size and shape in a selected field on the principle of random sampling, threshing the produce and weighing the harvested produce. Apart from physical difficulties, the CCEs have problems of mis-representation of the field situations, despite stratified multi-stage random sampling design.

Use of remotely sensed crop data on its acreage, health and vigour; and crop simulation models to estimate the growth, development and economic yield of the crop is catching up. Agronomists, soil scientists, plant physiologists, agricultural economists and meteorologists have used hierarchy of models from statistical to dynamic simulation for prediction of yield for last many years. The former depends heavily on empirical correlation between yield and climatic variables, while the latter simulates the crop biophysiological processes that underline growth and development of crop to assess the grain yield. Both techniques are constrained by lack of knowledge of future weather, especially of precipitation. Test studies on use of simulation models have been reported by Aggarwal and Kalra (1994), Bishnoi *et al.* (1996), Hundal and Kaur (1997), Attri *et al.* (1999) and Attri (2000). Singh *et al.* (1997) have evaluated medium range weather forecast using WTGROWS.

Time of crop assessment/yield forecast is very important from the point of view of strategic planning. Although one may make such an attempt soon after sowing or early vegetative state but more realistic estimates on crop yield could be made when crop enters the reproduction stage. This may be due to the knowledge of weather experienced by the crop upto the time when forecast of yield is attempted, while, weather for remaining part of the growing season has to be synthesised (forecast/normal weather/actual weather for previous years) for yield simulation. This synthesized weather (short range, medium range and climate) must be reliable for its use in planning purposes. Here, an attempt has, therefore, been made to predict yield and test the accuracy of weather forecast and quantify its peak utility during crop life cycle using crop growth simulator *viz*. CERES-Wheat model V3.5.

2. Materials and methods

2.1. *Model*

CERES-Wheat (Richie and Otter, 1985; Ritchie, 1991) is a process-oriented management model for wheat and has been developed to be generally applicable around the world where appropriate data are available as inputs to the model. The major components of the model are the vegetative and reproductive development, carbon balance, water balance and nitrogen balance modules. The model accounts for vegetative and reproductive development; photosynthesis, respiration, partitioning, growth of leaves, stem, roots, shells, and seeds; transpiration; root water uptake, soil evaporation, soil water flow; infiltration and drainage (Hoogenboom *et al.,* 1991; Ritchie, 1991). Details of various routines in CERES-Wheat V3.5 have been described by Attri (2000).

2.2. *Method for early assessment of yield*

Considering the genuine need of crop estimates much before its harvest, a procedure was developed for early assessment of yield during growing season of the crop employing CERES-Wheat model and using historical weather data, and perfect weather forecast (known weather) in addition to current weather data for the study. The crop year, in which yield prediction is attempted, is termed as the crop reference year. The reference year was selected depending on marked difference in the yield values. As the model simulates the crop as a closed system, weather information has to be defined from sowing until harvest. Normal sowing of 5 November in case of timely sown cultivars (WH542 and HD2329) and 25 November in late sown cultivars (HD2285, Sonalika and Raj3765) were selected as per package and practices of crop. The reference year's daily weather data were put into model upto the date on which the management decision and yield predictions were to be made, then the perfect weather forecast for next 10 days (actual data of reference year) were added to it which was followed by sequence of daily historical data (one sequence per year of weather data that have been observed at the station) until the end of growing season. The above procedure called "Replacement process" was repeated at every10-day interval by replacing the weather data of all the years by weather data of reference year upto the date of yield forecast, while actual weather data of all the years for remaining period of crop life cycle was used as such for yield simulation.

Using these sequences of weather data, yield estimate were carried out separately for each of 25 years for HD2329 (Ludhiana) and of 30 years for WH542

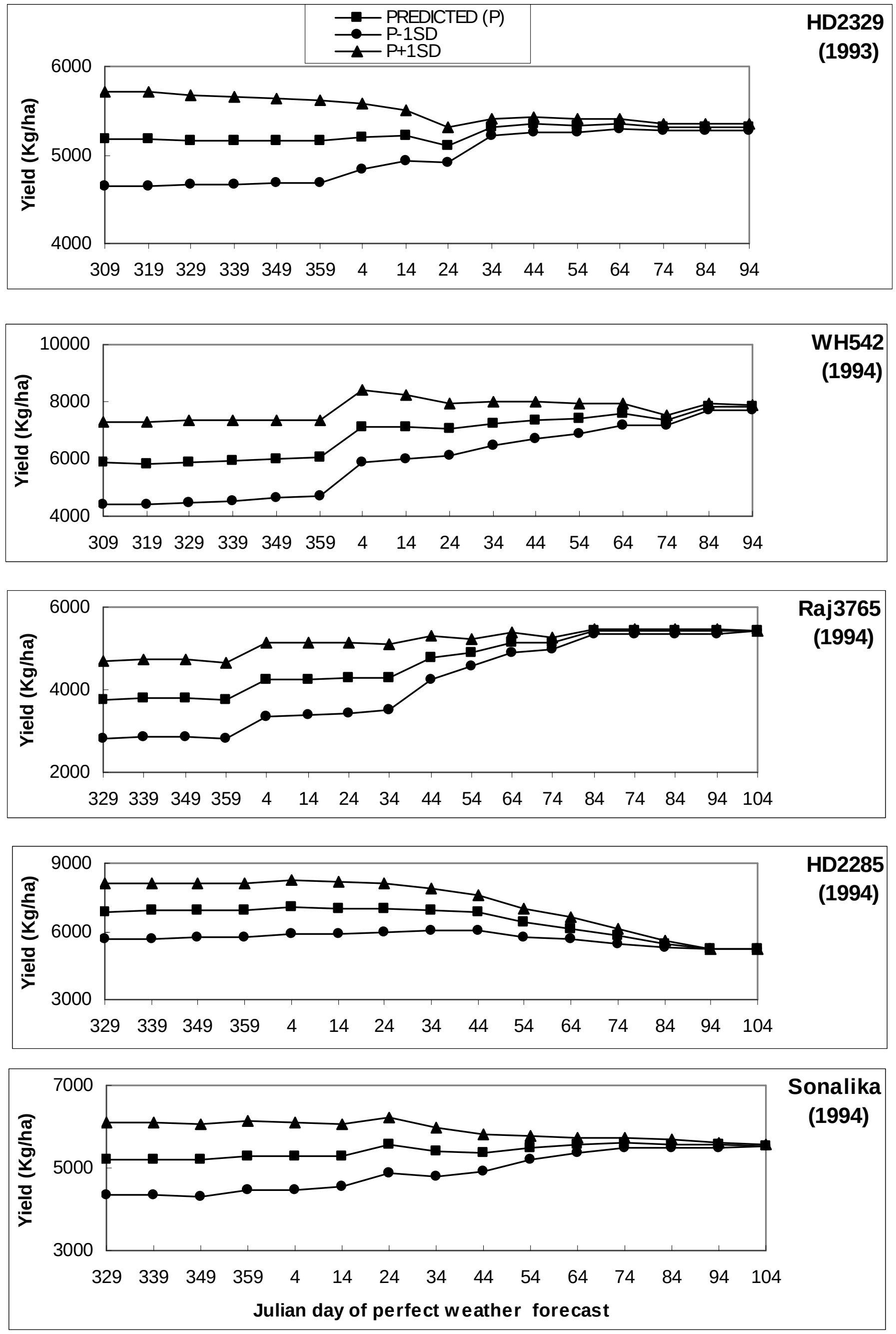

Fig. 1. Yield prediction using perfect weather forecast concept

(Hisar), HD2285 (Delhi), Sonalika (Pantnagar) and Raj3765 (Jaipur) using validated CERES-Wheat model under standard package and practices of crops of various genotypes. The mean of distribution of yield estimates at 10-days interval is taken as the prediction for the reference year at the time of forecast.

Weather forecast in medium range is crucial for tailoring management decisions during crop growth. MRWF (medium range weather forecast) file was created by replacing actual weather data with forecast weather (maximum and minimum temperatures, radiation and precipitation) for six days a week for Ludhiana and Hisar

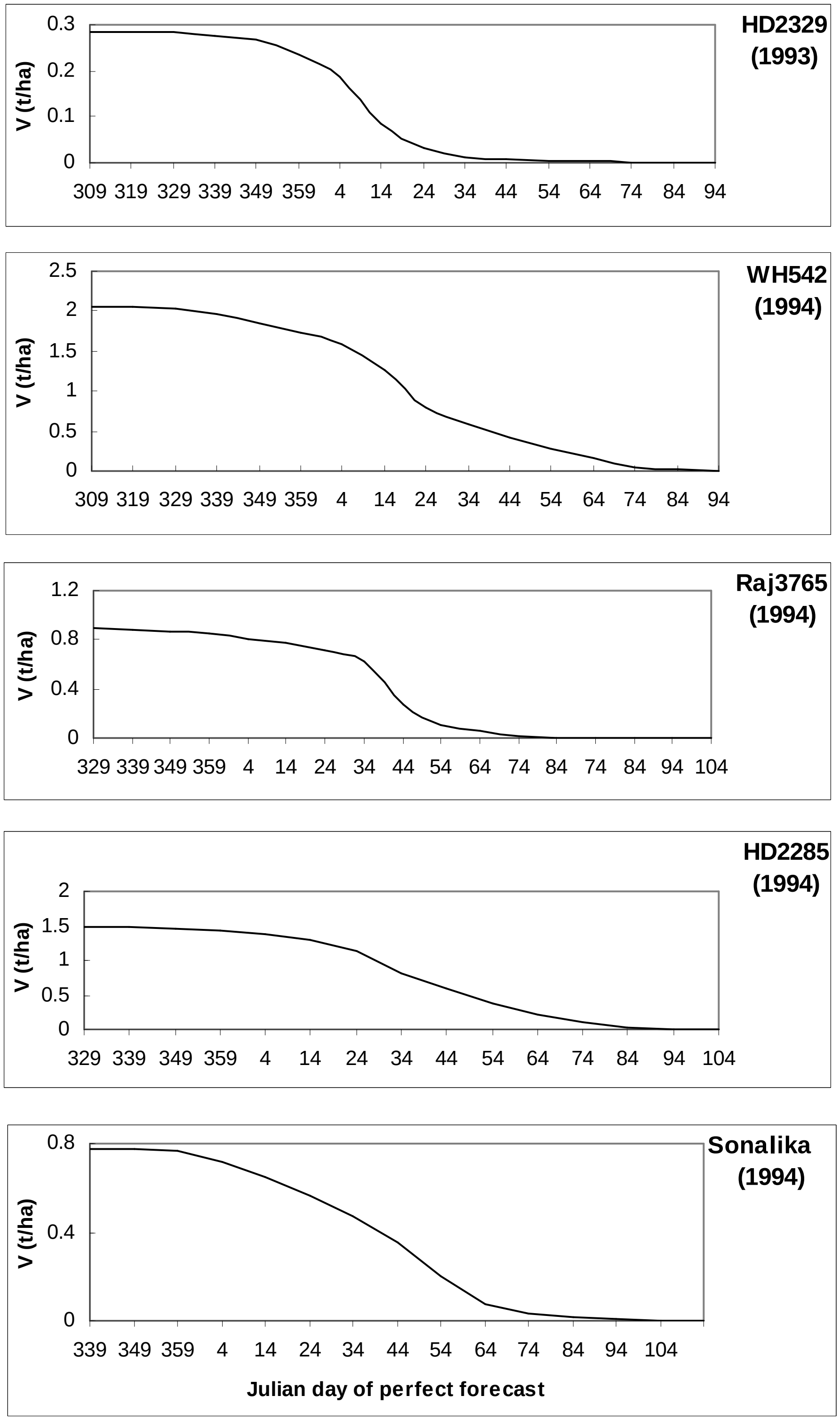

Fig. 2. Variance (V) of yield distribution at different dates using perfect weather forecast concept

and three days a week for Raipur and Pantnagar for two recent years (1996-97 and 1998-99). Actual weather data were used for the remaining days of the week. The simulation of growth and yield was carried out using validated CERES-Wheat model V3.5 (Attri, 2000) under normal package and practices of crop with actual weather

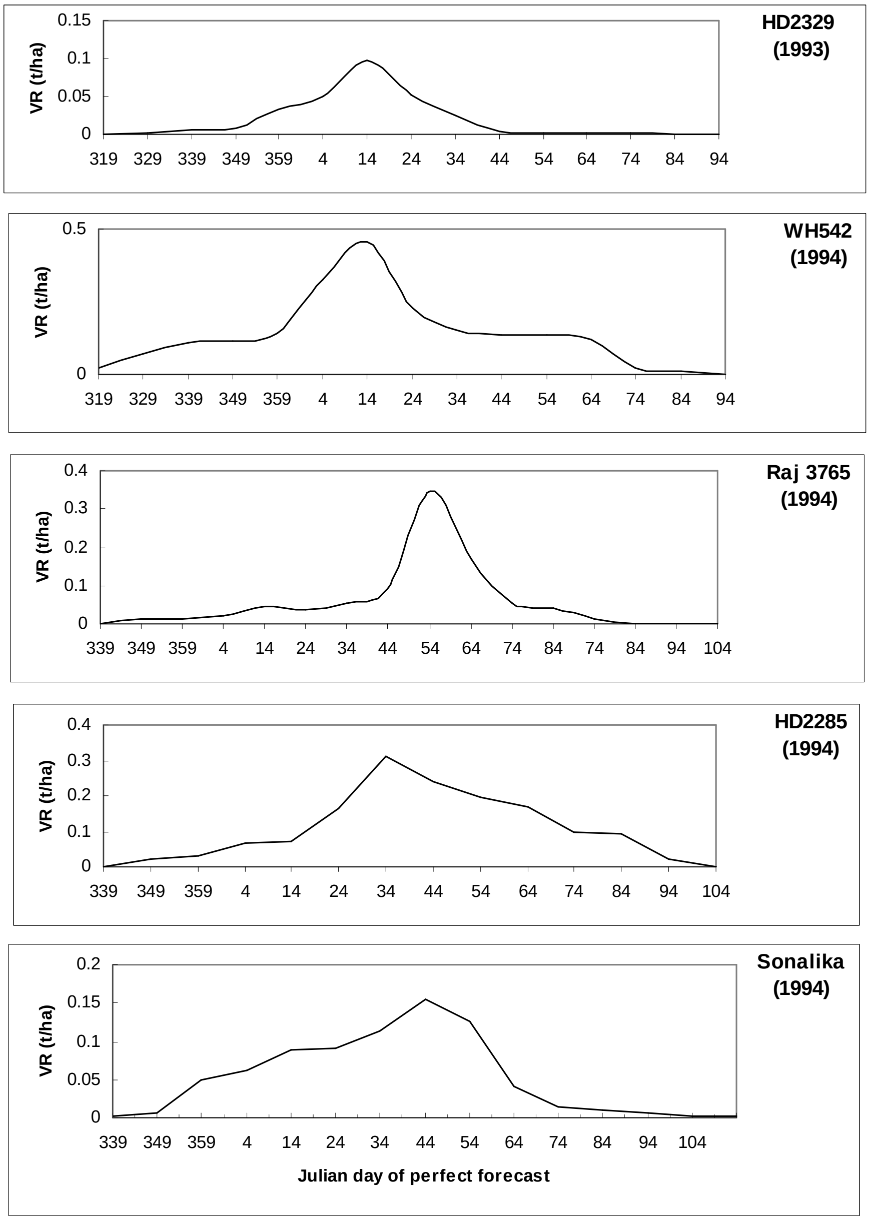

Fig. 3. Value of perfect weather forecast in medium range (10 Days)

and MRWF under rainfed and irrigated conditions *viz.* 1 irrigation at Crown Root Initiation (CRI, 21 days after sowing (DAS)), 2 irrigations at CRI and flowering (85 DAS), 3 irrigations at CRI, jointing (65 DAS) and flowering stages).

3. Results and discussion

3.1. *Yield distribution*

Yield predictions at different dates during crop life cycle for reference year are depicted in Fig. 1. Middle curve of the figure represents predicted yield as a function of forecast time. It is only after jointing stage that any reference year's weather plays a substantial role-unless it is extreme. The predicted yield rose sharply in response to weather after jointing stage in all other cultivars under study. Other two curves *i.e.* prediction ±1 standard deviation provide means of prediction with 95% confidence interval. In other words, one would be 95% confident that yield predicted by the CERES-Wheat model on 1 January, may be between 4691 kg/ha and 5623 kg/ha in HD2329 and 3751 kg/ha and 4673 kg/ha in Raj 3765 respectively.

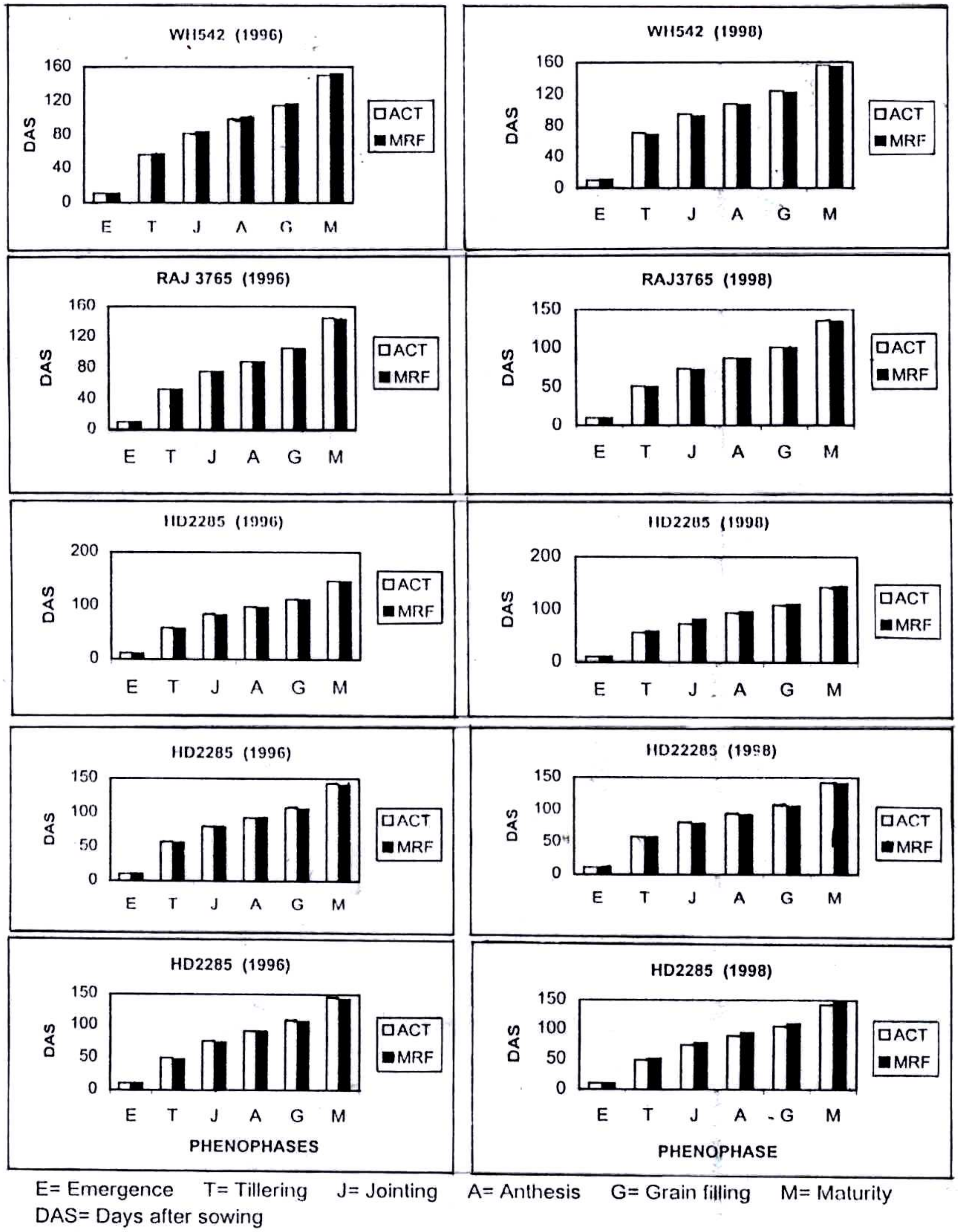

Fig. 4. Prediction of phenology for different genotypes using actual (ACT) and medium range weather forecast (MRF)

3.2. *Variance of yield prediction*

The variances associated with the simulated yield distribution at various dates during crop life cycle in different genotypes for reference year are plotted in Fig. 2. The variance of yield distribution decreased with the advancement of crop season in all the cultivars. However, change in variance was very less from sowing to tillering

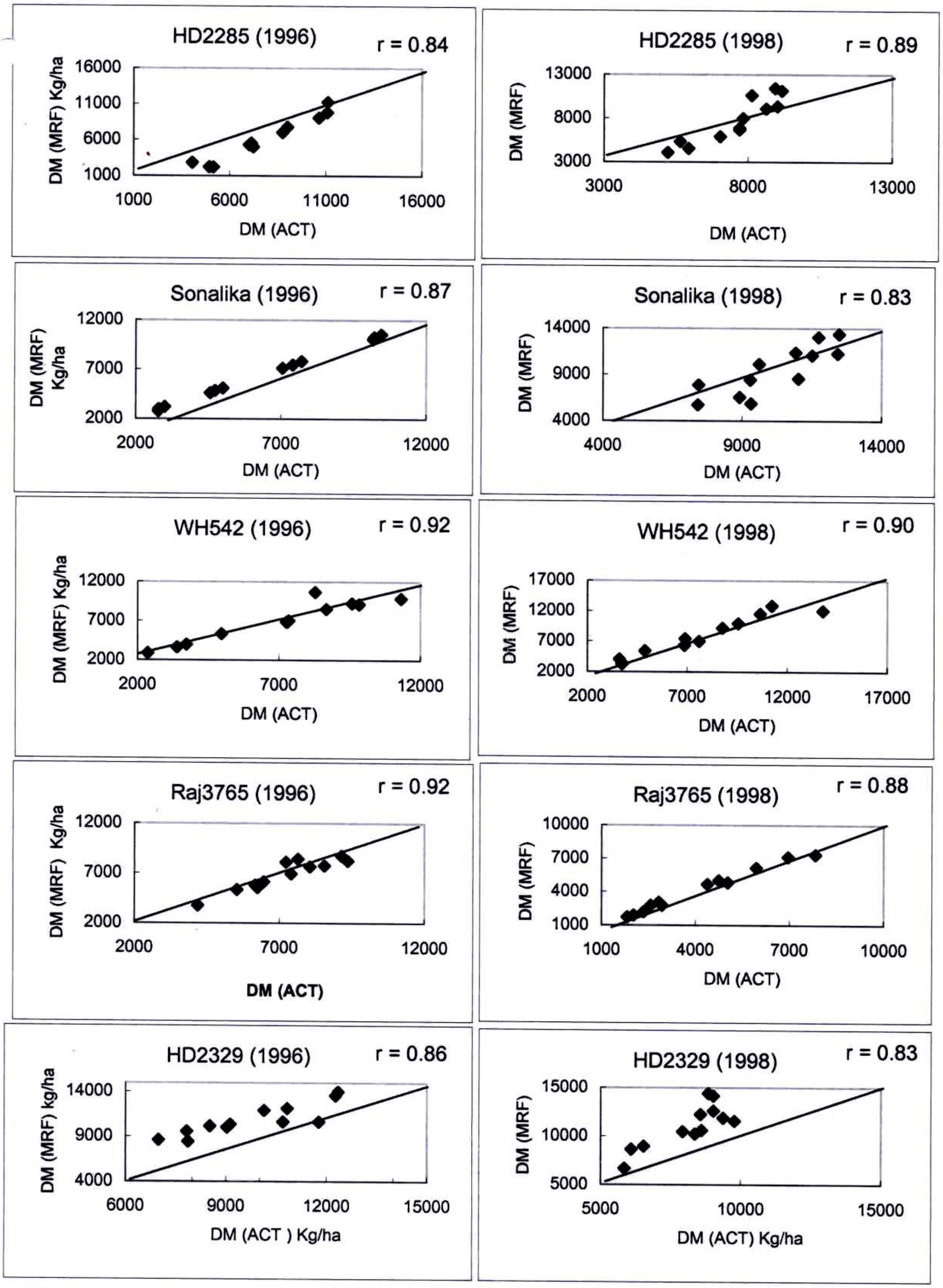

Fig. 5. Prediction of dry matter (DM) (kg/ha) for different genotypes using actual weather (ACT) and medium range weather forecast (MRF)

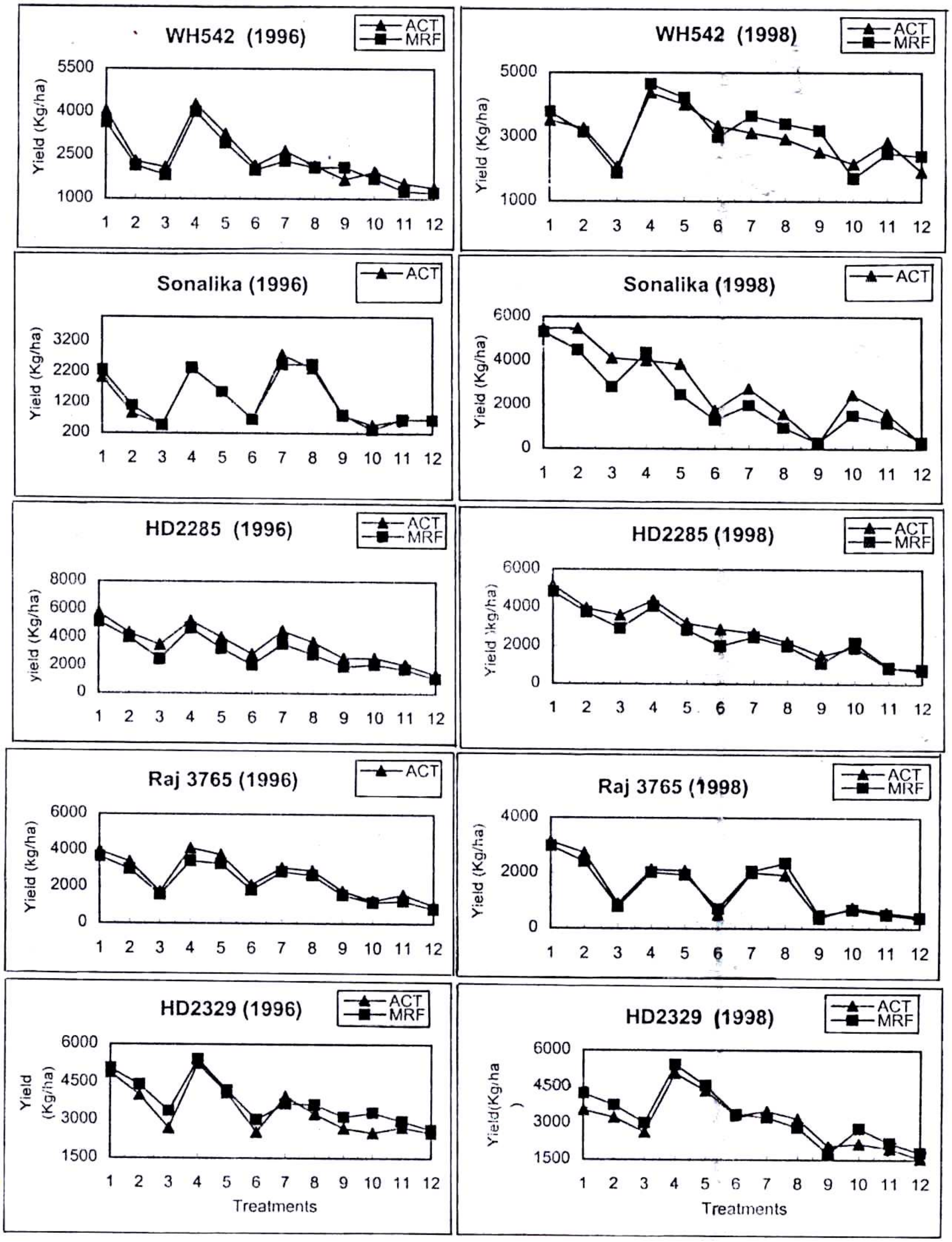

Fig. 6. Prediction of yield for different genotypes using actual weather (ACT) and medium range weather forecast (MRF)

(around 45 DAS). This means that the variation in yield is dominated by variation in weather (parameters used in the study are: radiation, maximum temperature, minimum temperature and rainfall) encountered by the crop after tillering stage. Variance started to decrease slowly untill late tillering in HD2329, early jointing stage in WH542, Sonalika, HD2285 and jointing stage in Raj3765, thereafter, it decreased rapidly up to anthesis stage in WH542, Raj 3765 and HD2285 and late jointing stage in other cultivars and finally to zero around physiological maturity in different genotypes. It means that in the process of replacing the 25/30 sequences of historical weather in a forecast period of 25/30 sequences of same current weather, the contribution of the former to the variance of yield in various genotypes is reduced to zero. The variance in yield that can increase from one forecast time to the next, is a reflection of non-linearity of the plant growth processes considered in the simulation model.

After the completion of the replacement process for a given forecast period, the weather sequences follow a different impact on model performance than before replacement. In short, the effect of variation in the weather input on the model performance at a given time depends on antecedent weather. For example, the phenological dates can change and as they do, the growth processes after the forecast period are altered. It may result to small increase in variances. With many more years of historical sequence, the variance should be much closer to a smooth curve type.

3.3. *Value of perfect weather forecast*

In general, it is difficult to assess the value of weather forecast because it has different implication to different users. However, this can be achieved from the concept of alternate values of resulting reduction in variance of yield distribution.

With the above meaning, it is relatively easy to obtain the value of a perfect daily forecast. This is done by taking the difference between the variance at the beginning and end of each forecast period for all possible dates during crop growth period. Thus, for a ten days perfect weather forecast at day 309, the variance at day 319 along the curve would be subtracted from that at day 309, for forecast date 310 the variance at day 320 from that at day 310 and so on. The results of carrying out this procedure in all genotypes are shown in Fig. 3.

The peak value of 10 day perfect forecast occurred around jointing stage in HD2329, WH542 and HD2285 and after jointing stage in remaining genotypes under study as reduction in variance of yield was highest during this period. The results indicate that 20-day period after tillering in HD2329, WH542 and Raj3765 and 30 day period in Sonalika and HD2285 associated with active vegetative stage were very important from forecast point of view. The findings suggest that during this part of growing season, daily weather predictions made in medium range scale should be as much accurate and reliable as possible reaching near a perfect forecast for accurate simulation of yield of different cultivars.

3.4. *Assessment of medium range weather forecast (MRWF)*

Utility of medium range weather forecast has been assessed in terms of crop growth, development and yield variations from the realized weather at the station and the results are presented as under :

3.4.1. *Phenology*

Predicted occurrence of different growth stages *viz*. emergence, tillering, jointing, anthesis, grain filling and maturity by the model from MRWF data for various cultivars under study was closed to that simulated using actual weather data for both the seasons *i.e*. 1996-97 and 1998-99 (Fig. 4). There was difference of 0-3 days in normal sown cultivars from both types of weather, while slightly higher variations were observed under early and late sown situations. Further, the variations were higher under stress conditions (1-4 days).

3.4.2. *Dry matter*

Simulated dry matters from actual weather was in agreement with that simulated using MRWF (Fig. 5). The closeness is exhibited by correlation coefficients of the order of 0.83-0.92 in different cultivars under study. However, over predictions from MRWF were observed when realised rainfall was significantly lower than actual weather and *vice-versa*. Further, variations were higher under rainfed conditions (-23% to +26%) as compared to irrigated ones in different genotypes (-11% to +16%).

3.4.3. *Yield*

Simulated yields from actual weather were in reasonable agreement with that from MRWF data in both the years in different genotypes (Fig.6). In general, variations in simulated yields increased with decrease in irrigation frequency in all the cultivars. Further, the variations were higher under rainfed conditions (–25 to +29%) as compared to irrigated ones (–18 to +20%). Higher variations were observed in HD2329 as compared to other genotypes, which may be due to realization of lower precipitation as compared to forecast one at the station. cultivars.

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