CHAPTER II

GENERAL ASPECTS OF CROP-CLIMATIC RELATIONSHIPS

Agricultural systems are complex, and they depend in very complex ways on the equally complex independent variables of weather and climate. They also depend very largely on the features of the soil, and on the pest-disease weed complex.

In agriculture, a large amount of descriptive biological, chemical and physical information about soils, crops, etc. is available. Moreover, empirical experimentation guided by the wider generalizations of pure and applied biology has given us a large amount of information about cultural methods. As a result, many of the factors of the environment of crops are controllable in practice. All this scientific and technical advancement has led in many technically advanced countries to highly successful methods of farming in which yields are many times greater than those which were formerly accepted as normal. These results have been achieved very largely by accepting weather and climate and learning how to live with them.
Climatology, has a long descriptive history but unlike agronomy it has made almost no progress into an experimental phase. There is a vast accumulation of good deal of reliable data about weather and climate which require the use of advanced recording and data handling and processing systems. In some limited areas, particularly in microclimatology some progress is made by having mathematical descriptions (Models) of the physical situation but studies in relation between climatology and agriculture have made little progress. In terms of economically useful results the state of agroclimatology is not satisfactory.

Therefore it has become very necessary to study agricultural phenomena with respect to climate and to find out the true nature of the relationships.

One of the most important parts of agroclimatology is the study of the effects within a season, of variations in weather on the growth and final yields of crops. The studies in controlled environmental installations are valuable for the study of many individual processes but they do not indicate realistically the conditions of the whole crop in the field. In these installations the plants are usually grown in restricted
volumes of artificial media. Since it is difficult to imitate field conditions in a sufficiently realistic way it is necessary to adopt field studies, in which the naturally available variations in the environment from place to place and from year to year are used to build up a picture of the effect of environmental factors in crop growth and yield. This requires extensive study in both time and space, with continuous or very frequent observations of climate and crop growth. From such studies it is possible to obtain an understanding of the underlying relationships. Such study is only possible in computer age where vast output of data produced can be analysed.

The utility of such an analysis has been remarkably brought out by Bunting (1966, 363) 'The Sudan data illustrate vitally important point. The soil of the Gezeira is fertile, nitrogen fertilizers are well used and the crop is irrigated at a rate which seems to meet the average rate of evaporation, and yet there have been marked fluctuations of yield from year to year (Yields are recorded field by field over hundreds of thousands of areas of cotton every year - a unique body of data anywhere, and particularly in the tropics). For many years these fluctuations, for the Gezeira as a whole
were successfully predicted by an equation which positively related the small amount of rainfall which fall before sowing to the final yield. No simple explanation could be found for this. We know that these fluctuations were associated with variation in pest incidence, perhaps in turn associated with differences in growth of alternate hosts in the early part of the season. As new varieties, and new means of pest control, have been introduced, the equation has ceased to hold and other factors, such as temperature in the early part of the winter, which affects not only the rate of evaporation at a critical time but also the incidence of yet other pests, have become more important. The Gezeira data show very well not only the complexity of the yield-climate relation but also the way in which it can change from year to year.

The climatic factors of the environment are many - since their effects are interrelated, the influences of any specific factor must be considered in the light of the others. The main climatic factors are temperature, moisture (vapour pressure, humidity, rainfall etc.) light and wind. The water balance factors like potential evapotranspiration, evaporation, ground water storage, water surplus and deficit etc. also seen
to have profound importance in crop-climatic relationship.

The general aspects of these relationships are discussed here.

1] Moisture :— The most outstanding factor of the physiological environment is moisture. The amount of moisture present in the atmosphere at given time may be expressed as vapour pressure, absolute humidity, relative humidity etc. Over large areas with similar temperature conditions the relative abundance of moisture available to plants has a more pronounced effect on the crop production. Robbins (1927) states, 'Water is the chief limiting factor in the growth of most crops. For the majority of crops, there is ample sunshine, and an abundance of oxygen and carbon dioxide in the air but the farmer except in most rainy sections of the country, is usually confronted at some time during the season with a shortage of water'. Schimper also emphasizes strongly the manifold influences of water on the expressions and appearances of plant life by stating that no factor affecting plant life is so thoroughly clear as the influence of water. Thompson (1936) states that moisture is unquestionably the dominant factor in the production of crops and animals in south Africa. It overrules all other aspects of farming enterprise in
the union and is closely related to the national welfare. Hann (1903) supports the statement with the following sentence: "The rainfall determines the productiveness of a country. Temperature and rainfall together are one of the most important natural resources of a country."

McDougall (1925) summarises the above various statements relating to the importance of the moisture factor thus: "It has long been recognised that the vegetative organs of different species were adapted to various conditions of water supply, and also that the occurrence of the larger plant formations was mainly determined by the moisture factor in the climate."

The internal as well as the external organizations of many plants are readily modified by variations in the amount of available moisture at their disposal. The significance of water to life is well brought out by the fact that all of the vital processes of the plant cell take place in a water medium. The assimilation of water by the plant from the soil is very small. Most of it passes to the atmosphere through the plant by performing vital functions. The amount of water present in a soil at any given time has a direct influence on the concentration of the soil solution and constitutes one of the main factors determining the ease with which water
and the soluble nutrients can be absorbed by the roots of the plants. Because of the striking differences produced by the water factor in vegetation in environment plants are divided into more or less well defined groups according to their water relations. (Klages, 1942, 137-140).

Schimper (1903) has listed out four factors impeding the absorption of water by plants (a) Low water content of the soil (b) abundant supplies of soluble salts in the soil (c) The presence of humic acids in the soil (d) Low soil temperature and (e) lack of oxygen in the soils with excessive amounts of water.

Out of the above five two factors viz. :- (i) Low soil temperature and (ii) Lack of oxygen in the soils with excessive amounts of water can be considered here. The temperature of the soil has a direct bearing on the rate of water absorption. Frozen soils, are physiologically dry. The effects of excessive amounts of moisture in the soil lead directly and indirectly to difficulties. Lack of soil aeration limits the supply of oxygen to the plants and accumulation of carbon dioxide produces toxic effects. According to Livingston and Free (1917) 'The exclusion of oxygen from
the roots of most plants interferes with the respiration of the protoplasm of the root cells, resulting in its death and the consequent failure of the roots to function as absorbers for the plant. The cessation of water intake is followed by wilting and death.

The relative availability of water has a pronounced effect on the development of plants during different periods of growth, especially in case of cereals during the jointing, flowering and early filling stages. Miller and Duley (1925) showed in the case of corn that the production of grain depended more than any other part of the plant upon a plentiful supply of moisture during the last 30 day period of growth.

Growth of plants may be regarded as a summation of responses to an environment complex. The responses to the climatic factors must be regarded as composite reactions to the climatic variables. Under given environmental conditions a specific climatic factor may exert a more immediate and a more readily measurable response than other factors. This is especially noticeable during phases of development that are recognized as critical. It is not only the single climatic element that influences the yield but a group of significant factors are responsible
for the final yield. A good illustration of this is presented by Rose (1936) in the results of correlation studies of climatic factors in relation to corn yields. In the heart of the corn belt, correlations with yields of single climatic factors, such as rainfall and temperature, failed to give significant values, that is variations in any one factor in this area had but slight effects on corn yields. Multiple correlations, that is, the consideration of several factors in their effects on yields, gave more significant coefficients. This has also been observed in the present study.

Separate multiple regression equations obtained out of a linear combination of each climatic parameter for the growing months were examined with a view to find out the yield-climatic associationship. Multiple correlations obtained out of a linear single climatic parameter failed to account for close associationship as the equations (Models) developed were not statistically valid. Multiple correlations obtained considering several climatic factors gave more significant correlations, satisfying almost all statistical tests.

In general, the values of coefficients of correlation between crop yields and receipts of precipitation
for specified periods of time are relatively low and frequently not great enough to be of significance in humid regions. In dry regions the values are generally high enough to be used for prediction purposes.

Smith (1920) shows the relationship of precipitation and the final yield of corn. In his statement he has brought out the close relationship of July rainfall to corn yields. Smith says, 'If all the years when the rainfall for July in Ohio has been less than three inches be grouped together, it will be found that the yield of corn averaged 30.3 bushels to the acre, and when the rainfall have been five inches or more the yield has averaged 38.1 bushels to the acre'.

Blair (1975) indicates that temperature relationships may be correlated more directly with spring wheat yields in Eastern North and South Dakota than moisture conditions. Correlations between rainfall and wheat yields show only moderate values, while more than normal temperatures show greater relationships to the yields obtained. High June temperatures have especially depressing effects on yields.

As far as spatial relationship is concerned, it is worthwhile to quote a significant remark from
Koeppel's (1934) paper, especially since it sums up in a concise fashion the probable reasons for differences in the results so frequently obtained from correlation studies in two remote regions. Two probable causes for these differences in results are presumed:

'(a) The difference in geographic location and consequently in physical conditions, for example, rainfall seems to be less critical in Ohio than in Kansas, because in Kansas available moisture frequently is insufficient, while in Ohio wheat rarely suffers from lack of moisture,

(b) The interrelations of meteorological elements are so complex that it is difficult to establish, for example, whether a poor yield of wheat is due to too little rain in September, too high temperatures in October, lack of snowfall in January, too much rain in April, too strong winds in May, or what not else'.

The above statement bears out the remark made by Chilcott (1927) to the effect that 'notwithstanding the fact that annual precipitation is a vital factor in determining crop yields, it is seldom, if ever, the dominant factor, but the limitation of crop yield is most frequently due to the operation of one or several inhibiting factors other than shortage of rainfall.'
Regarding soil moisture Chilcott (1927) states,
'The conservation and utilization of the scanty rainfall
is of such predominant importance as completely to
eliminate some factors and to relegate all others to
minor positions'.

'One of the weak points of the numerous studies
of precipitation-yield relationship is that no recognition
is made of the moisture present in the soil prior to the
period covered by the investigation. Such stored moisture
may be very effective in the production of plants and
may be a factor of considerable importance in the deter-
mination of the final yield'. (Klages, 1942, 196-197).

It may be mentioned here that in the present
study stored moisture has been considered as one of the
parameters in investigating the crop yield-climatic and
water balance relationship. The variation of the rela-
tionship is very well explained by the following example
Seely (1935) found no correlation of yield with total
seasonal rainfall at the Washington Agricultural Experi-
ment Station at Pullman. In marked contrast, at Lind,
70 miles west of Pullman, annual precipitation constituted
the largest single factor determining the yield of wheat.
Similar examples are also to be found in the present analysis.
2] Transpiration :- The factors related to the crop itself decide the transpiration. The slow rate of sorghum plants early in the season may help in the conservation of the soil moisture which is needed later. Crop-yield depends on the total amount of dry matter present at harvest. One of the factors largely affecting dry matter production is the amount of water available for transpiration. Real evapotranspiration from a cropped soil is not only dependent on meteorological factors but also on factors related to the crop and to the physical properties of the soil. It may be mentioned here that in the use of water balance parameters in this study due consideration has been given to the field capacity of the soil.

3] Temperature :- Temperature provides a working condition for nearly all plant functions. More than that, it provides the necessary energy for some processes, radiant energy, for example, is absorbed in photosynthesis and released in respiration. Low temperatures can cause chilling of the plants. White bands are caused on sorghum plant which are chilled at low temperature. Some plants require higher night temperatures for its growth. Especially this is true in case of sorghum.
4] **Light** :- Schimper (1903) designates light as, next to moisture, the most important environment factor determining the structure of plant. Both water and light provide actual materials essential to the building up of the structures of higher plants, while temperature, as has been pointed out, provides the necessary working condition. The sun is the source of both heat and light, which are associated. The exact composition of light coming in contact with plants is highly dependent on atmospheric conditions but especially on the amounts of moisture and dust in the air. The action of light on plants has many important and interesting physiological effects. The part played by light is given by the following points :-

1) By its chemical action on chlorophyll.
2) By its heating action.
3) By promoting transpiration.
4) By promoting growth.
5) By influencing the distribution of plants.

As far as this study is concerned, the losses from water vapour and clouds are of importance. The short
Wave rays are influenced to a greater extent than the long wave rays by the presence of clouds. The process, how clouds influence the crop and the yield will be understood by the above discussion. Periods with overcast skies and lower temperatures are very effective in conserving moisture.

5] Wind:— Wind has both mechanical and physiological effects on plants. As far as mechanical effects are concerned, it may be stated that breaking of the plants, covering by soil, snapping off of heads in mature cereals take place due to high winds. Wind is also concerned with transpiration and water loss. High winds may exert greater damaging effects upon plant growth than by increased transpiration.

The above description presents general aspects of crop-climatic relationships. Attempt has been made in the forgoing chapters to establish close relationships. With the above background it will be easier to understand the climatic influences on the crop yield.