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Research Article

Variations in Meteorological Conditions Resulted Decline in Wheat Yield in North-West Indo-Gangetic Plains

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ABSTRACT

There has always been a lack of consensus on the effect of climatic change on agriculture due to inadequate knowledge on response of crops to variable climatic conditions. In Indian conditions, effects of high temperature during grain filling of wheat have been well documented but the effect of humid environment during this stage has not been adequately studied. During 2012-13, prominent wheat growing regions in the Indo-Gangetic plains of the country have experienced rise in minimum temperature along with high humidity during wheat season. The change was due to western disturbance causing snow and rains in hill areas and rains in northern plains of the country during January-March, 2013. Although, India has progressed significantly in food grain production, but the variable climatic conditions impede the trajectory of growth, and decline of 2.42 Mt of production has been reported in 2012-13. Analysis of meteorological parameters particularly minimum and maximum temperatures, relative humidity and precipitation could provide useful insight to understand the effects of climatic variability on wheat grain production in India. The most possible reason for the decline in wheat production during 2012-13 could be the humid phase under moderately high minimum temperature, which resulted in the occurrence of brown and yellow rust, black point and karnal bunt fungal diseases during the grain filling stage.

Key words: Climatic variability, Wheat yield, Meteorological data, Fungal disease

Introduction

Globally, the major factor influencing the agriculture productivity is ascribed to the climatic variability. Nearly all crops in agricultural system express their optimum physiological output under the influence of favourable meteorological condition. Wheat, one of the major *rabi* cereal crops in India is no exception. The crop is extremely susceptible to variable environmental conditions. Effect of temperature particularly at its later stages of development, particularly after heading has been widely reported (Rawson, 1986; Farooq *et al*., 2011). Chowdhury and Wardlaw (1978) have confirmed that an average temperature of 15^{0}C during grain filling is close to the optimum temperature for maximum grain weight under subtropical and tropical conditions. In some of the wheat growing regions of India, higher temperature during grain growth and reproductive stage is one of the major concerns, because such weather constraint leads to reduced crop duration and reduction in grain yield. Sometimes, a prolonged period of rainfall, fog or heavy dew raises the risk of development of pathogens resulting in certain types of diseases in wheat. Within favourable range, there is an optimum temperature where most of the individuals of a species complete their development. Exposure to temperature on either

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side exerts an adverse impact on the insect by slowing down the speed of development (Pradhan, 1946).

India has progressed significantly in production of food grains (wheat, rice, pulses and coarse cereals). In 2011-12, India achieved a target of 257.44 Mt of food-grain production (Directorate of Economics and Statistics, 2011-12), registering an increase of 406% from 1950-51. Many factors like high-yielding hybrids, availability of chemical fertilizers and irrigation have been responsible for increasing the production (Tyagi *et al.*, 2012). Wheat contributed 36.5% of total production of food grains in the country during 2011-12 (Directorate of Economics and Statistics, 2011-12). But crop yield is the culmination of a diversified range of factors, and agriculture is sensitive to short-term changes in weather. For the long-term changes, agriculture is able to tolerate moderate variations in the climatic mean. Changes beyond these bands of tolerance may require shifts in cultivars and crops, new technologies and infrastructure or ultimately conversion to different land uses. The variations in the meteorological parameters are more of transitory in nature and have paramount influence on the agricultural systems (Khan *et al.*, 2009). Several studies have indicated how yield of wheat is affected by climatic variations (Goswami *et al.*, 2006). The importance of temperature and humidity in disease and pest infestation has been well documented.

The wheat production in India has been consistently improving since last decade (Fig. 1), and in 2011-12, it registered an all-time high 94.88 Mt production, mainly due to the favorable weather conditions. As per the 4th advance estimate of food grain production in India, released by Ministry of Agriculture on 22nd July, 2013, the total wheat grain production during 2012-13 is likely to be 92.46 Mt (Directorate of Economics and Statistics, 2012-13), which is 2.42 Mt less than the last year's production, indicating a decline of 2.55% (Fig. 1). Although this pertains to one particular year only, there is a need to understand the cause of the decline.

For sustaining the productivity and to minimize the effect of weather variability to crop yield, a better understanding of the weather pattern will be useful. By analyzing the meteorological parameters obtained from the Agromet Observatory of IARI, New Delhi, we tried to understand the yield decline in 2012-13 in comparison to that in so far the best productive year (2011-12). An attempt has also been made to explain the decisive factors for decline in wheat yield.

Methodology

Study area

Uttar Pradesh, Punjab and Haryana together supply about 65% of the country's wheat output.

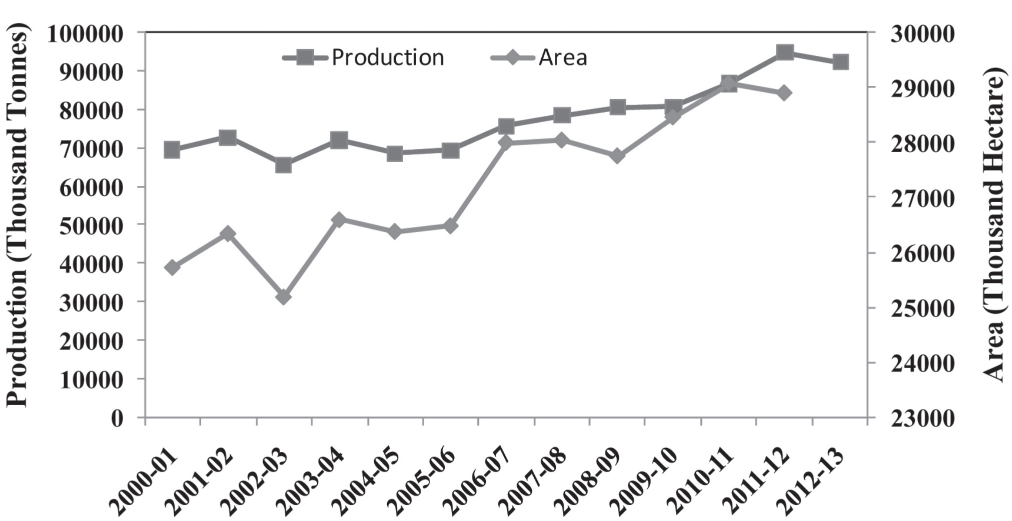

Fig. 1. Wheat crop production and wheat sown area in India

This region experience almost uniform climatic conditions throughout the wheat growing season. New Delhi is located in the north-west of this region, and the climatic conditions sufficiently resemble with that in Punjab, Haryana and western Uttar Pradesh, where the wheat crop density is maximum.

Acquisition and format of meteorological data

Data on the key meteorological parameters like maximum and minimum temperatures, relative humidity and precipitation were obtained from the Agromet Observatory of the Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi. Mean of 30 years (1984-2013) data, and daily data of the above mentioned parameters during wheat growing period (15^{th} November to 15^{th} April) for the years 2011-12 and 2012-13 were used. The relative humidity has been taken twice at 7.21 (RH-I) AM and 2.21 PM (RH-II) in each day. The precipitation amount was the total rainfall on a particular day irrespective of number of events.

Results and Discussion

Temperature disparity

The air temperature is a decisive factor in plant growth. Each crop is known to have its own threshold temperature conditions. In literature, many studies have established the effects of temperature at later stages of the development of wheat crop, particularly after heading (Rawson, 1986; Farooq *et al.*, 2011). An average temperature of 15°C during grain filling appears close to optimum for getting maximum grain weight in wheat under subtropical and tropical conditions (Chowdhury and Wardlaw, 1978). High temperature during grain filling imposes major limitation on kernel weight and grain yield through reduction in duration of grain filling which ultimately results in decline in production (Sayed and Gadallah, 1983; Wiegand and Cuellar, 1981).

Comparison of the minimum and maximum temperatures during wheat growing period (15 November, 2012 to 15^{th} April 2013) with the long-term (30 years) average during the same period is depicted in Fig. 2. During this period, on the long-term scale, mean daily maximum temperature varied from 18.1 to 36.5 °C, while minimum temperature ranged between 5.3 and 19.2°C. For 2012-13 year, the maximum and minimum temperature varied from 9.4 to 38.0 and 0.6 and 22.4°C. This indicated that both the temperatures diverged from the long-term average during 2012-13.

Data also indicated that during early stage of wheat, both minimum and maximum temperatures remained low with respect to the long term averages. During heading, flowering and milking stages, the minimum temperature follows the trend of long-term mean temperature, although the maximum temperature remained lower than the mean. However from grain filling to maturity,

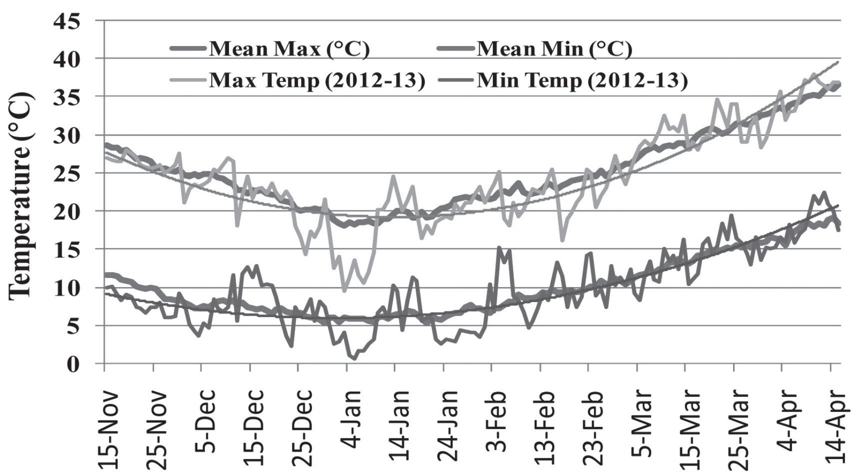

Fig. 2. Air temperature variability during wheat crop period in 2012-13 along with long-term averages

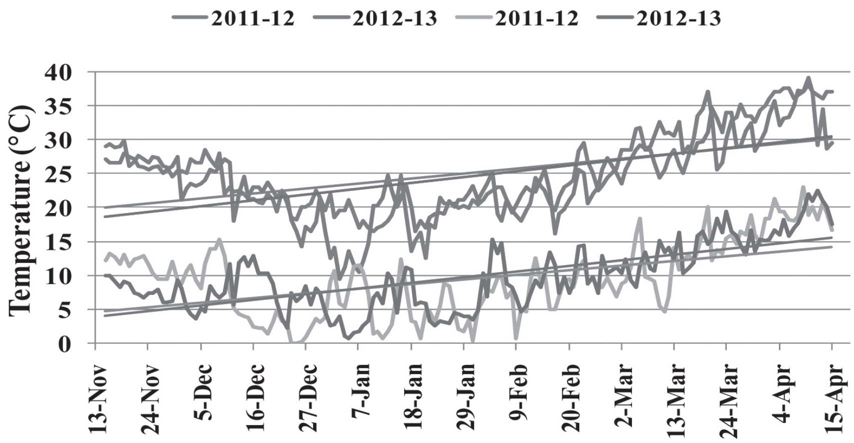

Fig. 3. Comparison of maximum and minimum temperatures during wheat growing period in 2011-12 and 2012-13

both the temperatures showed higher values in comparison to the long-term averages.

The variability between the temperatures during the growing period for 2011-12 and 2012-13 explains the likely cause of decline in production during 2012-13 (Fig. 3). In 2012-13, the maximum temperature remained low during the early stages of the crop, but did not vary much in later stages of the growth. In case of minimum temperature during early stages of the crop, slightly lower values were recorded, in comparison to 2011-12, which showed a rising trend from the milking stage till maturity. Increase in minimum temperature has detrimental effect for wheat. Decline in potential yield of wheat is linked to an increase in minimum temperature in the Indo-Gangetic Plains of India (Pathak *et al*., 2003). High night temperature decreases crop production by increasing dark respiration, a result of which photosynthetic sugars are utilized mainly for plant growth and maintenance. Thus, sugar metabolites are not consumed efficiently to fill grain and produce higher yields. Increase in minimum/night temperature therefore results in sugar mostly utilized for plant growth and maintenance rather than into increasing the kernel dry matter which results in potential yield loss for the plant (Loka and Oosterhuis, 2010; Turnbull *et al*., 2002).

Elevated relative humidity

Relative humidity along with temperature, rainfall, and wind velocity independently or in combination, can influence crop growth and productivity. For Indian conditions, 50-60% RH is optimum for wheat crop. If this is less, moisture loss occurs due to high evapotranspiration and results in more water requirement for irrigation. Disease infestation also increases when there is high humidity coupled with high temperature.

Long-term average daily RH-I during the period varied as 61-95%, while that of RH-II was 26-59% (Fig. 4). During the crop season in 2012-13, the RH-I varied from 60 to 98%, while the RH-II ranged between 15 and 94%. During 2012-13, the RH-I was more stable as compared to RH-II. The high fluctuations in RH-II were noted from the first rainfall event of the season *i.e.*, 12th December, 2012 onwards. This high RH variability persisted till 23rd February, 2013, as this period had experienced exceptionally high amount of rainfall (150.2 mm between mid January and February end) as compared to the long term average rainfall seasons (36.5 mm). Although the RH remained higher even after this period supported by the random rainfall events till early April. Figure 4 confirmed that during gain filling period, there has been persistently high RH mainly due to consistent rainfall.

A comparison implies that in 2012-13 season, both RHs were higher as the rainfall received in this season was 183.0 mm as compared to only 40.8 mm in 2011-12 during the same period (Fig. 5). Although RH-I showed increasing trends from January onwards and widened further. But RH-II

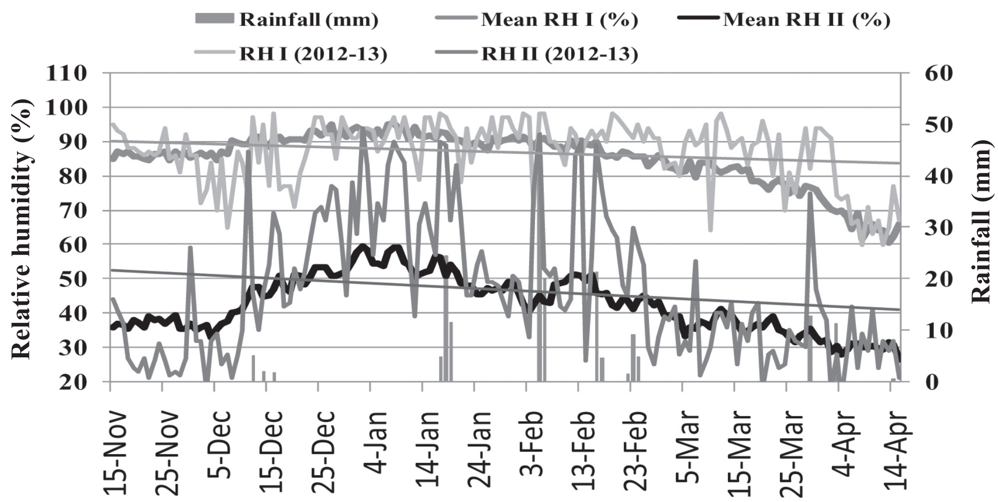

Fig. 4. Relative humidity profile during wheat in 2012-13 along with its long-term averages; and rainfall events during 2012-13

in 2012-13 remained lower than that of 2011-12. Hence, the prevailing condition of high humidity associated with higher minimum temperature during wheat season seems to be responsible for reduction in wheat production in 2012-13.

Outbreak of high humidity induced diseases

Favorable conditions for fungal disease development in wheat include cool, rainy weather or regular irrigation and high humidity at the time of heading. The severity of the disease can also increase when favorable temperatures occur during ear emergence. At gain filling stage, the lodged wheat crop, subjected to irrigation or unseasonable rain, is more vulnerable to diseases. During 2012-13, there was persistently high relative humidity along with higher minimum temperature associated with high rainfall. Speedy winds (H" 80 km h^{-1}) resulted in lodging of the crop in many parts of the Indo-Gangetic plains (Agropedia, 2012-13). Lodged grain is vulnerable and as the head fills with grain, and is subjected to irrigation or rain, multi-stage fungal diseases may spread. Considering the adverse situations and after identifying fungal diseases in some parts, Directorate of Wheat Research, Karnal brought out advisories in January, February and March, 2013 particularly linked with yellow/ brown rust, and advised the farmers to take precautionary measures.

Farmers of western Uttar Pradesh have reported blackening of wheat grain after harvesting. This is caused mainly due to occurrence of Karnal bunt or black point fungal diseases. The same has also been reported by many leading newspapers of the country. The preliminary observations suggest that there are possibilities of black point fungal disease. Black point disease is characterized by a brown to black discoloration of the embryos of the wheat kernels. The disease can be a problem in wheat growing areas receiving heavy rainfall during the early stages of kernel development (Kilpatrick, 1968). The disease reduces the crop yield and commercial grade of wheat causing economic losses to producers. Black pointed kernels had also an adverse effect on the quality of the flour (Rees *et al.*, 1984). Infestation of such diseases not only devaluate the market price of the product but also raises the concern of the importing countries.

Preventive measures

Climate variability is one of the most important aspects particularly with reference to crop diseases management. In majority of the cases in Indian conditions, it is observed that the temperature remains high during wheat grain filling period. But like the 2012-13 crop season of wheat, there is occasional occurrence of high

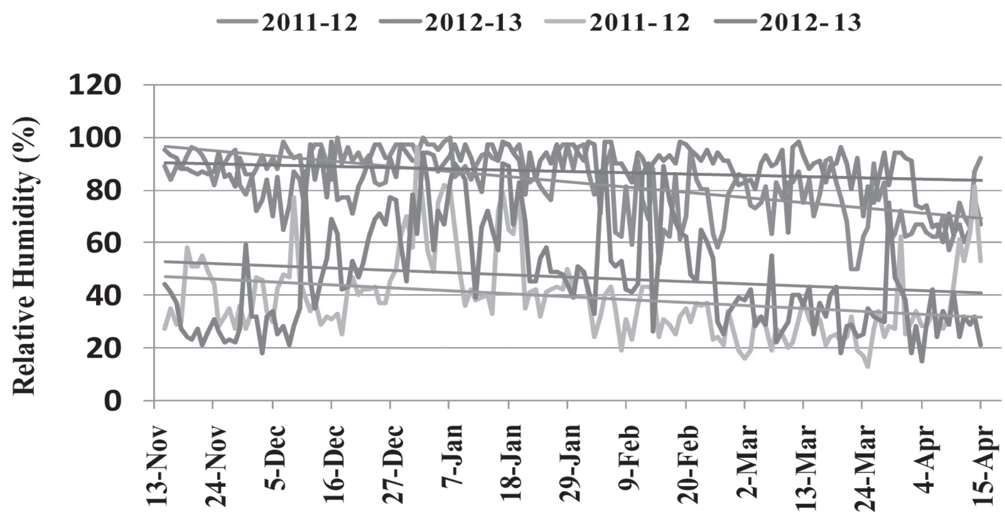

Fig. 5. Morning and evening relative humidity (RH-I & RH-II) during wheat in 2011-12 and 2012-13

humidity favouring the infestation of fungal diseases in the Indo-Gangetic plains of India. The weather fluctuations have created a suitable environment for the incidence of various kinds of pests and diseases (Ahmed *et al*., 2012). Rusts are important fungal diseases for wheat crop. Occurrence of Karnal bunt and black point fungal diseases are other important diseases which needs preventive measures. Farmers may be discouraged to grow disease susceptible wheat varieties and instead, advised to grow more varieties of rust and fungal disease resistant as such varieties have performed well in adverse environmental conditions. More importantly, breeders' attention may be invited towards development of these diseases resistant varieties.

Significant improvement in dealing with such issues may be achieved by educating the farming community through training programmes to identify the symptoms of the outbreak of the particular disease. More emphasis should be given on effective broadcasting of the agro-advisories. There is a need to develop strong monitoring and effective surveillance system. The remote sensing technology can be used to analyze reflected solar radiation from crop canopies to determine disease severity level and assess the crop health (Zhang *et al*., 2011). However, more studies are needed to explore the spectral response characteristics of crops under disease stress of different levels in field and weather conditions (Sabrol and Kumar, 2013).

Conclusions

In the recent past, researchers have paid attention on studies linked with the impact of only high temperature on wheat. But there are occasions when instead of hot and dry weather, occasionally high humidity phase associated with more rainfall and increased minimum temperature could affect wheat growth and yield adversely. Wheat crop season 2012-13 is an example, when unfavourable weather conditions resulted in decline of wheat grain production by 2.42 Mt in India. Prevention of diseases can be achieved through utilization of rust and fungal diseases resistant varieties, prevention of lodging and sustenance in humid conditions. Use of effective surveillance mechanism would also help to detect and predict the possibilities of occurrence of diseases and facilitate the scientific and farming communities to take timely preventive measure to avoid the food grain losses.

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