# Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (14): 2740-2743, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.2740.2743


# Meteorological Impact on the Winter Wheat Yield in Weishan, China

[1]ShiWei Xu, [1]Wen Yu, [2]Shu-Yun Liu, [1]A. Ahmed and [1]Yu Wang
[1]Agricultural Information Institute of Chinese Academy of Agricultural Sciences,
Key Laboratory of Intelligent Agricultural Early Warning Technology of Ministry of Agriculture,
Key Laboratory of Intelligent Agricultural Early Warning Technology and System of Chinese Academy of Agricultural Sciences, Beijing, 100081, China
[2]Technology Information Engineering Technology Research Center,
Shandong Academy of Agricultural Science, 250100, Jinan, Shandong, China

**Abstract:** To find out how the weather influences the winter wheat yield, the authors used the time series data from the years 1981-2009, such as rainfall and temperature. The simple linear regression model with trend was to be established to estimate the relation between yield and meteorological factors. According to the result, the temperature has positive influence except on sowing stage in October but rainfall have negative influence except during jointing stage in April. We could forecast the yield according to weather factors; based on the meteorological yield coefficients we also considered irrigation or film-covering to increase temperature so as to increase the wheat yield. This will give a theoretical basis for crop yield forecasting and the way to increase yield. In summary, this study could be used in the earlier warning for wheat yield.

**Key words:** Winter wheat yield, meteorological factors, forecast, Weishan of China

## INTRODUCTION

It is an indisputable fact that meteorological factors have important implications on agricultural production.

Some scholars focus on the long-term effects of climate on agriculture. Yang *et al*. (2010) thought that the climate warming would make the northern boundary of food crops to move to the southeast and northwest, which benefits crop yield increase. Anyway, pests and diseases will increase with the warming climate (Wang *et al*., 2011). On the other hand, in considering adaptable conditions, the wheat yield will increase in the rain-fed area in most parts of China (Sun *et al*., 2005). Generally, climate change will benefit the crop yield (Zhao *et al*., 2010; Li *et al*., 2010). Some scholars have studied the impact of extreme weather or agricultural condition on agricultural production. For example, Wu *et al*. (2008) found that drought is the most important factor that affects food crops production.

Crop yield are mainly affected by natural and non-natural factors. In fact, there are extensive researches on crop yield especially on the natural factors. Li *et al*. (2008) selected the meteorological and rice yield data in Chongqing, Southwest China from 1960 to 2001 and the results show that the main meteorological factors for rice yield decline is the cold rain in spring and summer droughts. In addition, many authors use meteorological data (temperature, sunshine, rainfall) to solve the partial correlation coefficient in the different growth stages (Wang and Ding, 2003; Zhan *et al*., 1999; Xiao *et al*., 2000; You, 1999), which provides a base for yield production forecasting.

In this research, the trend parameter of the winter wheat caused by technological progress and meteorological yield parameters caused by weather would be resolved. The objectives of this study are to determine the trend parameter and how the meteorological factors affect the crops yield in different growth stages. Through these results, not only the yield could be forecasted but also early warning supervision could be provided according to the weather condition.

Previous study often separate tendency from yield. We supposed that the weather factors affects meteorological yield in a linear or non-linear fashion. the function of weather factors. Paul and Michael (2013) use a simple non-linear model to estimate trend and meteorological parameters but in this study, we use simple linear model to estimate the winter wheat yield.

**Corresponding Author:** Wen Yu, Agricultural Information Institute of Chinese Academy of Agricultural Sciences, Key Laboratory of Intelligent Agricultural Early Warning Technology of Ministry of Agriculture, Key Laboratory of Intelligent Agricultural Early Warning Technology and System of Chinese Academy of Agricultural Sciences, Beijing, 100081, China Tel: +86-10-82109654

## DATA AND ITS DESCRIPTION

This research was supported by Agricultural information warning research project by Ministry of agriculture, China

This study adopted the meteorological material and winter wheat yields from the year 1981 to 2009 in Weishan County of Shandong Province, China. The Soil Fertilizer Station provided the data on winter wheat yield and all the data in this research have been processed by the Information Center of Shandong Academy of Agricultural Sciences.

**Rainfall:** We have simply processed the meteorological material in the following Table 1.

**Mean of the rainfall:** There was larger difference in rainfall amount among months during the growth period of winter wheat. For example, the mean of rainfall was 12.44 mm in December, but 90.2 mm in June.

**Range of the rainfall:** Nevertheless, in the same months among different years, the rainfall difference is obvious. For example, the range (the difference between maximum and minimum) of rainfall in December was 39.4 mm, but the range is 249.1 mm in June.

**CV:** To measure the different degree of each meteorological factor, we used the coefficient of variation (CV, defined as the ratio of the standard deviation to the mean) to show the extent of variability in relation to mean of the meteorological factors. We found that the minimum CV is 0.6 in May and June, but the maximum is 1.2 in January.

**Temperature:** From the average temperature each month, the absolute difference among months is larger. The average temperature in January is zero degrees centigrade, but the average temperature in June is the highest (25.1°C).

In order to estimate the meteorological yield model, it is needed to analyze the correlative coefficient among the meteorological factors. Generally, the correlation between rainfall and temperature is not significantly obvious.

## METEOROLOGICAL YIELD MODEL

In the previous analysis on the relationships between meteorological factors and yield, we separated the yield into trend yield and meteorological yield. The trend yield reflected the yield change from agricultural technological progress and the improvement and development of business management, which is denoted as the yield sum contributed by all non-natural factors. Meteorological yield is the residual of yield sequence after separating the tendency, which is the center content for agro-meteorological yield forecasting.

Meteorological yield model is set up in the first step and according to the relationship among meteorological factors above, the variables in the model should be restructured with the variable correlation removing, so as to ensure that the impact of meteorological factors on yield released.

The authors use the Orthogonal polynomial to estimate the integral regression for meteorological yield of winter wheat, but the coefficient of determinant (R-Squared) was very low about 40%; but in one simple linear regression, we get an ideal results (Table 2).

**Trend analysis:** Trend analysis is a useful tool to forecast crop yields in the future. Long-term trends in crop yields reflect yield improvements, such as hybrids seed, better pesticide, nutrient management and precision planting and so on. Excepted for long-term improvements,Meteorological factors also make yield waving obvious. Thus, to estimate crop yield, it is very important to estimate trend yields and meteorological yield.

Table 1: Meteorological characteristics of the year 1981-2009 sin Weishan

| Characteristic | October | November | December | January | February | March | April | May | June |
|---|---|---|---|---|---|---|---|---|---|
| **Rainfall (mm)** | | | | | | | | | |
| Mean | 38.6 | 23.0 | 12.4 | 12.5 | 16.9 | 26.7 | 31.3 | 67.7 | 90.2 |
| Standard deviation | 38.0 | 24.0 | 10.6 | 14.6 | 13.2 | 25.4 | 21.8 | 42.8 | 56.7 |
| Coefficient of variation | 1.0 | 1.0 | 0.9 | 1.2 | 0.8 | 0.9 | 0.7 | 0.6 | 0.6 |
| Maximum | 151.5 | 111.6 | 39.4 | 54.5 | 45.6 | 104.8 | 84.1 | 207.6 | 257.6 |
| Minimum | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 4.6 | 1.9 | 8.5 |
| Range | 151.5 | 111.6 | 39.4 | 54.5 | 45.4 | 104.8 | 79.5 | 205.7 | 249.1 |
| **Temperature (°C)** | | | | | | | | | |
| Mean | 15.8 | 8.3 | 1.9 | 0.0 | 2.9 | 8.0 | 15.0 | 20.4 | 25.1 |
| Standard deviation | 1.4 | 1.4 | 1.2 | 1.1 | 1.9 | 1.5 | 1.0 | 1.1 | 1.0 |
| Coefficient of variation | 0.1 | 0.2 | 0.7 | -30.8 | 0.7 | 0.2 | 0.1 | 0.1 | 0.0 |
| Maximum | 19.9 | 11.2 | 4.0 | 2.8 | 7.0 | 11.1 | 17.3 | 22.9 | 27.2 |
| Minimum | 13.1 | 5.7 | -0.9 | -2.8 | -0.2 | 5.4 | 13.3 | 18.2 | 23.6 |
| Range | 6.8 | 5.5 | 4.9 | 5.7 | 7.1 | 5.6 | 4.0 | 4.7 | 3.6 |

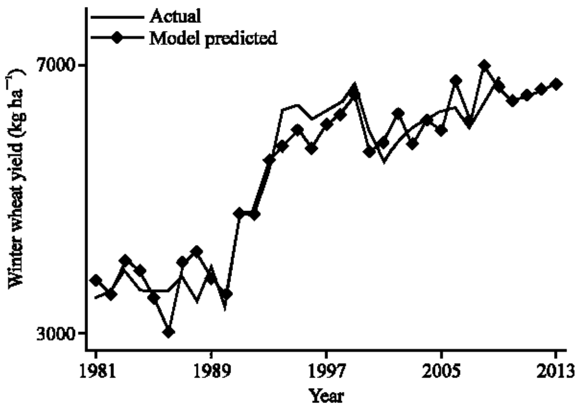


Fig. 1: Predicted and actual results from winter wheat yield model in Weishan, China

Table 2: Weishan winter wheat yield model, using trend and meteorological factors

| Factors | Coef. | SE | t-statistic |
|---|---|---|---|
| Intercept | 4815.029 | 915.656 | 5.26 |
| Trend | 67.332 | 15.550 | 4.33 |
| October temperature | -178.936 | 71.590 | -2.50 |
| December temperature | 181.657 | 77.194 | 2.35 |
| December rainfall | -14.277 | 7.418 | -1.92 |
| February temperature | 150.223 | 51.023 | 2.94 |
| February rainfall | -14.251 | 5.819 | -2.45 |
| November temperature | 217.789 | 84.701 | 2.57 |
| April rainfall | 11.727 | 3.242 | 3.62 |
| May rainfall | -4.089 | 1.726 | -2.37 |
| June rainfall | -2.999 | 1.384 | -2.17 |
| R-squared = 0.9301 | | | |
| Estimation period 1981-2009 | | | |

**Winter wheat yield model:** Winter wheat Yield Model was estimated over the past 29 years (1981-2009). In addition to a trend variable, the model uses as explanatory variables, including monthly precipitation and average daily temperature in selected years. Those variables helps explain previous yield variations and deviations from trend.

The effects of temperature, rain fall and trend on winter wheat yield are each linear in the model---for those variables, each unit of change has a constant effect on yield. The model focuses on how meteorological factors influence actual yield relative to those trends and the analysis does not include how various non-meteorological factors contribute to long-term yield trends.

The estimated regression equation (Table 2) explains over 93% of the variation in winter wheat yield during the estimation period.

Figure 1 and 2 show various model results. Figure 1 show the model predicted values with the actual yields,describing model running results over the estimation period. Figure 2 provides an illustration of the winter wheat yield with weather-adjusted trend. This trend estimation is calculated using sample averages for meteorological factors and an adjustment is made to derive this trend to reflect winter wheat yield.

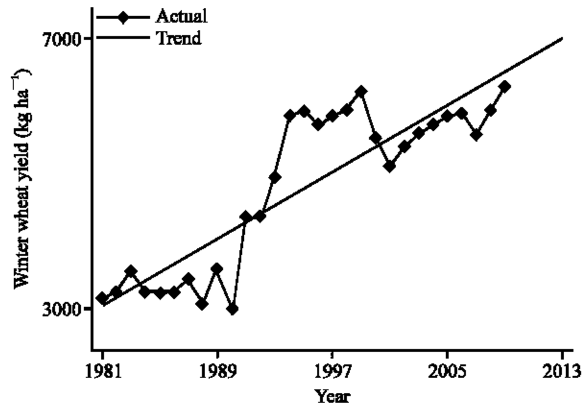


Fig. 2: Weather-adjusted trend results from winter wheat yield model in Weishan, China

## RESULTS

Seedling stage (from sowing in October to the beginning of overwintering in December) The average temperature in October is 15.8°C, but the too high temperature did not benefit to yield increasing (increasing 1°C than average level, yields would reduced 178.94 kg $h^{-1}$ $m^{-2}$). The higher temperature could be easy to prosperous seedlings; therefore the young plant during lower temperature would be damaged dead by frozen weather. The average temperature in November is 8.3°C. Higher temperature benefits the yield increasing (every 1°C increase, the yield would increase by 217.79 kg $h^{-1}$ $m^{-2}$). Strong seedlings of 3 leaves before winter is the premise to ensure the winter wheat winter safely. The key of yield formation is tiller numbers in the groups and the critical period to form the groups is before the winter. In December, average monthly rainfall and daily temperature are 12.4 mm and 1.9°C. In fact, less rainfall and higher temperature are good to future yield. Every 1°C increase, the yield would increase by 181.66 kg $h^{-1}$ $m^{-2}$ and every 1 mm increase, the yield will reduce 14.28 kg $h^{-1}$ $m^{-2}$.

Overwintering stage (January-February) like December, less rainfall and higher temperature benefit for winter wheat yield potential. Too low temperature is not suitable for winter wheat, overcoming the winter, is decided by the main characteristics and species selection in the region. Every 1°C increase, the yield would increase by 150.22 kg $h^{-1}$ $m^{-2}$ and every 1 mm increase, the yield will reduce 14.25 kg $h^{-1}$ $m^{-2}$.

Reviving and jointing stage (March-April) In early March is reviving stage and mid-March to late-April is jointing stage. Rainfall in April benefits yield increasing (per 1 mm additional increase, the yield would increase by 11.73 kg $h^{-1}$ $m^{-2}$). Insufficient rainfall will seriously affect the wheat spikelet differentiation and grain number, which does not lead to the formation of high-yield with big spike.

Flowering and harvesting stage (May-June) In May, the winter wheat was at the flowering stage. The average rainfall is 67.7 mm (Table 1). More rainfall is not good for pollination and grain filling. During these stages, additional 1 mm rainfall, the yield will reduce 4.09 kg $h^{-1}$ $m^{-2}$; In June, especially in the middle and end of this month, the meteorological factors have no meaning for it is time to harvest wheat. But in the earlier of June, the rainfall has the similar effect on yield.

## DISCUSSION

In the following, we analyzed the results connecting meteorological yield coefficient and get the results in the following.

- In this study, we use trend and meteorological factors to fit winter wheat yield equation, the results of yield coefficient could explain the crop growing characters from mechanism system
- Only considering main meteorological factors, there is different meteorological factors in different regions, such as coastal areas, the crop yield could be influenced by wind speed. In dry area, maybe the rainfall is the only factor to influence the yield. Therefore, the meteorological model should consider more in the later research
- Generally, this research is based on the time series data of meteorological data and yield of winter wheat. During the practice, we could forecast the meteorological yield according to rainfall and temperature and then estimate yield according to the trend yield; at the mean time, also based on the yield coefficients, adoption of irrigation or film-covering to increase temperature so as to increase the wheat yield. This will give a theoretical basis for crop yield forecasting in short period and the way to increase yield

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