Int J Biometeorol (2012) 56:621–629
DOI 10.1007/s00484-011-0460-3

ORIGINAL PAPER

Factors affecting summer maize yield under climate change in Shandong Province in the Huanghuaihai Region of China

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Received: 24 August 2010 / Revised: 3 May 2011 / Accepted: 2 June 2011 / Published online: 21 June 2011

Abstract Clarification of influencing factors (cultivar planted, cultivation management, climatic conditions) affecting yields of summer maize (*Zea mays* L.) would provide valuable information for increasing yields further under variable climatic conditions. Here, we report actual maize yields in the Huanghuaihai region over the past 50 years (1957–2007), simulated yields of major varieties in different years (Baimaya in the 1950s, Zhengdan-2 in the 1970s, Yedan-13 in the 1990s, and Zhengdan-958 in the 2000s), and factors that influence yield. The results show that, although each variety change has played a critical role in increasing maize yields, the contribution of variety to yield increase has decreased steadily over the past 50 years (42.6%–44.3% from the 1950s to the 1970s, 34.4%–47.2% from the 1970s to the 1990s, and 21.0%–37.6% from the 1990s to the 2000s). The impact of climatic conditions on maize yield has exhibited an increasing trend (0.67%–22.5% from the 1950s to the 1970s, 2.6%–27.0% from the 1970s to the 1990s, and 9.1%–51.1% from the 1990s to the 2000s); however, interannual differences can be large, especially if there were large changes in temperature and rainfall. Among climatic factors, rainfall had a greater positive influence than light and temperature on yield increase. Cultivation measures could change the contribution rates of variety and climatic conditions. Overall, unless there is a major breakthrough in variety, improving cultivation measures will remain important for increasing future summer maize yields in the Huanghuaihai region.

Keywords Summer maize (*Zea mays* L.) · Yield-influencing factor · Climatic condition · Cultivation measure · Variety

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Introduction

Rapid increases in population and economic development have increased the demand for food (Huang et al. 2002). Maize has traditionally been one of the three most important crops (corn, rice and wheat) used as human and animal food in the world (Dong et al. 1997). The issue of how to increase maize yields has been a key research question for agronomists for many years (Cai et al. 2006). The use of high-yield varieties, combined with best crop management practices, would further increase grain production (Wang 2000; Xiao et al. 2008).

In addition, a global warming trend has been well documented at most locations around the world during the last several decades, and this trend is projected to accelerate in the future (Tao et al. 2006). Future climate change could have significant impacts on agriculture (Chiotti and Johnston 1995), and the potential impacts of climate change on crops are of concern and have been evaluated extensively (Southworth et al. 2000; Fu and Wen 2002; Qin et al. 2002; Tao et al. 2006; Yang et al. 2008). Climate change (e.g., higher temperatures, elevated atmospheric CO_2 concentrations, and various rainfall patterns) have become another important factor affecting crop yield.

Since 1950, the Chinese maize yield has increased nearly 4.5-fold (Wang 2000), and there have been four main stages in the development of maize cultivars. Better cultivation measures—such as increased use of chemical fertilizer, increased planting density, better planting patterns, and use of herbicide—have been practiced widely by farmers. Meanwhile, the impact of future climate change on crop production has been predicted widely by modeling the interaction of crops and climate change (Howden and Jones 2001; Jones et al. 2003; Abraha and Savage 2006; Mera et al. 2006; Fischer et al. 2007; Challinor and Wheeler 2008). There was a general consensus that climate change could reduce maize yield. However, it should be possible to adapt to future climates by breeding better varieties (Anwar et al. 2007; Özdogan 2011) and changing crop management practices (Ortiz et al. 2008; Xiao et al. 2008). Because it would be difficult to further increase the yield of maize dramatically, as growers did in the past, it has been proposed recently in China that breeding better varieties would be critical. However, the influences of variety, cultivation measures, and climate conditions are often entangled with one another, making it difficult to determine whether variety has a decisive effect on future yield increases. Therefore, clarification of the extent of the effects of climatic change and cultivation is necessary.

In this study, we used actual data and the Hybrid-Maize model to analyze the factors that have influenced the yield of summer maize grown in the Huanghuaihai region of China over the past 50 years. Our objective was to clarify the contribution rates of variety, cultivation measures and climate change to maize yield increases in the Huanghuaihai region of China over the past 50 years, and to show whether these contribution rates change significantly under different climatic conditions. We hope that the data gained from this study will provide valuable information for growers to maximize their summer maize yield.

Materials and methods

Experimental locations

Located in northeastern China (32°N–40°N), the Huanghuaihai region is the main agricultural area of China; it has a temperate monsoon climate and rainy, hot seasons. The average annual rainfall ranges from 500 to 800 mm, of which 60–80% falls from June to September, with uneven distribution throughout the region and both seasonal and annual variations. Double-cropping of winter wheat and summer maize has long been practiced by sowing summer maize at the beginning of June and harvesting at the end of September. All five data collection locations are within Shandong Province of the Huanghuaihai region (Fig. 1): Dongping County (35.91°N and 116.3°E, 39.9 m elevation), Xiajin County (36.95°N and 116.0°E, 38.5 m elevation), Guangrao County (37.04°N and 118.41°E, 14.9 m elevation), Junan County (35.17°N and 118.83°E, 38.5 m elevation), and Laizhou County (37.34°N and 119.94°E, 48.3 m elevation).

Hybrid-Maize model

The Hybrid-Maize model is a software program developed by the University of Nebraska-Lincoln to generate information for understanding corn yield potential and the interactive effects of crop management practices and climate on corn yields. This model simulates maize growth and development (Yang et al. 2004), combining the strengths of two modeling approaches: the growth and development functions in maize-specific models (e.g., CERES-Maize; Jones et al. 2003) and the mechanistic formulation of photosynthesis and respiration in generic crop models (e.g., INTERCOM; van Ittersum et al. 2003). The purpose of this simulation model is to allow maize growers, crop consultants, and researchers to explore hypothetically the impact of weather and management factors on crop performance. The Hybrid-Maize model will help lead to a better understanding of site yield potential, year-to-year variation in yield potential, and potential management options that affect yield and yield stability (Yang et al. 2004). It allows us to assess the overall site yield potential and its variability; evaluate changes in attainable yield based on different choices of planting date, maize hybrid, and plant density; analyze maize growth in specific years; explore options for irrigation water management; and conduct in-season simulations to evaluate actual growth, thereby forecasting final yield starting at different growth stages.

Model parameters

The summer maize varieties selected for the present study were distributed widely during the 1950s (Baimaya), 1970s (Zhendan-2), 1990s (Yedan-13), and 2000s (Zhengdan-958). This study examined the following parameters: maximum photosynthetic rate, potential grain-filling rate, potential grain number, initial efficiency of radiation utilization, and growth period GDD (growing degree days—the thermal time from germination to physiological maturity, base temperature 8°C) (Table 1). These parameters were taken from Wang (2000) and Ning (2004). The maximum value of each parameter for each cultivar under the given climatic conditions was used; however, the influence of CO_2 concentration on yield potential was ignored.

The daily climatic data collected from January 1957 to December 2007 in the five counties within the Huanghuaihai region include the maximum and minimum daily temperatures (°C), solar radiation (MJ cm^{-2} day^{-1}), day length (h), relative daily moisture (%), and daily evaporation (mm). The basic model inputs include a 4-cm sowing

Fig. 1 Experimental locations in the Huanghuaihai area, Shandong, China. *1* Xiajin, *2* Guangrao, *3* Laizhou, *4* Dongping, *5* Junan

depth, a sowing density of 75,000 plants ha^{-1}, and a sowing date (6 June).

Actual yields data

The actual yields data were taken from the Shandong Agricultural Statistical Yearbook (2009).

Calculations for each influencing factor

The variations in summer maize yields are influenced by variety, cultivation measures, and climatic conditions. This study assumed that the variety and cultivation measure have a positive influence on the yield, whereas the climatic conditions have a negative influence, assuming that there is no perfect climatic condition. The annual yield can be calculated using the following equation:

$$Yield_{year} = Yield_{base} \times ((1 + fve) \times (1 + fcu) - fcl \quad (1)$$

In Eq. 1, $Yield_{year}$ is the annual yield; $Yield_{base}$, defined as yield before the increase in this study, is the basic yield; fve is the influencing factor of variety; fcu stands for the cultivation measures; fcl stands for the climatic conditions. Each contributing factor in the yield change is expressed based on the following equations:

$$CR_{ve} = \frac{fve}{fve + fcu + fcl} \times 100\% \quad (2)$$

$$CR_{cu} = \frac{fcu}{fve + fcu + fcl} \times 100\% \quad (3)$$

$$CR_{cl} = \frac{fcl}{fve + fcu + fcl} \times 100\% \quad (4)$$

CR_{ve},CR_{cu}, and CR_{cl} represent the contribution rates of variety, cultivation measures, and climatic conditions, respectively.

Results and analysis

Yield variations

The summer maize yield showed an S-curve rising trend from 1950 to 2008 in Shandong Province of the Huanghuaihai region, with an average annual yield increase of 97.23 kg ha^{-1} (Fig. 2) and an average annual growth rate of 7.39%. The annual growth rate showed a rising trend from 1950 to 1970. A rising trend for yield and a declining trend for growth rate were observed from 1971 to 2000. After 1990, the growth rate of the annual yield was less than 1%, the lowest within the past 50 years. However, the average increase in annual yield was more than 100 kg ha^{-1} during the 1961 to 1990 period. After 1990, the yield continued to increase, but the average growth in annual yield was low. In the past 50 years, the interannual

Table 1 List of the model input cultivar parameters. *GDD* Growing degree days, *PAR* photosynthetically active radiation

Parameter	Baimaya	Zhendan-2	Yedan-13	Zhengdan-958
Maximum photosynthetic rate(μmol m^{-2} s^{-1})	25.0	27.0	30.0	40.0
Potential grain-filling rate(mg kernel^{-1} day^{-1})	8.4	7.9	8.0	9.0
Potential grain number	320	490	630	650
Initial light use efficiency(g CO_2 MJ^{-1}PAR)	8.0	8.5	9.7	12.0
Growth period GDD (°C day)	1,450	1,560	1,740	1,800

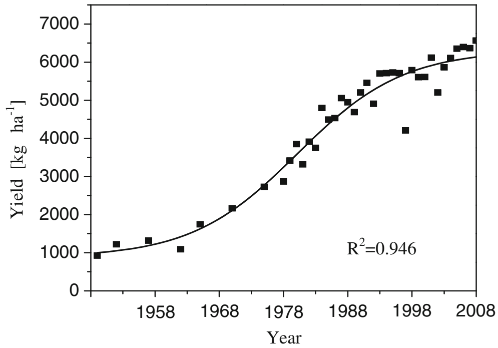

Fig. 2 Change in actual yield of summer maize in Huanghuaihai over the last 50 years

yield change increased, as seen in R^2 analysis, especially from 1991 to 2000 (only 0.15 with R^2, Table 2).

During the past 50 years, the maize varieties grown in the Huanghuaihai region underwent four major changes; the dominant varieties were Baimaya in the 1950s, Zhengdan-2 in the 1970s, Yedan-13 in the 1990s, and Zhengdan-958 in the 2000s. The data shown in Table 2 indicate that each variety change resulted in a large yield increase. Since the variety changes in the 1990s, the annual rate of yield growth has been similar, whereas the annual yield growth has shown a large difference. Such a positive effect on annual yield growth was the result of the application of new varieties in the 1990s, which was more than twice of that in the 1970s. However, the change in varieties after 2000 resulted in a significant decline in the annual rate of yield growth, with an average annual yield growth of only 60.96 kg ha^{-1}, suggesting that this variety change had less of a positive effect on yield than those during earlier periods.

Clearly, the yield increases following the variety change in each period are due mainly to the influence of varieties. However, during any given growth period of a certain variety, the yield increase is the result of a combination of factors, including new cultivation measures and good climatic conditions. The influence of these factors and their relationships can be expressed by the following equations:

$$\begin{cases} (1+fve_1)\times(1+fcu_1)-fcl_1 = 1+122.9\% \\ (1+fve_2)\times(1+fcu_2)-fcl_2 = 1+102.3\%. \\ (1+fve_3)\times(1+fcu_3)-fcl_3 = 1+10.9\% \end{cases} \quad (5)$$

Here, fve_1, fve_2, and fve_3 represent the influence of variety in the 1950s through the 1970s, the 1970s through the 1990s, and the 1990s through the 2000s, respectively; fcu_1, fcu_2, and fce_3 are the influence of cultivation measures in the 1950s through the 1970s, the 1970s through the 1990s, and the 1990s through the 2000s, respectively; fcl_1, fcl_2, and fcl_3 indicate the influence of climatic conditions in the 1950s through the 1970s, the 1970s through the 1990s, and the 1990s through the 2000s, respectively.

Variety impact on yield

In order to clarify the influence of variety on the change in summer maize yield, this study adopted the Hybrid-Maize model to simulate the yields of four summer maize varieties under optimal cultivation conditions for the past 50 years (Table 3). After change of variety, compared with the former variety, the yield growth rates of the latter were 75.3%, 54.7%, 30.1% respectively (Table 3). In general, the changes in varieties from 1950 to 2007 showed a declining trend in their influence on yield due to decreased variety diversity. However, during the real production process, cultivation measures (including fertilizer use, irrigation, plating density, etc.) were not optimized to match the yield potential of each variety;

Table 2 Analysis of growth rate of summer maize in Huanghuaihai Region

Period	Annual growth rate (%)	Annual yield increase (kg ha^{-1})	Total yield growth rate (%)	R^2(X year, Y yield)
1950–2008	7.39	97.23	73.9	0.95
1950–1960	5.22	39.11	52.2	-
1961–1970	10.95	107.39	109.5	-
1971–1980	7.81	153.57	78.1	0.93
1981–1990	5.69	188.85	56.9	0.87
1991–2000	0.28	15.44	2.8	0.15
2001–2008	0.92	56.28	9.2	0.72
1955–1975 (variety change from Baimaya to Zhengdan-2)	5.48	69.56	122.9	-
1975–1995 (variety change from Yedan-2 to Yedan-13)	5.23	142.69	102.3	0.95
1995–2005 (variety change from Yedan-13 to Zhengdan-958)	0.99	60.96	10.9	0.62

Table 3 Change in simulated yield and contribution rate to yield of varieties without cultivation measure limit

	Baimaya - Zhengdan-2		Zhengdan-2 - Yedan-13		Yedan-13 - Zhengdan-958	
	Annual yield increase (kg ka^{-1})	Contribution rate to yield(%)	Annual yield increase (kg ka^{-1})	Contribution rate to yield(%)	Annual yield increase (kg ka^{-1})	Contribution rate to yield(%)
1950–1960	3,470	75.1	4,627	57.2	4,312	33.9
1961–1970	3,428	73.9	4,368	54.2	4,025	32.4
1971–1980	3,660	73.7	4,155	48.1	3,767	29.5
1981–1990	3,532	72.2	4,288	50.9	3,713	29.2
1990–2000	3,345	71.4	4,834	60.2	3,700	28.8
2001–2007	3,692	91.4	4,695	60.7	3,773	28.8
Average	3,521	75.3	4,495	54.7	3,882	30.1

thus, the actual influence of variety on yield would have been limited by cultivation measures. Therefore, the actual influence of variety on maximal yield can be expressed by the following equations:

$$\begin{cases} fve_1 = 75.2\% \times fcu_1 \\ fve_2 = 54.7\% \times fcu_2 \, . \\ fve_3 = 30.1\% \times fcu_3 \end{cases} \quad (6)$$

Climatic impact on yield

Figure 3a shows that, in the past 50 years, during the growth season of the summer maize (June–October) in Shandong Province of the Huanghuaihai region, the interannual and interarea changes in rainfall have fluctuated widely. The overall rainfall amounts generally declined, especially from 1955 to 1990, reaching the lowest level at an average of 310 mm in 1990. However, after 1990, average rainfall showed an increasing trend, represented by large interannual changes (the largest reached 411 mm). The average daily maximum temperature decreased and then increased gradually after a bottom value in 1990. In recent years (around 2007), the average daily maximum temperature has been basically consistent with that of the 1960s. The average daily minimum temperature in recent years was 2.8°C higher than that in the 1960s; a steadily increasing trend was shown over this period.

The varieties planted in different years were used to simulate the changing trend in summer maize yield with the changes in climatic conditions under uniform cultivation conditions. Figure 3b suggests that, although different varieties showed a similar trend relative to the climate change, the variation was large. Overall, the yield did not show a trend of significant increase or decrease. The data in Fig. 4a indicate that, with the alternation of varieties, the rate of yield change increased in the past 50 years, and the change in climatic conditions had a greater influence on the current variety than on former varieties. After taking all the summer maize varieties into consideration, the actual influence of climatic conditions on the rate of change in summer maize yield is shown in Fig. 4a (red line). This suggests that the actual influence of climatic conditions on summer maize yield showed a positive trend, with a high interannual change, especially after 1990. Statistical analysis suggests that the ranges for the influence of major climatic conditions were 0.7%–36.1% in the 1950s through the 1970s, 2.3%–42.3% in the 1970s through the 1990s, and 1.3%–96.1% in the 1990s through the 2000s, respectively.

The varieties planted in different years were used to simulate the influence of the climatic factors of light and temperature on the yield of summer maize with optimal rainfall (Fig. 4b). The result reveals that, as was the case with variety changes, the influence of light and temperature on yield showed a decreasing trend. Figure 4b describes the information gained regarding all changes of summer maize varieties from the 1950s to the 2000s, as well as the overall influence of climatic conditions on yield. Rainfall amounts (shown in Fig. 3) had a greater influence on maize yield than did light and temperature (shown in Fig. 4b). With more rainfall, the difference between the influences of rainfall and light/temperature was not significant, whereas with less rainfall, the influence of rainfall was much greater than that of light and temperature.

Management impact on yield

Cultivation measures include irrigation, fertilization, sowing density, sowing date, and harvest time. Because of the strong correlations between these measures, quantifying the contribution of each measure is difficult, but it is possible to analyze influence trends. The yields of summer maize under the condition of rain-fed and sufficient irrigation were analyzed to obtain the contribution rate of irrigation (Fig. 5a). These data suggest that, along with the change of variety, irrigation plays an important role in increasing

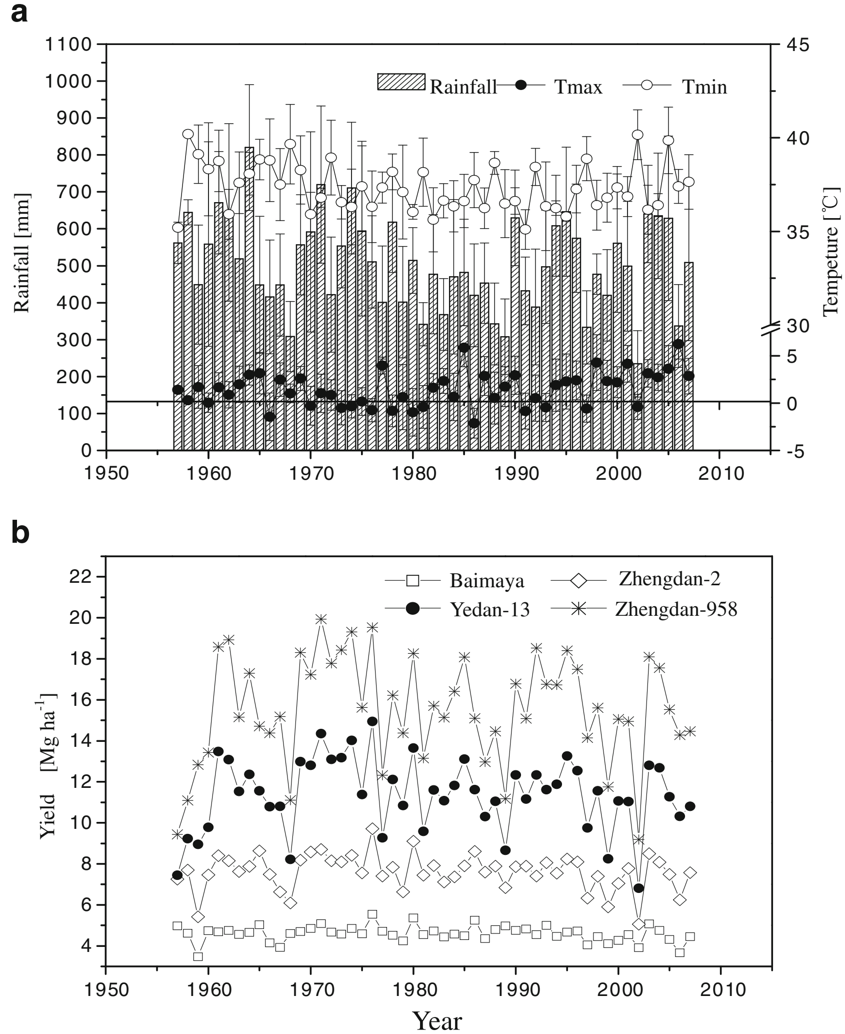

Fig. 3 Variation in climate (**a**) and simulation yield (**b**) over the last 50 years

yield. Compared with the information shown in Fig. 3a, the rainfall in the year with the higher contribution rate of irrigation was lower. While in some years with similar rainfall, the contribution rate of the irrigation differed significantly (e.g., 1991 and 1999), which may result from the different distribution of rainfall in different months. Data on the changes of summer maize varieties from the 1950s to the 2000s strongly suggest that irrigation made a large contribution to the yield increase over the past 60 years (Fig. 5a, red line).

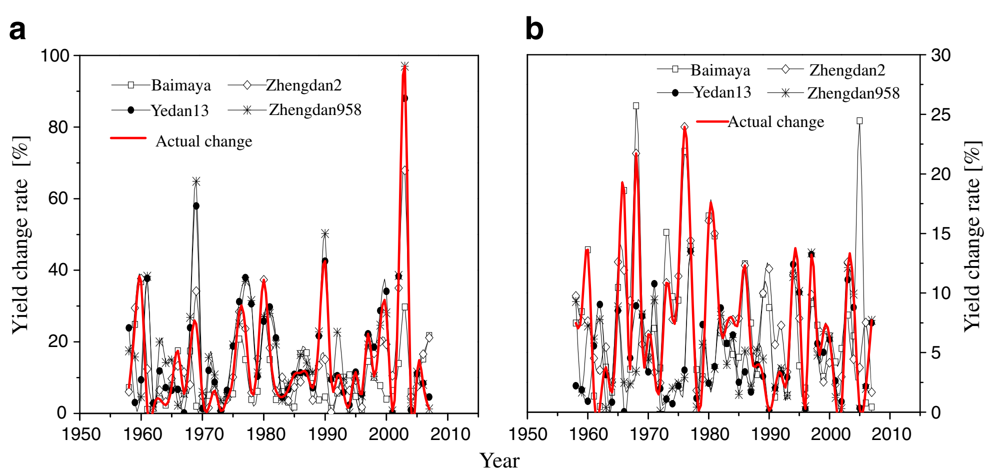

Fig. 4 Impact of normal climate conditions (**a**) and climate conditions without water limits (**b**) on yield change rate of summer maize

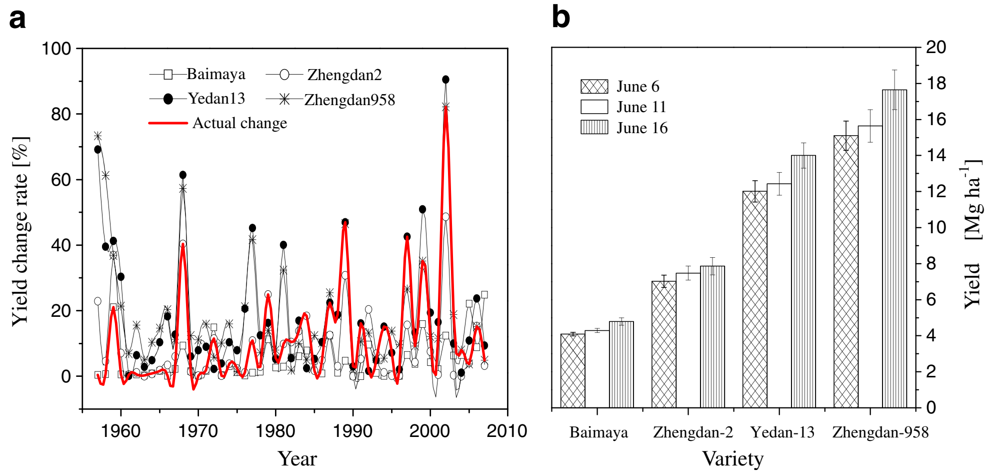

Fig. 5 **a** Impact of irrigation on yield change rate, and **b** impact of delaying seeding date on the yield of summer maize

The high temperature during the summer growth period had a large influence on yield, especially at the filling stage. To analyze the influence of the sowing date on yield, we selected different sowing dates (6, 11, and 16 June) in the years of the highest average daily temperature at several locations (e.g., the counties of Dongping, 1998; Guangrao, 1997; Lvnan, 1998; Xiajin, 2000; Laizhou, 2000) (Fig. 5b). In years with higher average temperatures, late sowing can increase the yield significantly. Compared with sowing on 6 June, sowing on 11 June and 16 June resulted in increasing the average yield by 3.5% and 16.7%, respectively.

Relative importance of yield factors

Using Eqs. 1 and 5 and the influencing range of climatic conditions, the values of the influencing factors fve, fc, and fcl on the yield of summer maize can be calculated, and the contribution rate of each factor can be obtained based on Eqs. 2, 3, and 4, together with the data shown in Table 4.

This study indicates that, through the changes of varieties from the 1950s to the 2000s, the contribution rate of variety exhibits a declining trend, whereas the contribution of climatic conditions shows an increasing trend. Although extreme climatic conditions occur occasionally, the trend does not change. Under the minimal influence of climatic conditions, the contribution rate of the cultivation measures showed a rising trend. On the other hand, the contribution rate of the cultivation measures decreased under the maximum influence of climatic conditions. When the influence of the climatic conditions was highest, change without cultivation measures in the whole Huanghuaihai region was rare. Therefore, the contribution rate of the cultivation measures will continue to grow.

Discussion

In the past 50 years, summer maize varieties have undergone four major changes in Shandong Province of the Huanghuaihai region of China. Each change brought a large yield increase (Wang 2000). In general, the yield of summer maize is influenced greatly by a number of factors, including variety, climatic conditions and cultivation measures. Based on the analysis of measured and simulated yields, along with year changes and the changes of varieties, the influence of variety on yield is decreasing. Looking at the influence of variety alone, we see that the yield went up significantly following each major change of varieties. For example, the yield of the variety used in the 2000s was 30.1% higher than that used in the 1990s. However,

Table 4 The contribution rate of each factor

	Minimal influence of climatic condition[a]			Maximum influence of climatic condition		
	Contribution rate of the variety (%)	Contribution rate of the cultivation measure (%)	Influence rate of the climatic condition (%)	Contribution rate of the variety (%)	Contribution rate of the cultivation measure (%)	Influence rate of the climatic condition (%)
1950s–1970s	42.63	56.69	0.67	33.29	44.27	22.45
1970s–1990s	34.44	62.97	2.59	25.82	47.20	26.98
1990s–2000s	21.03	69.88	9.08	11.31	37.58	51.10

[a] Minimal and maximum influence of climatic condition are the minimum and maximum influence of climatic condition on the yield, referring to 3.3, 1950s–1970s, 1970s–1990s, 1990s–2000s. The major ranges of climatic condition influence are 0.7-36.1%,2.3-42.3%, and 1.3-96.1%

the real yield increase was only 10.9% (Table 2). This suggests that the yield has been hampered by the factor of cultivation measures. Wang (2008) suggested that, under the current soil conditions in Shandong Province of the Huanghuaihai region, increasing the input of fertilizer and water could further enhance the yield of summer maize. Therefore, studies on maximizing the yield of the varieties under common cultivation measures have been important in research to increase the yield of summer maize.

Climatic conditions are variable, and their influences on yield have been shown to be extensive, both in China (Tao et al. 2006; Zhu and Jin 2008) and elsewhere (Southworth et al. 2000; Challinor et al. 2005; Abraha and Savage 2006). It is currently expected that, with current climate changes, especially rising temperatures, yield will decrease, and the climate will have a negative effect on grain production. Our study suggests that the influence of climatic changes on maize between years has been increasing overall. Under extreme climate conditions, such as drought in a given year, the influencing rate of climate could be as high as 50%. Among the climatic factors, rainfall showed a greater influence than light, temperature, and other factors. When it is extremely dry, rainfall becomes the main factor for influencing yield. Luo et al. (2005) found that temperature increase has some impact on change in wheat grain yield, but its effects are much less than that of rainfall alteration. This result is similar to that reported in this research. However, the influence of rainfall on crops is spatially and temporally heterogeneous (Rosenzweig and Tubiello 1997); in zones that already have a high rainfall, an increase in rainfall can also increase soil water-logging and nutrient leaching, which can reduce crop growth (Xiao et al. 2008). High temperatures can have a negative influence on grain yield when these temperatures occur during flowering time (Wheeler et al. 2000). This study suggests that, in years when higher temperatures are encountered, delaying the sowing date can effectively minimize the level of negative influence on grain yield.

Increasing concentrations of CO_2 in the atmosphere are linked to global climate change. But the response of C_4 crops such as maize to future elevated CO_2 concentration is uncertain (Long et al. 2006). Under laboratory-controlled environments, C_4 crop yield had a positive response to elevated CO_2 concentrations. While all of these methods provide an atmosphere with enriched CO_2 concentration, they also significantly alter other aspects of the environment surrounding the plant, and overestimate the CO_2 concentration effect (Ainsworth and Long 2005; Long et al. 2005). Some evidence has shown that the elevated CO_2 concentration did not directly stimulate C_4 photosynthesis (Leakey 2009). Atmospheric CO_2 concentration in China has risen about 70 ppm, from equilibrium levels of about 310 ppm in the 1950s, to approximately 390 ppm in 2008 (Zhu et al. 2010). But C_4 crops such as maize are likely to be less sensitive to this range of CO_2 concentration than C_3 crops. Estimates of CO_2 responses obtained from analysis of historical data were highly uncertain (Lobell and Field 2008). So the effect of elevated CO_2 concentration on summer maize yield was not included in this research.

Adaptation is a key factor that will shape the future severity of climate change impacts on food production (Lobell et al. 2008). The future potential agricultural adaptation of C_4 crops is less than that of C_3 crops due to their lower response to increasing atmospheric CO_2 concentration (Drake et al. 1997). Southworth et al. (2000) found that potential future adaptations to climate change for maize yields would require either increased tolerance of maximum summer temperatures in existing maize varieties. As the most important adaptation, cultivation measures play a very important role in realizing the yield potential of the variety, relieving any negative influence of climate change on grain production. Meanwhile, the positive contribution rate resulting from optimal cultivation measures has been increasing in the Huanghuahai region over the past 50 years. In the years of great influence of climatic conditions, the influence of cultivation measures would be lowered, but it is possible to mitigate the influence of climatic conditions by adjusting cultivation measures.

Conclusion

Optimal cultivation techniques derived from intensive cultivation research are important in efforts to increase yield and fully explore the highest yield potential of new summer maize varieties grown in Shandong Province of the Huanghuaihai region of China. The influence of climate conditions will increase in the future. The application of optimized cultivation practices can reduce future negative effects of unfavorable climate changes on maize production. Cultivation techniques such as changing the irrigation strategy according to changes in rainfall, or changing the seeding date and harvest time to adapt to changes in light and temperature are effective at maintaining high grain production. Development of very productive varieties is the most important factor in enhancing yield. However, unless there is a variety development breakthrough, frequent changes in the planted variety of summer maize will not increase yield significantly.

Acknowledgments This work was supported by grants from the State Key Program of Basic Research of China (No. 2009CB118602), Special Fund for Agro-scientific Research in the Public Interest (No. 200903003) and the National Natural Science Foundation of China (No. 30571098). We thank our colleagues (the State Key Laboratory of Crop Biology, China) for their assistance in this study.

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