Study on Fluctuation of Grain Yield in China's Major Grain Producing Areas

GU Li-li *

College of Economics and Administration, Jilin Agricultural University, Changchun 130118, China

Abstract By using the statistical data of grain yield in China's major grain producing areas from 1949 to 2008, and fluctuation theory, the historical process and main cause of fluctuation of grain yield in China's major grain producing areas are analyzed. The results of research show that the grain yield in China's major grain producing areas grows in unstable fluctuation, with high-frequency fluctuation cycle and regular length; the amplitude of fluctuation, on the whole, is moderate, with not strong stability; the fluctuation of grain yield has correspondence, reflecting the N-shape developmental trend of grain production at present; the fluctuation of grain yield has gradient characteristics; in the process of comparison of grain yield, the average growth rate annually of grain yield in China's major grain producing areas is higher than that of the national average, but the relative fluctuation coefficient is also higher than that of the national average. From five aspects, namely natural disaster, agricultural policy, production input, grain price and grain circulation, the cause of fluctuation of grain yield in China's major grain producing areas is analyzed, and measures of preventing and arresting super-long fluctuation of grain yield are put forward. Firstly, stick to strict farmland protection system, and strive to promote farmland quality; secondly, strengthen infrastructure construction of grain production and beef up the ability of preventing natural disaster; thirdly, quicken the pace of agricultural technology and establish robust technology supporting system; fourthly, lay stress on innovation of agricultural organization system and provide implementation path and vehicle for application of agricultural technology measures; fifthly, perfect disaster precaution system and grain market system, and strengthen the ability of preventing risk of grain production.

Key words Grain yield, Periodic fluctuation, Major grain producing areas, Grain price, Grain circulation, China

Grain, a special commodity of strategic importance, is an important part of the national security strategy. China is the most populous country in the world, and China's future grain supply must be guaranteed on the basis of self-sufficiency. Since the founding of New China, China has created the miracle that using 9% of world's arable land and 6% of the fresh water to feed people who account for about 20% of the world's population.

Major grain producing area is the main body of grain production in China, The grain production in major grain producing areas is directly related to the situation of national food security. Major grain producing areas play an important role in promoting grain production in China. In the light of contribution of grain in major grain producing areas, the grain production in major grain producing areas holds sway over total grain yield of China, and has a close relationship with food security of China. From 1980 to 1998, 2/3 of increase amount of grain yield of China is from major grain producing areas; from 1999 to 2003, 2/3 of decrease amount of grain yield of China is also from major grain producing areas; since the year 2004, 80% of increase amount of grain yield of China is from major grain producing areas. In 2008, the grain farmland area of 13 major grain producing provinces in China accounts for 64% of total farmland area in China, and the total grain yield reaches 75.50% of total yield of China.

Although the grain production in major grain producing areas is important strategically in China, the grain yield in major grain producing areas takes on undulant rise. The fluctuation of yield is the recurrent and unstable phenomenon in the process of grain production growth in major grain producing areas. If we do not conduct moderate control over fluctuation of grain yield beyond the reasonable range, it is bound to impact sustainable development of grain production. So according to the statistical data of grain yield in China's major grain producing areas from 1949 to 2008, I use fluctuation theory to analyze fluctuation of grain yield in major grain producing areas, in order to ensure that China can obtain steady commodity grain supply in the future, provide reference for policy formulation of government and offer theoretical basis for relevant researches.

1 Analysis of fluctuation of grain yield in China's major grain producing areas

1.1 Fluctuation coefficient and fluctuation period of grain yield Fluctuation of grain production is a kind of universal and objective phenomenon, emerging in the process of grain production development. Sharp and abnormal fluctuation of production will greatly impede balance of supply and demand of grain. By reviewing and summing up the development process of grain production in major grain producing areas of China, it is not difficult to find that the grain production always follows the path of "growth-fluctuation-growth" develop. In the process of growth of grain yield, this kind of undulant year change is fluctuation of grain yield[1]. Analyzing fluctuation of grain yield, similar to general economic fluctuation, needs to select certain indicators to define the quantity characteristics of cycle, wavelength, amplitude and so on. This thesis mainly researches

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* Corresponding author. E-mail: llgu2006@163.com

longer-term fluctuation of grain yield in major grain producing areas of China, so the fluctuation coefficient is used to conduct depiction when analyzing fluctuation degree. The fluctuation coefficient of grain yield reflects the degree of total grain yield deviating from tendency yield, and the expression is as follows:

$$V_t = (Y_t - \hat{Y}_t) / \hat{Y}_t$$

In the above formula, V_t is the fluctuation coefficient of grain yield in the tth year; Y_t is the actual grain yield in the tth year; $\hat{Y}_t$ is the tendency grain yield in the tth year. The bigger the $|V_t|$, the farther the yield from tendency yield, and the poorer the stability is; and *vice versa*.

In order to calculate the fluctuation coefficient, the thesis first uses Eviews software to fit regression equation of growth tendency of total grain yield, then selects optimal regression model, so as to obtain tendency value of total grain yield, and finally takes it into the above formula of fluctuation coefficient to conduct calculation. By the comparison of fitted results (analyze from goodness of fit of model, F statistic of model, $D.W$ test value and test value of coefficient T), the cubic expression model is selected is as fitted equation of tendency grain yield ($\hat{Y}_t = 12\ 635.668\ 2 - 530.934\ 2t + 38.180\ 9t^2 - 0.375\ 4t^3$). Then the fluctuation coefficient of grain yield is calculated and based this, the fluctuation coefficient curve is drawn (Fig. 1).

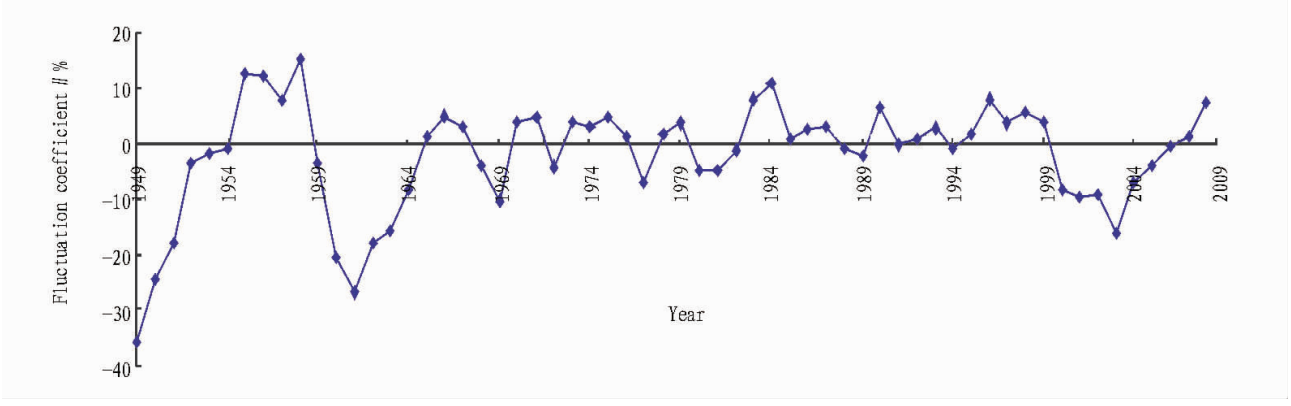

Fig. 1 The coefficient of fluctuation of grain yield in major grain producing areas from 1949 to 2008

From Fig. 1, we can see clearly that since the founding of New China, the grain production in major grain producing areas has experienced 14 complete fluctuation cycles, and in the years 2003-2008, it experienced a incomplete cycle, which can be seen in Table 1.

Table 1 The fluctuation cycle of grain yield in major grain producing areas from 1949 to 2008

Cycle	Beginning and ending year	Years in between	Trough frequency % and year		Crest frequency % and year		Distance between crest and trough//%	Amplitude %	Type of amplitude
1	1949-1957	8	-35.83	1949	12.58	1955	48.41	24.21	Strong amplitude
2	1957-1961	4	-20.82	1960	15.27	1958	36.09	18.05	Strong amplitude
3	1961-1969	8	-26.80	1961	5.03	1966	31.83	15.92	Strong amplitude
4	1969-1972	3	-10.40	1969	4.57	1971	14.97	7.49	Medium amplitude
5	1972-1974	2	-4.31	1972	4.22	1973	8.53	4.27	Weak amplitude
6	1974-1977	3	1.29	1976	4.77	1975	3.48	1.74	Weak amplitude
7	1977-1980	3	-6.83	1977	3.70	1979	10.53	5.27	Medium amplitude
8	1980-1985	5	-4.79	1980	10.71	1984	15.50	7.75	Medium amplitude
9	1985-1989	4	-0.89	1988	3.25	1987	4.14	2.07	Weak amplitude
10	1989-1991	2	-2.14	1989	6.63	1990	8.77	4.38	Weak amplitude
11	1991-1994	3	-0.33	1991	2.79	1993	3.12	1.56	Weak amplitude
12	1994-1997	3	-0.94	1994	7.91	1996	8.85	4.43	Weak amplitude
13	1997-2001	3	-8.11	2000	5.71	1998	13.82	6.91	Medium amplitude
14	2001-2003	2	-9.70	2001	-9.05	2002	0.65	0.33	Weak amplitude
15	2003-2008	5	-16.16	2003	7.47	2008	23.63	11.82	Strong amplitude
Average	1949-2008	4	-9.78		5.70		15.48	7.74	Medium amplitude

By the analysis of Table 1, we can get that the fluctuation of grain yield in China's major grain producing areas takes on the following characteristics.

1.2 Fluctuation characteristics of grain yield

1.2.1 The fluctuation of grain yield has periodicity. Currently, the agricultural disaster-prevention ability of China's major grain producing areas is not strong. The periodic activity of natural disaster makes the formation of fluctuation of grain yield periodic and necessary. In light of every grain fluctuation in China's major grain producing areas, after the grain yield grows continuously for several years, it is always impacted by external factors, so the grain growth rate falls to a relatively low level, and hovers at this level for several years. This kind of periodicity reflects the periodic characteristic of formation of fluctuation of grain yield.

1.2.2 The fluctuation type of grain yield is basically the classic fluctuation. Fluctuation of grain yield can be divided into two categories: one is classic fluctuation, that is, the growth rate of grain yield changes from positive value to negative value after the decline, and generally the trough is negative and crest is

positive; the other is growth-type fluctuation, that is, the growth rate of grain yield begins to decline, but there is no negative value, and generally the trough and crest are both positive. From the morphological characteristics of crest and trough, the sixth cycle (1974 – 1977) is close to growth – type fluctuation, and the rest of circles belong to the classic fluctuation. Classic fluctuation cycles are the years 1949 – 1957, the years 1957 – 1951, the years 1961 – 1969 , the years 1969 – 1972, the years 1972 – 1974, the years 1977 – 1980, the years 1980 – 1985, the years 1985 – 1989, the years 1989 – 1991 , the years 1991 – 1994, the years 1994 – 1997, and the years 1997 – 2001 respectively, and half-cycle the years 2003 – 2008 also is also the classic type. Through the above analysis, we can see that the fluctuation in major grain producing areas is basically the classic fluctuation, indicating that there is great degree of vicious fluctuation of grain yield.

1.2.3 The frequency of fluctuation cycle of grain yield is high and the length is regular. As for the 14 half-cycles of grain yield fluctuation in the years 1949 – 2008, the average year interval is only 3.87 years, indicating that on average, there is one fluctuation every 4 years approximately, with relatively high frequency of fluctuation. In addition, apart from the relatively long cycle (the first cycle 1961 – 1969 and the third cycle 1949 – 1957, with the year interval reaching 8 years) and relatively short cycle (the fifth cycle 1972 – 1974, the tenth cycle 1989 – 1991 and the fourteenth cycle 2001 – 2003, with year interval of only 2 years), the year interval of other cycles is four years, on average, indicating that the variation degree of cycle length of grain yield fluctuation is small on the whole.

1.2.4 The fluctuation amplitude of grain yield is moderate on the whole. Fluctuation amplitude refers to the fluctuation intensity of grain in all cycles, which is an important indicator of measuring stability of grain yield growth. From the amplitude of fluctuation, the average fluctuation amplitude of grain yield in major grain producing areas is 7.74%; the minimum amplitude of fluctuation is in the fourteenth cycle (2001 – 2003), with amplitude of fluctuation smaller than 5%; the maximum amplitude of fluctuation is in the first cycle (1949 – 1957 years), with amplitude of fluctuation of 24.21%. On the whole, the stability of grain yield in major grain producing areas is not strong enough.

1.2.5 The fluctuation amplitude of grain yield has correspondence. Fluctuation of grain production and increase of grain production always form and emerge alternately. After the formation of several grain-production-increase years, correspondingly there will be one fluctuation of grain production; while after fluctuation of grain production, it will form several grain-production-increase years correspondingly again. The two always form and disappear relatively. This correspondence reflects the N-shape development trend of current grain production.

1.2.6 The fluctuation amplitude of grain yield has gradient characteristics. Different years of grain production fluctuation at different stages of grain production, the level of grain production is also different. Due to the improvement of overall grain production capacity and strengthening of disaster-prevention ability, the latter grain yield level in the grain production fluctuation years is generally no less than the grain yield level in the previous grain production fluctuation years, showing gradient development. This gradient characteristics show that through the efforts, we can make the grain production grow in fluctuation.

1.3 Comparison of fluctuation of grain yield Changes of grain yield in major grain producing areas are caused by changes of grain yield in the regions of all provinces. In order to objectively reflect the periodic characteristics of rapid growth of grain production and fluctuation of grain production in major grain producing areas of all provinces, this paper uses relative fluctuation coefficient as the indicator to measure fluctuation of grain yield in all provinces.

Relative fluctuation coefficient is the arithmetic mean of absolute value of ratio of the difference between year-to-year yield change rate and average change rate to average change rate in a certain period[2]. Relative fluctuation coefficient can objectively reflect the fluctuation of grain production during a given period in a region. The bigger the relative fluctuation coefficient, the bigger the fluctuation is, namely the poorer the stability is.

The formula is as follows:

$$RR = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{D_i - D}{D}\right| \times 100\%$$

$$D_i = \left(\frac{a_i}{a_{i-1}} - 1\right) \times 100\%$$

$$D = \left(\sqrt[n]{\frac{a_n}{a_0}} - 1\right) \times 100\%$$

RR is relative fluctuation coefficient; D_i is the growth rate of grain yield in the year i as against that of the previous year; D is average growth rate of grain yield in whole period; n is time span, namely years; a_i is the grain yield in the ith year; a_n is the yield at the end of period; a_0 is the yield at the beginning of period.

According to grain yield in major grain producing areas in whole China and major grain producing areas in provinces from 1949 to 2008, the relative fluctuation coefficient is calculated respectively, which can be seen in Table 2.

Table 2 Comparison of fluctuation of grain yield

Province	Relative fluctuation coefficient // %	Average growth rate annually // %	Province	Relative fluctuation coefficient // %	Average growth rate annually // %
China	174.43	6.22	Anhui	379.03	6.32
Major grain producing areas	206.28	6.99	Jiangxi	197.07	6.87
Hebei	287.04	8.80	Shandong	281.85	6.61
Inner Mongolia	370.30	15.30	Henan	254.77	11.05
Liaoning	508.65	6.08	Hubei	321.98	4.83
Jilin	445.10	8.79	Hunan	255.16	5.73
Heilongjiang and	391.19	10.71	Sichuan	325.20	3.18
Jiangsu	267.46	5.50			

As can be seen from Table 2, the relative fluctuation coefficient of grain yield in major grain producing areas of all provinces is higher than the national average. The provinces with relative fluctuation coefficient of grain yield prominently higher than the national average include Inner Mongolia, Liaoning, Jilin, Heilongjiang, and Anhui, with the relative fluctuation coefficient of grain yield higher than one time the national average. Among them, Liaoning is 2.92 times the national average, Jilin is 2.55 times the national average, Heilongjiang is 2.24 times the national average, Anhui is 2.17 times the national average, and Inner Mongolia is 2.12 times the national average, indicating that the stability of grain production in these provinces is poor, but these provinces are none other than the main provinces of producing commodity grain in China. Jiangxi Province has the smallest relative fluctuation coefficient, indicating that its grain production in the main producing areas is most stable. In terms of average annual growth rate of grain yield, the provinces with average annual growth rate of grain yield higher than the national average are Hebei, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Shandong, and Henan. The major grain producing area of Inner Mongolia ranks first, followed by Henan, Heilongjiang successively. On the whole, the average annual growth rate of grain yield in major grain producing areas is above the national average, but the relative fluctuation coefficient is also higher than the national average, indicating that the grain yield in the major grain producing areas grows along with unstable fluctuation.

2 Analysis of cause of fluctuation of grain yield in China's major grain producing areas

The grain production system is a complex system coupling natural system and social system in a certain region[3]. The grain yield is vulnerable to various kinds of production factors, such as input amount, agricultural technology progress, national grain policy, agricultural production organization and management system, various kinds of natural disasters and so on. Therefore, the fluctuation of grain yield comes about, which is interfered by many factors. However, in one specific fluctuation of grain yield, only one or a few factors that play a leading role. In this paper, in light of the actual situation of grain production in major grain producing areas, combined with fluctuation cycle of grain yield in major grain producing areas, analyzes the reason of fluctuation of grain yield in major grain producing areas as follows.

2.1 Natural disaster Suffering from natural disaster is an important factor of grain yield fluctuation. China is a country where the natural disasters frequently happen, with weak ability of preventing agricultural risk, so the grain production is vulnerable to natural disasters. In agricultural natural disasters of China, drought and flood account for about 70%; in drought and flood disasters, drought accounts for around 70%. Therefore, drought is often the main disaster causing fluctuation of grain production in China. For example, in 2000, Jilin Province suffered from the worst drought disaster in history, with the total stricken area up to 3.662 million and the drought area reaching 3.538 million hm^2, which directly consigned the grain yield in a slump. In northeast China, the early frost poses a big threat to grain production. In 1997, due to drought and early frost, the grain yield of Jilin Province and Liaoning Province decreased by 5 million tons and 4 million tons.

2.2 Agricultural policy Since reform and opening, the formulation of important policies regarding system change, increased purchasing price of agricultural products and establishment of commodity grain bases, has greatly mobilized the production enthusiasm of farmers, and meanwhile, released the accumulated energy on agricultural infrastructure and technology input formerly, so that grain production has significantly increased. The grain production output in major grain producing areas increased from 0.212 860 9 billion tons to 0.282 208 6 billion tons in 1978, increasing by 6.934 77 million tons, with average annual growth rate of 5.43%.

2.3 Production input Under normal circumstances, grain production inputs including fertilizers, pesticides, agricultural machinery and so on, are positively correlated with yield. Historically, the period of grain production input increase is also the period of rapid development of grain production; if the input is decreased, it will significantly affect grain production. The role of increasing output the input plays has continuity. Increase or decrease of grain production input in one year will affect grain production in the years subsequently. Some years with fluctuation of grain yield are also the years with decreased financial agricultural input.

2.4 Grain price Grain price is a direct factor affecting grain production, and also a factor related with farmers' benefit. China has more than two hundred million farmers engaged in grain production, and most of them produce the same product, which makes China's grain supply and demand close to perfectly competitive market. The individual farmers are the passive recipients of the market price, and they cannot influence their output through the variance of supply. Therefore, the balance status of grain supply and demand in the year first causes fluctuation of grain market price, while the fluctuation of grain market price will directly affect farmers' economic behavior and change of input of production factors, and further determine the fluctuation of grain yield in the following year. In fact, as far as farmers' concerned, what impacts fluctuation of grain production or farmers' activity in growing grain is the comparative benefit through activity of growing grain and other economic activities, that is, the variables of external brunt concerning fluctuation of grain yield in China not only include the price of grain itself, but also include prices of input products in grain production and prices of other agricultural products (opportunity cost of growing grain).

2.5 Grain circulation If grain produced by farmers can not be successfully sold, it will inevitably affect the farmers' benefit in activity of growing grain and dampen the enthusiasm of farmers to grow grain. Farmers are accustomed to regarding the existing circulation status as the signal of market demand and basis for arranging production in the following year. Especially under the circumstance of a series of good agricultural harvests and abundant grain supply, circulation will become an important factor related to grain production. The impact of sluggish flow on grain production has particularities: first, it will generate indi-

rect or direct comprehensive impact, namely through impacting planting acreage, farmers' input, government input and field management to influence grain production; second, when it is difficult to sell grain, the unblocked circulation will always amplify supply degree of grain. This amplification effect easily misleads farmers, so that farmers are inactive in grain production, resulting in decreased grain production.

3 Policy suggestions

Major grain producing areas should be fully aware of and prevent the violent fluctuation in grain production, and inhibit and arrest abnormal fluctuation of grain production. They should in particular strengthen the following aspects.

3.1 Stick to strict farmland protection system and strive to promote farmland quality We should conscientiously carry out and implement rules, regulations, policies and regulations regarding protection of arable land, in order to effectively control the decrease amount of arable land to a minimum. We should also adopt legal measures to ensure the improvement of quality of cultivated land, improve agricultural cultivation modes, prevent soil erosion, speed up the transformation of low-yield farmland, establish and improve the measures of fertility of soil, and implement compensation system of soil fertility[4].

3.2 Strengthen infrastructure construction of grain production and beef up the ability of preventing natural disaster Increase of grain yield depends on three types of technological measures, that is, biotechnology, engineering technology and mechanical technology. The three technological measures have different orderings of importance at different stages of production in different regions. On the part of major grain producing areas, the grain production is greatly influenced by natural disasters, and the greatest constraint of withstanding natural disasters is backward agricultural infrastructure, therefore, we should pay attention to the application and construction of engineering measures; strengthen construction of farmland water conservancy; adhere to the leading role of water conservancy construction; accelerate the improvement of production conditions of the low-yield fields; implement water saving irrigation project and popularize technology; create favorable conditions for sustainable development of grain production in major grain producing areas.

3.3 Quicken the pace of agricultural technology and establish robust technology supporting system We should focus on research, development, promotion and application of high-yield, high-quality, high-efficiency and safe technology of grain; use continuous technological innovation to promote increasing growth of grain yield. At the same time, we should pay attention to construction of agricultural technology popularization service system, in order to provide effective public products and services for major grain producing areas and open up effective channels for promotion and application of new technologies.

3.4 Lay stress on innovation of agricultural organization system and provide implementation path and vehicle for application of agricultural technology measures The high-degree scattered family management on land use at present, balking construction of water conservancy facilities, mechanic technology promotion and regionalization production of specific varieties. It affects the long-term stable development of grain production. Therefore, in the process of choosing measures to reduce fluctuation in grain production, we should not only pay attention to the improvement of productivity factors, but also attach importance to analysis and clarification of factor of agricultural organization system, and use innovation of agricultural organization system to provide implementation path and operation carrier for improvement of agricultural production conditions and application of new technology. Currently on the basis of stabilizing family management, we should further promote the development of cooperative economic organizations of farmers and use rural cooperative economic organizations to promote the rational use of production factors.

3.5 Perfect disaster precaution system and grain market system, and strengthen the ability of preventing risk of grain production Preventing natural risks and market risks is necessary requirement for stable and sustainable development of grain production[5]. We should improve disaster prevention and control system of grain production; establish emergency and handling mechanism of prevention of pest and major natural disasters in grain production; improve the level of monitoring and forecasting; formulate a variety of contingency plans regarding prevention of disasters and assistance; minimize the effect of disasters on grain production. In addition, we should further improve and perfect the grain market system; actively improve the grain market access system; improve and strengthen grain market supervision; improve the agricultural futures markets; protect the interests of grain growers; promote stable and sustainable development of grain production.

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