TEMPERATURE VARIABILITY ASSESSMENT IN RELATION TO CROP SOWING?? AND HARVEST DATE

X. Liu, A.K.S. Huda, F.M. Kelleher and P.S. Cornish

Farming Systems Research Centre, University of Western Sydney, Hawkesbury, NSW 2753

Abstract

Adouble cropping system, *viz.* summer maize plus winter wheat, in the North China Plain is practised in an intense monsoon climate. Farmers in this district are faced with decisions on the choices of harvest date for maize and sowing date for wheat. In this paper, the interannual temperature variability around autumn was characterised by dividing the historical years into three categories of "climate-years" in terms of the sowing date of wheat. The optimum sowing date of wheat and the latest harvest date of maize were determined for each category of the "climate-years" at twenty-one sites in the district. On average, wheat should be sown 5 days earlier in "early-sowing" years and should be 4 days later in "late-sowing" years than that in "normal-sowing" years. This has been done by using the concept of the "starting" and "ending" dates of threshold temperature, which were assumed to be the reference crop sowing and harvest dates. The approach taken proved to be useful for assessing temperature variability on a regional scale.

Key words : Climate, climate variability, threshold temperature, interannual temperature variability, climate-years, cropping systems.

The North China Plain is one of the most important crop production regions in China. It is located in a temperate zone with a semihumid climate pattern and is dominated by an intense east Asian monsoon. A winter wheat plus summer maize cropping system is the most important cropping system on the plain. In this double cropping system, wheat is sown in late September or early October and harvested in the following June (growth stops during winter). The reminder of the year (June to September) is the maize growing season. The temperature regime around autumn (late August to late November) is crucial for both crops. Warm weather during August to September is favourable to maize filling, whereas low temperature would reduce maize yield. Wheat is in its seedlings stage in October and November. Considerable research (1, 2) and industry experiences have shown that strong growth and development of wheat seedlings up to the 5-6 leaf stage before they stop growing during winter is essential for achieving high yield. Farmers in this district are thus faced with the choices of latest harvest date for maize and optimum sowing date for wheat.

The aims of this study were:

- to characterise the interannual temperature variability around autumn in terms of crop sowing and harvest dates in the cropping system;
- to determine the optimum sowing date of wheat and the latest harvest date of maize for different categories of "climate-years" in the region; and,
- to evaluate the performance of maize from four different maturity groups at each site in the region.

Methods

Climate data

Historical (1961-1990) daily mean temperature records at twenty-one meteorological stations in the region, especially in Hebei and Beijing, were analysed.? The station names and their geographical coordinates are listed in Table 1.

Starting and ending dates of threshold temperature

Athreshold temperature refers to a value of daily mean temperature such as $0^{o}C$ at which growth ceases or begins. Because the pattern of annual variation in moving average daily mean temperature takes the shape of a sine curve, this enables us to assume that a "starting" date and an "ending" date for each threshold temperature exists. The "starting" and "ending" dates of threshold temperature have been commonly used by Chinese agroclimatologists to indicate crop phenology. Several methods have been reported to define the starting and ending dates of threshold temperature (5). In this paper, we adopted the method known as the Moving Average Temperature Approach recommended by the Meteorological Bureau of China, which takes the following steps:

• *Step 1:* Successively calculate the 5-day moving average temperature for each day in a year;

• *Step 2:* Pick out the first moving average temperature (Tm1) and the last moving average temperature (Tm2) from the longest period of the year within which the moving average temperature is no less than the predefined threshold temperature (Ti);

• *Step 3:* Among the five days from which the Tm1 has been derived, the first day on which the daily mean temperature equals or exceeds Ti is defined as the starting date of Ti; Among the five days from which the Tm2 has been derived, the last day on which its daily mean temperature equals or exceeds Ti is defined as the ending date of Ti.

The starting and ending dates of threshold temperature were used as reference sowing and harvest dates for crops in this study, and have been used to quantify temperature variability in relation to crop sowing and harvest dates.

Reference sowing and harvest dates of crops

Wheat was assumed to stop growing by the ending date of $0^{o}C$ (1). 500 degree-days of thermal time was assumed to be the thermal-time requirement for ensuring strong seedlings (5-6 leaves of age) of wheat before they stop growing during winter (1, 2). Therefore, the reference sowing date of wheat was defined as the date from which 500 degree-days would accumulate before the onset of the ending date of $0^{o}C$; The ending date of $18^{o}C$ was assumed to be the reference harvest date of maize (3).

At least a 4-day time interval were assumed to be required for transitions between the harvest date of wheat and the sowing date of maize, and between the harvest date of maize and the sowing date of wheat.

In practice, the harvest date of wheat appeared to be relatively stable at each site except for some years in which wheat is driven into prematurity by hot and dry weather. Actually, if wheat is harvested late the risk of incurring rainy weather during harvesting is high and there is also a risk that maize may not be sown on time.? Therefore, it was assumed that the harvest date of wheat and the sowing date of maize were stable for every year at each site. That is, the reference harvest date of wheat was empirically defined as the mean starting date of $23^{o}C$ over 1961-1990. The reference sowing date of maize was assumed to be the reference harvest date of wheat plus 5 days.

The above assumptions were made to reflect the average status of the current climate, crop cultivars and production technology over the region. Daily mean temperatures of $0^{o}C$ and $10^{o}C$ were used as the base temperatures for wheat and maize, respectively, in calculat- ing the degree-days in this study (2, 3).

"Climate-years" of the sowing date of wheat

In order to characterise interannual temperature variability in relation to the sowing date of wheat, clustering analysis (4) was done on the reference sowing date of wheat to divide the historical years into three categories of "climate-years". They were termed as "early-sowing", "normal-sowing" and "late-sowing" years.

Results

Sowing date of wheat

The historical frequencies of appearance of the "early-sowing", "normal-sowing" and "late-sowing" years are 26%, 41% and 32% respectively. The average optimum sowing date of wheat for each category of "climate-years" is given in Table 1. The data indicate an optimum sowing date ranging from September 23 in the north to October 7 in the south in early-sowing years; from September 28 to October 11 in normal-sowing years; and from October 1 to October 16 in late-sowing years.? On average, wheat should be sown 5 days earlier in "early-sowing" years and should be 4 days later in "late-sowing" years than that in "normal-sowing" years.? The results are consistent with industry experiences and would be able to be used by farmers to improve decisions on the sowing date of wheat, especially when relevant long-term weather forecasting is available.

Regional divisions of maize maturity

Local maize cultivars were divided into four maturity types termed "early maturity", "mid-early maturity", "mid maturity", and "mid-late maturity" (3). The thermal time requirements for each type were defined as 2100-2300, 2300-2500, 2500-2700, and 2700-2900 degree-days, respectively.

The probabilities of the thermal time during the reference maize growing season meeting the thermal time requirement of each cultivar maturity group mentioned above are outlined in Table 2. The probability distribution indicates that the 21 sites can be readily divided into four maize maturity subregions. The "thermal-time-insufficient" subregion comprises Zunhua, Tangshan and Changli. The "early maturity" sub-region comprises Changping, Beijing, Langfang, Zhuozhou and Baxian.? The "mid-early maturity" subregion comprises Baoding, Quyang, Huanghua, Cangzhou and Xianxian. The "mid maturity" subregions comprises Shijiazhuang, Hengshui, Nangong, Qinghe, Xingtai, Quzhou, Handan and Daming.

Table 1 The average optimum sowing date of wheat in three categories of "climate-years"

Station name	Latitude °N	Longitude °E	Elevation M	Early-sowing	Normal-sowing	Late-sowing
Zunhua	40° 12′	117° 57′	54.9	23-Sep	28-Sep	1-Oct
Tangshan	39° 38′	118° 10′	25.9	27-Sep	2-Oct	5-Oct
Changli	39° 43′	119° 10′	13.3	28-Sep	4-Oct	7-Oct
Changping	40° 15′	116° 14′	74.9	27-Sep	2-Oct	7-Oct
Beijing	39° 56′	116° 17′	54.0	26-Sep	2-Oct	7-Oct
Langfang	39° 28′	116° 42′	13.3	26-Sep	2-Oct	5-Oct
Zhuozhou	38° 20′	116° 55′	9.6	26-Sep	2-Oct	6-Oct
Baxian	39° 07′	116° 23′	9.0	26-Sep	2-Oct	6-Oct
Baoding	38° 51′	115° 31′	17.2	30-Sep	5-Oct	9-Oct
Quyang	38° 38′	114° 41′	104.1	30-Sep	5-Oct	8-Oct
Huanghua	38° 22′	117° 21′	6.6	1-Oct	6-Oct	9-Oct
Cangzhou	38° 20′	116° 55′	9.6	2-Oct	7-Oct	11-Oct
Xianxian	38° 11′	116° 07′	12.6	30-Sep	6-Oct	9-Oct
Shijiazhuang	38° 02′	114° 25′	80.5	2-Oct	7-Oct	12-Oct
Hengshui	37° 44′	115° 42′	22.4	2-Oct	7-Oct	10-Oct
Nangong	37° 22′	115° 23′	27.4	5-Oct	9-Oct	11-Oct
Qinghe	37° 05′	115° 32′	30.5	5-Oct	9-Oct	11-Oct
Xingtai	37° 04′	114° 30′	76.8	5-Oct	9-Oct	14-Oct
Quzhou	36° 46′	114° 57′	39.6	6-Oct	10-Oct	12-Oct
Handan	36° 36′	114° 30′	57.2	7-Oct	11-Oct	16-Oct
Daming	36° 18′	115° 09′	45.3	6-Oct	11-Oct	14-Oct

Table 2 The probability of thermal time (degree-days with daily mean temperature >= 10 °C) during maize growing season meeting thermal-time requirements of different maturity groups of maize cultivar

				Probability		
Regional divisions for maize maturity	Station Name	Thermal-time <2100 degree-days	Early maturity (2100-2299 degree-days)	Early-mid maturity (2300-2499 degree-days)	Mid maturity (2500-2699 degree-days)	Mid-late maturity (2700-2899 degree-days)
Thermal time insufficient	Zunhua	0.93	0.07	0	0	0
	Tangshan	0.93	0.07	0	0	0
	Changli	1.00	0.00	0	0	0
Early maturity subregion	Changping	0.24	0.45	0.28	0.03	0
	Beijing	0.07	0.41	0.38	0.14	0
	Langfang	0.10	0.41	0.38	0.10	0
	Zhuozhou	0.24	0.45	0.28	0.03	0
	Baxian	0.17	0.41	0.34	0.07	0
Mid-early maturity subregion	Baoding	0	0.10	0.52	0.31	0.07
	Quyang	0.07	0.24	0.48	0.21	0
	Huanghua	0	0.21	0.59	0.21	0
	Cangzhou	0	0.14	0.45	0.34	0.07
	Xianxian	0.03	0.07	0.41	0.41	0.07
Mid maturity subregion	Shijiazhuang	0	0.03	0.24	0.52	0.21
	Hengshui	0	0.07	0.17	0.59	0.17
	Nangong	0	0.07	0.10	0.52	0.24
	Qinghe	0	0.03	0.17	0.52	0.28
	Xingtai	0	0.07	0.31	0.41	0.17
	Quzhou	0	0.07	0.17	0.55	0.21
	Handan	0	0	0.10	0.45	0.41
	Daming	0	0	0.07	0.41	0.45

Latest sowing date of maize in the thermal-time- insufficient region

In the thermal-time-insufficient subregion, the thermal time during the reference maize growing season for over 80% of years is less than 2100 degree-days. In other words, even early-maturity types of maize are unable to reach maturity if sown after wheat has been harvested.? Therefore, maize has to be sown before wheat has been harvested, that is, short-term intercropping is necessary.? The latest sowing date of the early maturity maize cultivars was defined as the date, with 80% probability, from which 2200 degree-days would accumulate before the ending date of 18^{o}C. The latest sowing dates of early maturity maize are 13 June for Zunhua, 18 June for Tangshan, and 19 June for Changli.

Latest harvest date of maize

The latest harvest date of maize was defined as the reference sowing date of wheat minus 5 days. Maize has to be harvested before its latest harvest date. Otherwise, wheat can not be sown on time and develop to the "sturdy" seedlings (5-6 leaf stage before growth is halted by low temperature).

Conclusion

Temperature variability assessment in relation to the timing of climatic events is beneficial to farmers to improve their decisions on crop sowing and harvest dates. The starting and ending dates of threshold temperature can be reasonably used as a measure to characterise interannual temperature variability in relation to crop sowing and harvest dates, especially on a regional scale. The results achieved are consistent with industry experiences. The information produced is of value to farmers and agronomists for aiding decisions on crop sowing and harvest dates and on cultivar selection.

In this study, the ending date of 18°C was used as the reference harvest date of maize and 500 degree-days of thermal time was used as the optimum thermal-time requirement for ensuring strong seedlings (5-6 leaves of age) of wheat before they stop growing during winter for all the sites in the region. The effect of latitude on these indices needs to be considered for achieving more accurate results. Additionally, different methods of estimating the starting and ending dates of threshold temperature warrants further comparison.

Reference

1. Cheng, Y. 1991. Beijing Agricultural Science. **9,** 16-17.

2. Deng, G. 1988. China Agometeorology **2,** 13-16.

3. Li, B. 1990. In "Theory and Technology for Maize Production in Huang Huai Hai District." Edited by B. Li. Academic Book and Journal Press, Beijing. pp. 25-30.

4. Pei, X. 1991. In "Multivariate Statistical Analysis and its Applications". Edited by X. Pei. Beijing Agricultural University Press. pp. 161-172.

5. Qu, M. 1991. In "A Guide for Agroclimatological Experiment". Edited by M. Qu. Beijing Agricultural University Press. pp. 1-4.