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Thermal regime in wheat growing regions of India

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सार — इस शोधपत्र में भारत के गेहूं उगाने वाले सम्पूर्ण क्षेत्र के विभिन्न तापमान प्राचलों का अध्ययन किया गया है। गेहूं की फसल के लिए स्वीकृत उष्मा की आवश्यकताओं को दृष्टि में रख कर गेहूं वाले क्षेत्रों में तापमान के दीर्घकालीन आंकड़ों, उनसे व्युत्पन्न प्राचलों और उनके बंटन के आधार पर गेहूं के क्षेत्र के विभिन्न भागों में बुवाई और कटाई की अनुकूलतम अवधियों का अन्दाजा लगाया गया है। कुछ क्षेत्रों में जलवायु के हिसाब से आकलित बुवाई की अवधियां, वहां किए गए प्रयोगों से मालूम की गई अवधियों से काफी मेल खाती है।

ABSTRACT. The paper presents a study of various temperature parameters for the entire wheat zone of India. By taking into account the accepted heat requirements of the wheat crop, optimum periods for sowing and harvesting in different parts of the wheat zone have been assessed on the basis of long term data of temperature, its derived parameters and their distribution over the wheat zone (area). The periods for sowing, as assessed climatologically, generally fit in well with those obtained experimentally for certain areas.

1. Introduction

In the wheat belt of the country, the average yield increases from south to north. The yield is highest in Punjab while it is lowest in the southernmost parts of the wheat belt. But during the crop season (October to April), the mean temperature generally decreases from south to north. The duration of crop growth on the other hand, decreases from north to south. This inverse relationship between wheat yield and temperature over the entire wheat zone of the country indicates the significant role played by temperature on wheat yield. Therefore, the thermal regime in the wheat growing areas of the country has been studied for evolving better strategy in crop planning.

2. Areas of study

The area covered by the main wheat producing States in the country, Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Uttar Pradesh, Rajasthan, Gujarat, Madhya Pradesh, Bihar and Maharashtra, has been selected for the present study. The entire area, referred hereafter as the 'wheat belt' is shown in Fig. 1.

3. Climatological features and their influence on wheat production

The distribution of long term means of the following temperature parameters over the wheat belt, has been examined in relation to sowing, growth and harvesting periods of the wheat crop :

(a) Temperature summation,
(b) Mean air temperature and
(c) Extreme temperatures.

3.1. *Temperature summation (T.S.)*

It is the sum of mean daily air temperature over a certain period expressed in degree-days. The concept of temperature summation has been utilised since a long time to study the amount of heat required in the various phases of crop growth. As early as in the eighteenth century, Reaumur (1735) observed that each variety of agricultural crops required a fixed temperature summation value from sowing to ripening and that this value was constant from year to year. Boussingault (1834) calculated the total quantity of heat required for ripening the grain by utilising this concept. Nuttonson (1955) observed that the duration of the vegetative phase of a crop was strongly and linearly related to the mean daily effective growing temperature. In recent years, on the basis of experimental observations taken at some Indian observatories, Venkataraman and Kazi (1972) showed that the number of heat units (degree-days) for the period from sowing to ear-emergence of the tall varieties of wheat was approximately constant.

There are two ways of working out the temperature summation. The first is called the 'Effective Temperature Summation', where the sum of the excess of mean air temperature over the biological zero or some threshold value is worked out. The second one is called the 'Active Temperature Summation', where the sum of only those mean air temperature values which are above the biological zero or some threshold value is worked out.

The authors have worked out 'Active Temperature Summation' assuming threshold value of 5 deg. C, for a fairly dense network of stations in the area under

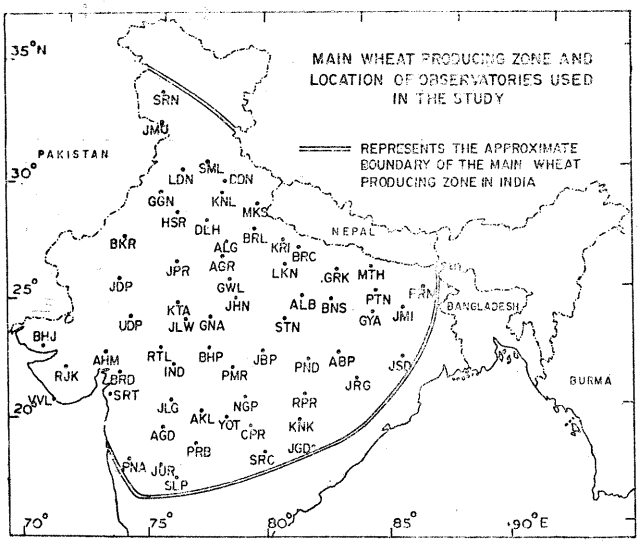

Fig. 1. Main wheat producing zone and locations of observatories

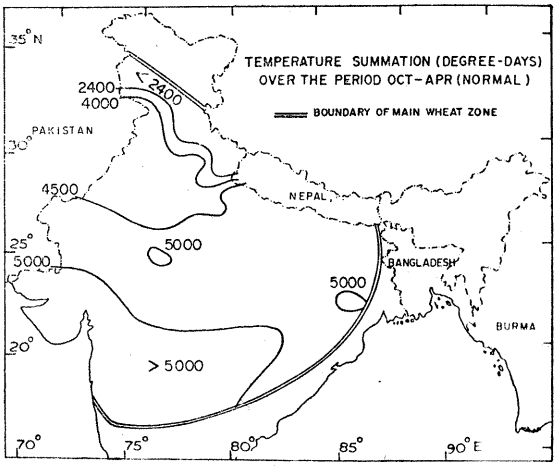

Fig. 2. Temperature summation (deg.-days) over the period Oct- Apr (normal)

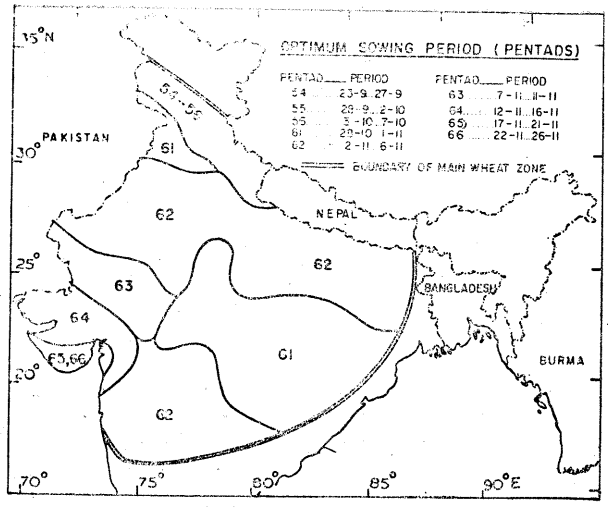

Fig. 3. Optimum sowing period (pentads)

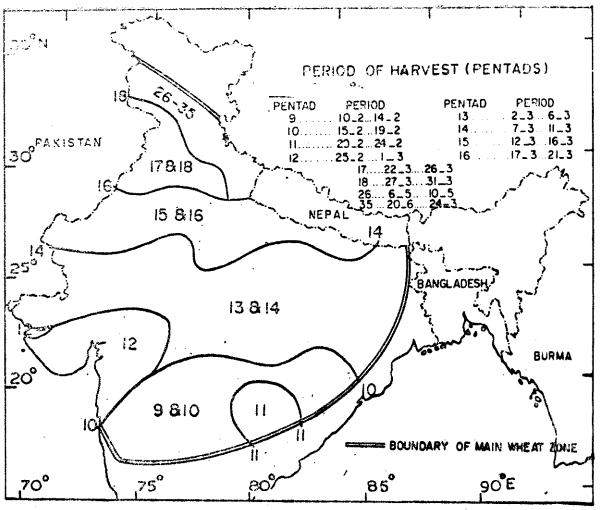

Fig. 4. Period of harvest (pentads)

TABLE 1

Place	Experimental	Reference	Theoretical (as obtained from T.S. values)
Powerkheda (Near Hoshanga-bad in Madhya Pradesh)	Sowing in early Oct. leads to considerable mortality of the seed-lings, optimum sow-ing date around 3rd week of October	Kalamkar, R.J. and Ekbote, R.B. (1954)	28 Oct to 1 Nov
New Delhi	Best yield per acre-age was generally obtained when sow-ing was done bet-ween 25 October to 12 November	Raheja (1959)	1st week of November (2-6 Nov)
Kanpur	31 October to 10 November	Agarwal, J.P. *et al.* (1972)	Do.
Mandore (Rajasthan)	Around 30 October	Mehta & Mathur (1972)	Do.
Ludhiana	1 to 20 November	Chela & Brar (1975)	End of October (28 Oct to 1 Nov)

study for the wheat season, October to April, by using the long term temperature normals published by India Meteorological Department. The distribution of temperature summation values is shown in Fig. 2. Against the suggested normal heat requirement of wheat crop, which is between 1600 deg. C and 2400 deg. C. Pali-Shikhulu (1974) & Pandey *et al.* (1974) have found that about 2200 photo thermal units are required for short varieties during the period from sowing to maturity. It is seen from Fig. 2, that this requirement is adequately met in almost every part of the wheat belt except in the hilly tracts of northwest India where the values are less than 2400 deg. C. Thus, in the above period, adequate thermal resources are available for the crop in most parts of the wheat belt.

3.1.1. *Assessment of optimum sowing period*

The shorter growing period of the crop has been suggested (Pal 1966) to be the major cause for generally low yields of wheat crop in India. The prospects of yield at a particular place, thus, can be brightened by ensuring a longer crop duration. Knowledge of degree-days has been used for maximising the crop duration and thus determining the optimum sowing period is detailed below.

The normal heat requirements of the crop was calculated utilising the wheat crop data and temperature data recorded in experimental plots at New Delhi, Dharwar, Nagpur and Chinsarah. On an average, the crop (NP_4) required (ready for harvest) active temperature sum (degree-days) of about 2400 deg. C from sowing to maturity.

On the basis of the 2400 degree-days required for wheat crop the optimum periods of sowing (Fig. 3), ensuring maximum crop duration have been calculated. The optimum period of sowing over major parts of Madhya Pradesh, Punjab and Jammu & Kashmir is found to be towards the end of October. Over Gujarat State, it extends from 12 November to 26 November and is found to be towards the first week of November in rest of the area except hilly regions like Srinagar, Simla and Mukteshwar where the optimum period of sowing is towards the end of September and beginning of October. The above mentioned periods, by and large, agree with the results of the experiments conducted in various parts of the country. To have an idea on the extent to which the experimental dates of sowing differ from the theoretical dates arrived on the basis of study of temperature climatology over the wheat zone, some of the results are given in Table 1.

High temperatures, which may have adverse effect on crop during germination and ripening stages, are automatically avoided, as shown later, by undertaking sowing operation during the optimum periods shown in Fig. 3.

3.1.2. *Determination of harvest period*

After having fixed the optimum sowing period, the concept of degree-days was further utilised to assess the harvesting periods, which are shown in Fig. 4. It can be seen that crop is ready for harvesting first in Maharashtra and southeast Madhya Pradesh and later in the northern regions. It is of interest to note that although sowing period is as late as middle of November in Gujarat, the harvesting period is comparatively early. This is because of the high mean air temperatures prevailing over this area. It is also seen that the crop takes maximum time, from sowing to harvest, in the hilly tracts of Jammu & Kashmir, Himachal Pradesh and Uttar Pradesh, where it is sown towards early October and ready for harvest during May and June. The crop duration goes on decreasing towards south.

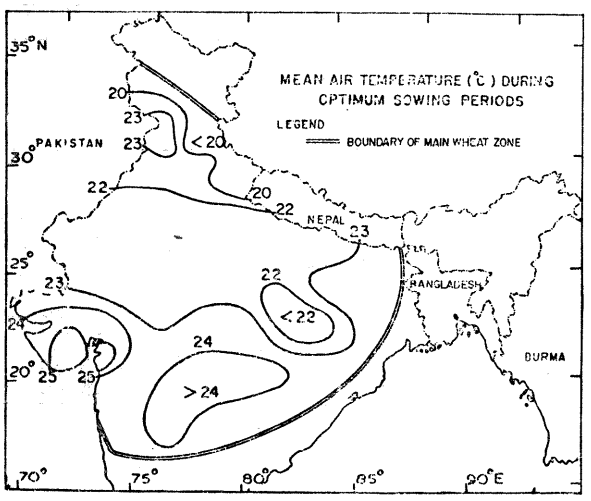

Fig.. 5 Mean air temperature (°C) during optimum sowing periods

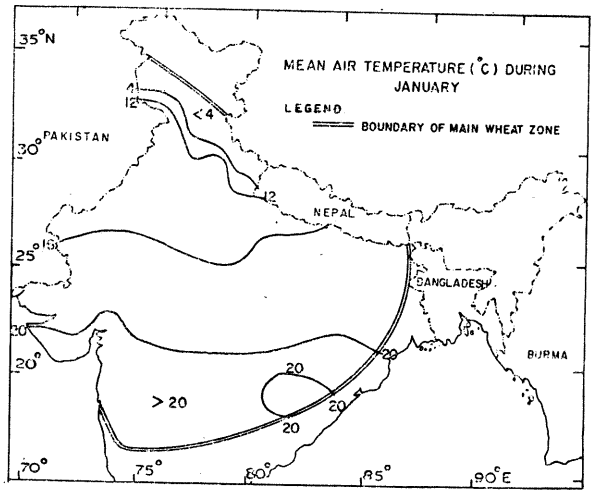

Fig. 6. Mean air temperature (°C) during January

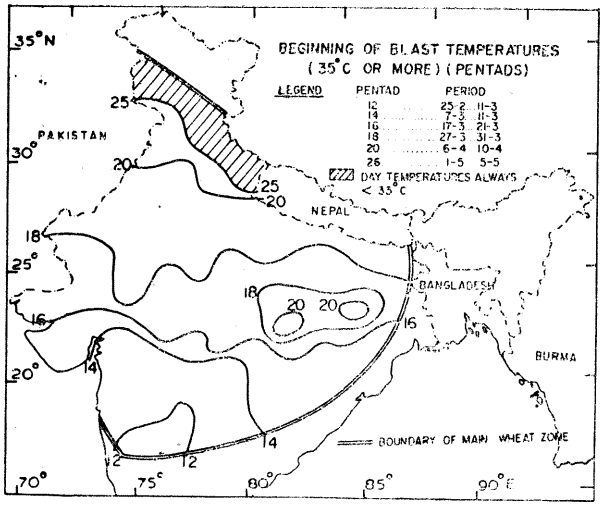

Fig. 7. Beginning of blast temperatures (35°C or more; Pentads)

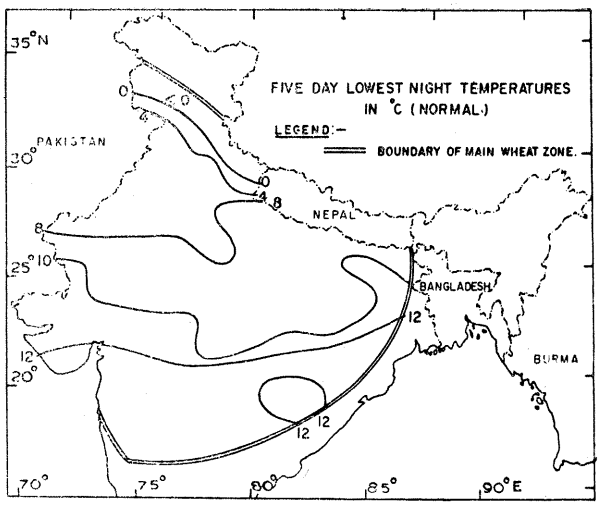

Fig. 8. Five-day lowest night temperatures °C (normal)

3.2. *Mean air temperatures*

Mean air temperatures alone are rarely used for agrometeorological assessment of temperature conditions, but more often used as an additional information with the values of temperature summation. However, the information about mean air temperature is essential to determine whether it is adequate to ensure proper physiological functioning of the plant. In general, the following cardinal temperatures for germination are considered valid, *viz.*, minimum 3.5 to 5.5 deg. C, maximum 35 deg. C (Pali-Shikhulu 1974).

Similarly, for vegetative growth, mean air temperature of the order of 5 deg. C is usually accepted as minimum and 20 deg. C as the optimum. For tillering, optimum temperature range is suggested to be between 15 deg. C and 20 deg. C. Normal mean air temperatures during the optimum sowing period, as already determined, are shown in Fig. 5. Temperature greater than 24 deg. C prevails only over Gujarat State and Marathwada, Vidarbha and adjoining areas of southeast Madhya Pradesh. Over a major part of area under study it is about 22 deg. to 23 deg. C. In hilly tracts around Srinagar, Simla and Mukteshwar, it is between 15 deg. to 20 deg. C. Therefore, in general, the temperatures at the time of sowing are near their optimum values for germination and for the subsequent vegetative growth.

Mean air temperatures for the month of January, which is generally the coldest month in India, are also shown in Fig. 6. It is quite obvious that except for Punjab and hilly regions, the mean air temperature over the entire area under investigation varies between 13 deg. C and 22 deg. C. Thus, for a large part of the area under study, the temperature even during this coldest month do not reach limiting values to hinder the growth of the wheat crop. In areas of higher altitudes around Srinagar, Simla, etc mean air temperatures are too low to sustain the growth of the crop. There the crop either does not grow at all, or if it does, the growth is insignificant during this period, and as a consequence, the crop takes 8 to 9 months for maturity.

3.3. *Extreme temperatures*

Though temperature summations provide means to assess the thermal resources, these ought to be supported by information regarding extreme temperatures.

3.3.1. *Maximum temperatures*

The temperatures which cause halt or decrease in the growth and development of the plants are called 'blast temperatures'. The maximum temperature value for any crop variety depends on the duration of high temperature and also on other factors such as soil moisture, carbon dioxide, light conditions etc. However, the most widely accepted maximum value is 35 deg. C. It has been suggested by Pali-Shikhulu (1974) and others that high temperatures during the ripening period reduce the yield. Therefore, care must be taken to ensure harvesting before the blast temperatures (35 deg. C) begin to occur. The periods (pentad) when the temperature of 35 deg. C normally sets in at the various stations in the wheat belt are shown in Fig. 7. The blast temperatures in parts of Madhya Maharashtra and Marathwada, set in during the last week of February and over north Rajasthan, Haryana and Punjab after the first week of April and still later in the regions further to the north.

On comparing with the harvest periods shown in Fig. 4, it is seen that the wheat crop is harvested at all places well before the blast temperatures set in.

3.3.2. *Minimum temperatures*

Though wheat can withstand relatively low temperatures, frost can cause serious damage to the crop.

From the climatological data (five day normals), the lowest normal night (minimum) temperatures during the crop season at different places in the wheat zone are depicted in Fig. 8. One can see clearly that over the major part of the zone, temperatures are between 8 & 12 deg. C. Obviously, in these areas, the chances of occurrence of frost are quite negligible. But in the northwestern region, *viz.*, Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir and extreme western parts of Uttar Pradesh, the lowest minimum temperatures are normally less than 6 deg. C and in these parts, the minimum temperature may touch freezing point during individual years. So it is advisable to adopt frost resistant measures for wheat crop in these parts.

4. Conclusion

Thus from the above study, following conclusions can be drawn :

(*i*) Heat requirements for the wheat crop (NP_4) in India are about 2400 degree-days which are adequately met in almost all parts of the wheat zone except in the hilly tracts of northwest India where the values are somewhat less.

(*ii*) Optimum sowing periods, so as to give better yield, for different sectors of the wheat zone (Fig. 3), fit in well with those obtained experimentally by other workers for some areas.

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