

Influence of temperature climatology on productivity of wheat crop in India

S. VENKATARAMAN and A. K. RAHI

Meteorological Office, Pune

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सार— इस शोधपत्र में गेहूँ की फसल की उत्पादकता में रबी सत्र की ताप मान जलवायु की जांच की आवश्यकता को दर्शाया गया है। गेहूँ की विभिन्न अवस्थाओं के लिए इष्टतम तापमान की आवश्यकताओं को भी इंगित किया गया है। तापमान के आधार पर बनाए गए चौदह क्षेत्रों में से प्रत्येक में गेहूँ की फसल के अधिकतम उत्पादन के लिए जलवायु के व्यबरोधों और शस्यविज्ञान संबंधी युक्ति का विवेचन किया गया है।

ABSTRACT. The need for an examination of Rabi season temperature climatology in wheat crop productivity is mentioned. The optimum temperature requirements for various phases of wheat are indicated. The climatic constraints and agronomic strategy for maximal wheat crop production in each of the fourteen temperature based wheat zones are detailed.

1. Introduction

The observation of Howard (1924) that wheat crop production in India is a gamble on temperatures obviously refers to effects of temperature vagaries in the Rabi season. The unfavourable effects may come about by either too warm or too cool temperatures in early part of the season leading respectively to (i) curtailment of the vegetative duration and (ii) lengthening of the vegetative phase resulting in maturity phase commencing in warmer weather. In the reproductive phase, very warm and very cool temperatures would lead respectively to (i) curtailment of maturity phase and excessive respiratory consumption of post-flowering photosynthates and (ii) the grain-drying period being pushed into the regime of convective summer showers.

Besides temperature vagaries, temperature climatology by itself exerts an influence on unit area productivity of wheat. Swaminathan (1968), introducing the concept of yield per day, had pointed out that wheat yields when expressed as yield per day of crop growth become comparable in various regions. Venkataraman and Kazi (1972) had estimated the heat requirements for the completion of the vegetative phase for the tall wheat varieties grown over a wide latitudinal range. For this they added the mean daily temperatures above 4°C in the crop growth period from germination to commencement of flowering. They found that despite large variations in the duration of vegetative period of wheat across the stations the accumulations called 'Heat units'

were nearly constant and about 1,000 in value. Since photoperiod also influences crop development the photothermal unit (PTU) which is the product of the photoperiod and the mean daily temperature above a base temperature, has been used as a measure of crop development in place of the heat units. Pande *et al.* (1974) have reported that accumulated PTUs above a base temperature of 4.5°C amounted to 10,000 and 12,000 for the vegetative and reproductive phase respectively for dwarf wheats. Since the photoperiod in the first half of the Rabi season in various tracts is about 10½ hours it is seen that the vegetative duration of dwarf wheats would only be marginally shorter than the tall ones.

Recent investigations also show that the grain yield in wheat mostly comes from post-floral photosynthesis, which is influenced by leaf area index, ear heads per unit area and leaf area duration. The temperature regime during maturity influences leaf area duration and hence of gross photosynthesis and determines the quantum of respiratory depletion and hence the net fraction of accumulation of post-floral photosynthates.

Sowing date trials on irrigated wheat show that with no variations in straw yield, there can be drastic reductions in grain yield due to unfavourable temperatures during maturity. Experimental evidence in many crops show that the effects of curtailed vegetative duration can be compensated by adjustment of population density at sowing. Thus, reduced leaf area index and



Fig. 1. Temperature based wheat crop zones

ZONE	MONTHS	MONTHS						
		OCT	NOV	DEC	JAN	FEB	MAR	APR
ZONE-1	Jammu	_____						
ZONE-2	Punjab & Ganganagar	_____						
ZONE-3	Haryana & Delhi	_____						
ZONE-4	Charu & Jhunjh	_____						
ZONE-5	Awad, Bhopal & Plains of West U.P.	_____						
ZONE-6	East U.P., Bihar Plains & Higher Bihar Plateau	_____						
ZONE-7	Lower Bihar Plateau, Gangetic W. Bengal, Tripura	_____						
ZONE-8	Sub-Himalaya W. Bengal, Arunachal Pradesh & Assam	_____						
ZONE-9	Mizoram	_____						
ZONE-10	Nagaland & Manipur	_____						
ZONE-11	S.E. Rajasthan, Jhansi & M.P. except S.E. Districts	_____						
ZONE-12	Orissa & S.E. M.P.	_____						
ZONE-13	North Gujarat, Interior Maharashtra & N.W. Karnataka	_____						
ZONE-14	Telangana	_____						

Fig. 2. Optimum wheat growth periods

tillering in wheat, arising out of temperature per sec. can be taken care of by crop agronomy, appropriate to the local, early season temperature.

In view of the foregoing it is seen that a proper balance needs to be achieved between the durations of vegetative and reproductive phases of the crop, with emphasis on the crop experiencing the longest possible but safe reproductive period. For this, the crop must be sown at the optimum period. For determining optimum sowing times for realising the objective stated above, an examination of (i) the optimum temperature requirements for various growth phases of wheat on one hand and (ii) the Rabi season temperature climatology on the other is required. The photoperiod regime being more equable will have some marginal effects but can be accounted for. Such an examination and the results flowing from it, are presented and discussed below.

2. Temperature needs for wheat crop phases

From published work it is seen that the optimum temperature requirements for the various phenological stages of the Indian wheat varieties would be as follows :

Germination : 20-25°C, (Geslem 1944, Favereau *et al.* 1968); Tillering : Mean maximum of 30°C and mean minimum of 10°C (Porole and Kolhe 1975); Leaf Development : 20-25°C (Friend 1966); Vegetative growth : 31°C maximum and 13°C minimum (Fazlullah Khan and Meenakshi 1971); Ripening : 21-22°C with minimum greater than 12°C, maximum less than 32°C and mean temperature less than 24°C (Nuttonson 1955; Azzi

1956), Grain formation : maximum 25°C and minimum 12°C (Asana and Saini 1962; Asana and Williams 1965).

3. Temperature based wheat crop zones

In this the hilly regions of the country were left out of consideration (as the temperature in such areas is highly dependent on elevation) and the following procedure was adopted. The India Met. Dep. has selected representative stations for each meteorological sub-division for presentation of the *Weekly Weather Report*. Such stations in the non-hilly areas were taken. For demarcation of the meteorological sub-divisions the main consideration is homogeneity of rainfall. Therefore, the average maximum and minimum temperatures for these stations for the months October to April were taken. The stations were regrouped on the basis of near identical maximum and minimum temperatures. The areas represented by each sub-group were demarcated. In this process some meteorological sub-divisions could be grouped together while other had to be split up and recombined.

Thus the area in which wheat is of economic importance were demarcated into 14 thermally homogeneous zones (Fig. 1). The boundaries of the zones do not follow either those of the states or of the meteorological sub-divisions. This is a significant improvement over existing zonations.

4. Optimum growth periods for wheat

In view of the phasic temperature requirements of wheat, the optimum growing period was deemed to be one with mean maximum temperature 30°C

and minimum temperature less than 15°C. Marginal adjustments for commencement and end of the period for minimum temperatures upto 18°C subject to maximum remaining below 30°C and maximum temperatures upto 32°C subject to minimum temperatures remaining below 15°C were deemed permissible. The optimum wheat crop season so delineated are shown, zonewise in Fig. 2. It can be seen from this that the optimum crop seasons were quite distinct in almost all the zones. In a few, the parity that seems to prevail is not real and they cannot be amalgamated due to variations in the actual values of normal monthly temperatures within the delineated crop growing season. For example Jammu has warmer nights and cooler days while Punjab and Sriganagar have warmer days and colder nights. Haryana and Delhi have minimum temperatures intermediate to that of Punjab and Jammu while at Churu and Jhun Jhunu cool and warm temperatures set in comparatively late and early respectively.

5. Materials and method

For the period from beginning of October to end of April, based on the average temperature of the stations, fortnightly photothermal units (PTUs) above a base temperature of 4.5°C were calculated zonewise. From these the time by which 10,000 and 22,000 PTUs could be realised in each zone was arrived at for periods commencing from October 1, October 15, November 1, November 15, December 1, December 15 and January 1. From these the time of commencement and hence the dates of sowing for realising maximum duration of vegetative growth and reproductive growth were found separately.

During the computations it was seen that with little increase in vegetative growth the post-flowering duration could be drastically reduced below 60 days. It was similarly noted that near-maximal post-flowering duration could be had with a vegetative duration of at least 70-75 days in north India and about 60 days in others except Telangana. So in deciding optimal dates for vegetative or reproductive phase the criteria that minimum duration of other phase should be 60 was adopted. In terms of physiology this was to ensure the requisite photosynthetic 'capacity' at flowering time and photosynthetic 'opportunity' in the post-flowering period. In short a shift from the delineated dates of sowing for a given phase to an earlier and/or later fortnight would lead to a significant reduction in the other phase even though the duration of the phase under consideration gets little affected by the shift.

6. Results and discussion

The optimum sowing dates for (i) maximal vegetative duration with a reproductive duration

TABLE 1
Sowing times for maximal vegetative and reproductive phase durations of wheat

Zone	Optimum date for maximal vegetative phase	Duration		Optimum date for maximal maturity phase	Duration	
		Vegetative (days)	Maturity (days)		Vegetative (days)	Maturity (days)
1	15 Nov	90	60	1 Nov	75	82
2	15 Nov	90	60	1 Nov	75	90
3	15 Nov	90	60	1 Nov	75	82
4	15 Nov	82	60	1 Nov	75	82
	1 Dec	75	60	1 Nov	75	82
5	15 Nov	82	60	1 Nov	67	68
6	1 Dec	72	55	1 Nov	67	68
7	15 Nov	57	63	15 Nov	57	60
8	1 Dec	67	60	1 Dec	67	60
9	1 Nov or 1 Dec	75	60	15 Oct or 15 Nov	60	82
10	1 Nov Nagaland	105	60	15 Oct	82	90
	1 Nov Manipur	97	68	1 Nov	97	68
11	1 Nov	67	68	1 Nov	67	68
12 &						
13	15 Nov	52	60	15 Nov	52	60
14	1 Nov or 1 Dec	45	52	1 Nov	45	52

of 60 days or more and (ii) maximal reproductive phase duration with a minimum of about 60 days vegetative durations are given in Table 1 zonewise. Only in zone 14, Telangana, maximal vegetative and reproductive phases of only 50 days each were obtained.

It was felt that zone-wise presentation of results, as in the case of ICAR wheat project reports, would be appropriate so that the conclusions apply to all stations in the zone. Therefore, specific zone-wise features that emerge from an examination of information generated by Table 1 are detailed below :

(a) In zones 1 to 4 sowing by beginning of November would curtail vegetative duration and result in crop flowering in mid-January. This is not desirable from the point of view of frost and/or neck-rust infection risks. Curtailment of reproductive phase would occur if sowings are delayed beyond mid-November in zones 1 and 2 and beyond end of November in zones 3 and 4. Thus mid-November sowings are a must in zones 1 and 2. In zones 3 and 4 mid-November sowings are optimum but delayed sowings with increased seed rates can be practised upto end-November.

(b) In zone 5 early November sowings would pose the same problems as in zones 1 to 4. Mid-November sowings would carry flowering into February with little effect on the reproductive duration and hence are optimum. Delayed sowings beyond November are not desirable.

(c) In zone 6 sowings are best done in early November as late November sowings would carry the crop maturity period into April, when high temperatures and convective showers are likely.

(d) In zones 7 and 8, wheat has to follow rice and sowings before mid-November will not be feasible. Sowings upto mid-December only marginally affect crop development. In zone 8 convective showers are strong and occur in early summer. Therefore, sowings upto mid-December in zone 7 and as early as possible in December in zone 8, with adequate population density at sowing time are warranted.

(e) In zone 9, the tolerable sowing period is long. However, sowing by mid-October may not be feasible and sowings very early or very late in November would curtail maturity duration. Therefore, mid-November sowings become inevitable. Such a crop must be harvested without any delay.

(f) In Manipur of zone 10 early November sowings carry some frost risks. Mid-November sowings and immediate harvest of the crop are warranted.

In Nagaland of zone 10 only the latter half of October is suitable. Such a crop may serve as an infection source for the rust inoculum from Nepal. Therefore, wheat cultivation in Nagaland would not be encouraging.

(g) In Zones 11 and 12 timely preparation of land for wheat may pose problems. Sowings upto mid-December in zone 11 and upto end December in zone 12 with adequate population density are warranted.

(h) In zones 13 and 14 sowings in first half of November would be optimum.

7. Agronomic relevance

From the above discussion the following inferences can be drawn with respect to the dwarf wheats in vogue :

(a) Except in NW plains and to some extent in Mizoram the scope for maximising vegetative duration is poor. Therefore the NW plains carry a climatically higher yield potential.

(b) In Assam and sub-Himalayan West Bengal early December sowings carry a yield potential equal to that of Uttar Pradesh and Madhya Pradesh.

(c) Delayed sowings in November in Uttar Pradesh, Madhya Pradesh and adjoining areas of Rajasthan and Bihar and in early half of December in the rice tract need not impair the yield poten-

tial. This feature should assist in timely sowing and harvest of crops preceding wheat.

(d) Optimum population density for yield would vary for different zones and different dates of sowing.

8. Conclusions

(1) Mid-November sowings are a must in zones 1,2,5,6,9 and in Manipur of zone 10.

(2) Delayed sowing with increased seed rates can be practised upto end November in zones 3, 4, 13 and 14 upto early December in zone 8, upto mid-December in zones 7 and 11 upto end December in zone 12.

(3) Wheat cultivation in Nagaland would not be encouraging.

(4) Greater attention should be paid to sowing technology as a measure for protection of yield potential in non-optimal climatic and weather situations.

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