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Zero Growth of Chemical Fertilizer and Pesticide Use: China's Objectives, Progress and Challenges

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Abstract: In 2015 China's Ministry of Agriculture introduced two Actions that seek to achieve zero growth in the use of chemical fertilizer and pesticides by 2020. Success in reaching these targets will help control agricultural non-point source pollution, increase cost efficiency, energy conservation and emission reductions, help to ensure the safety and quality of the national grain supply and agricultural products and the safety of the ecological environment, and realize the sustainable development of agriculture. However, successful implementation will be crucial. This article considers the main contents of the Actions and analyzes their feasibility from the perspectives of policy formulation, local practices, technical support and achievements. We identify problems and challenges and suggest that zero growth of chemical fertilizer and pesticide use can be achieved by undertaking basic research on the factors that shape the use of farm chemicals, making improvements to the monitoring and statistical system for chemical fertilizer and pesticide use, setting up demonstration projects and enhancing policies formulated to reduce chemical fertilizer and pesticide use.

Key words: zero growth of chemical fertilizer; zero growth of pesticide; feasibility; China

1 Background of action to achieve zero growth of chemical fertilizer and pesticide use

Overuse of chemical fertilizer and pesticides has been a concern in China for some years due to the implications for food safety, agricultural sustainability and the health of the ecological environment. In 2015, the Chinese Ministry of Agriculture introduced two important measures that seek to halt the growth in the use of fertilizers and pesticides: the "Action to Achieve Zero Growth of Chemical Fertilizer Use by 2020" and the "Action to Achieve Zero Growth of Pesticide Use by 2020" (MOA, 2015). This article introduces the background to these Actions and provides an analysis of the main strategies they employ, progress to date and the challenges for implementation.

In recent years, China's agricultural economy has developed rapidly with the support of a series of policies to strengthen agriculture and benefit farmers. Agricultural production capacity has risen to a new level and grain production has achieved a historical milestone of growing for eleven consecutive years. These accomplishments have made great contributions to the smooth functioning of the national economy. From 2004 to 2014, China's total grain output increased to 607.1 million tons from 469.47 million tons with an average annual increase of 3.2%; total grain output exceeded 600 million tons in two consecutive years (Fig. 1). Other important agricultural products also had high yields that resulted in adequate supply and stable prices. The good condition of agriculture and the rural economy provides the material basis, strategic space and important opportunities to achieve zero growth of chemical fertilizer and pesticide use.

Studies have shown that chemical fertilizers and pesticides are important inputs in agricultural production and both play

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important roles in ensuring stable, high yields of agricultural products and driving growth of the agricultural economy (Wang *et al*., 1996; Wang & Xiao, 2008). More than 40% of grain production increases have been attributed to the use of chemical fertilizers (MOA, 2015). China has become the world's largest producer and consumer of chemical fertilizers and pesticides. Total fertilizer use increased from 41.46 million tons in 2000 to 59.12 million tons in 2013, with an average annual increase of 2.8%. This is equivalent to the total amount of fertilizer used in both the United States and India. The intensity of chemical fertilizer use grew an average of 2.5% per year, increasing from 265 kg per ha in 2000 to 357 kg per ha in 2013. This use intensity far exceeds the internationally recognized standard to limit the use of fertilizer to 225 kg per ha (Fig. 2).

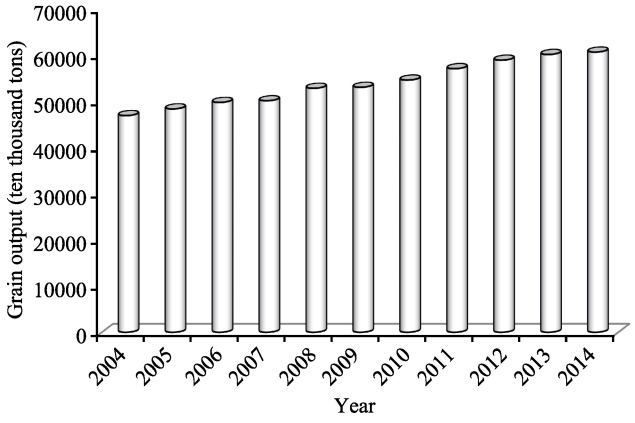

Fig.1 China's grain output during the years 2004 to 2014

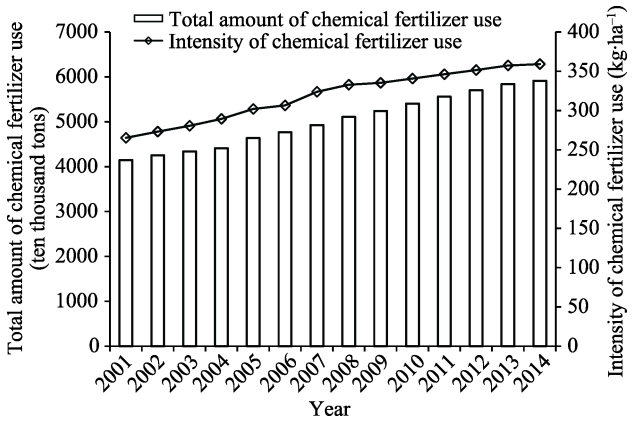

Fig.2 Total amount and intensity of chemical fertilizer use in China

The total amount of pesticides used per year grew from 1.28 million tons in 2000 to 1.8 million tons in 2013, with an average annual increase of 2.7%. The intensity of pesticide use increased from 8 kg per ha in 2000 to 11 kg per ha in 2013, with an average annual growth of 2.3 % (Fig. 3). The average utilization rates of fertilizers and pesticides are 33% and 35%, respectively, 15% to 30% lower than utilization rates in developed countries.

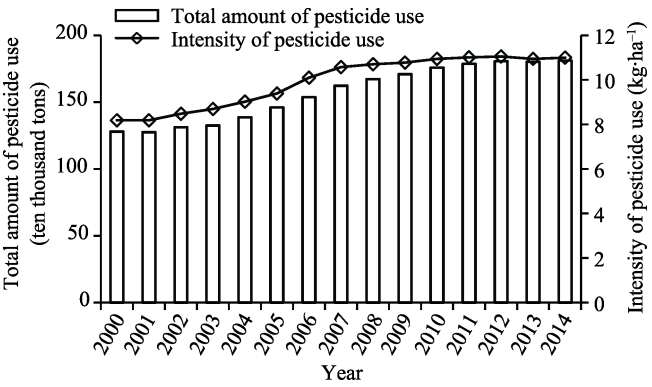

Fig.3 Total amount and intensity of pesticide use in China

Fertilizers and pesticides are double-edged swords for agriculture. Their use raises expectations for increased output of agricultural products, but it also has unwanted consequences such as non-point source pollution. The large amount of fertilizer and pesticide use, and the high intensity combined with low efficiency and unscientific application methods increase the cost of agricultural production and waste resources, and result in problems like degraded soil fertility, excessive pesticide residues, and agricultural non-point source pollution. The use of these inputs influences the safety of the ecological environment and agricultural production, and the quality and safety of agricultural products, and it threatens human health and sustainable agricultural development (Xing & Zhu, 2000; Lai *et al*., 2009; Fischer *et al*., 2010; Xin *et al*., 2013; Shen & Zhang, 2015).

Agricultural development faces two main constraints: resources and the ecological environment. The Actions to achieve zero growth of chemical fertilizer and pesticide use have the potential to help promote improved methods for and structural adjustments of agriculture, control agricultural non-point source pollution, increase cost efficiency, energy conservation and emission reductions, ensure the safety of the national grain supply, the quality and safety of agricultural products and the safety of the ecological environment, and realize the sustainable development of agriculture. They will therefore bring significant economic, environmental and social benefits.

2 Key points of action to achieve zero growth of chemical fertilizer and pesticide use

2.1 Targets

The first objective of the "Action to Achieve Zero Growth of Chemical Fertilizer Use by 2020" is to achieve annual growth rates of chemical fertilizer use of less than 1% from 2015 to 2019, and strive to realize zero growth of chemical fertilizer use for principal crops by 2020. The objective of the "Action to Achieve Zero Growth of Pesticide Use by 2020" is to keep the use of pesticides per unit of land area below the average level in the years 2012 to 2014, and

strive to achieve zero growth in the total use of pesticides by 2020. These targets can be broken down into more specific targets, as described in Table 1.

2.2 Technical paths

Because the characteristics of crop production and the damage caused by pests differ from region to region, the technical path to zero growth of chemical fertilizer use shall be guided by the key words "accuracy, adjustment, improvement, replacement". *Accuracy* refers to accurate fertilization. Unit area limits for fertilization will be set for each region and each crop according to soil conditions and crop yield potentials, in order to minimize blind fertilization. *Adjustment* refers to adjusting the chemical composition of fertilizers. The ratio of nitrogen, phosphorus and potassium shall be optimized and efficient fertilizers will be promoted in order to adapt to the needs of modern agricultural development. *Improvement* refers to improving fertilization methods. Soil testing and formulated fertilization will be popularized and applicable fertilization devices will be developed, such as machines for deep fertilization to replace traditional methods of surface application and spraying. *Replacement* refers to replacing chemical fertilizers with organic fertilizers. Some chemical fertilizers will be replaced by organic fertilizer so as to realize a combination of inorganic and organic fertilizers.

Table 1 Specific targets for action to achieve zero growth of chemical fertilizer and pesticide use

Items	Chemical fertilizers	Pesticides
Specific objective	Optimize the structure of fertilization. By 2020, the coverage of soil testing and formulated fertilization shall reach more than 90%; application rate of livestock and poultry manure shall reach 60%, up to a 10% increase; application rate of straw shall reach 60%, up to a 25% increase.	Green prevention. The coverage of biocontrol and physical control of pests on main crops shall reach more than 30%, increasing 10% over coverage in 2014.
	Improve fertilization methods. More than 40% of crop acreage shall be fertilized by machine, an increase of 10%; application area of integrated irrigation and fertilization shall increase to 150 million mu, growth of 80 million mu.	Unified control. The coverage of professional unified control of pests on main crops shall reach more than 40%, increasing by 10% over coverage in 2014.
	Enhance the utilization rate of fertilizer. From 2015 onwards, the utilization rate of chemical fertilizer for main crops shall be enhanced by at least 1% per year, and the utilization rate of chemical fertilizer for main crops shall be above 40% by 2020.	Scientific pesticide use. The utilization rate of pesticide on main crops shall reach more than 40%, increasing by 5% over the rate in 2013, with a significant increase in the proportion of efficient low toxicity and low residue pesticide.

Based on the characteristics of damage from pests, the technical path to zero growth of pesticide use will focus on the key words "control, replacement, accuracy, unification". *Control* refers to controlling damage from pests. Green prevention techniques, which refer to agricultural control, biocontrol and physical control, will be applied to reduce the use of pesticides. *Replacement* refers to replacing high toxicity and high residue pesticides with efficient low toxicity and low residue pesticides such as bio-pesticides. *Accuracy* refers to the accurate and scientific application of pesticides. On the basis of accurate identification and diagnosis of the resistance levels of pests, pesticides will be formulated and applied to deal with crop pests while avoiding abuse. *Unification* refers to unified control of pests. Professional service organizations for the unified control of pests and new agricultural business entities will be supported to carry out large-scale professional unified control of pests.

2.3 Tasks

The key tasks to achieve zero growth of chemical fertilizer use are the "four promotions and one improvement":

(1) Promote soil testing and formulated fertilization[1]. On the basis of past experiences, soil testing and formulated fertilization shall be promoted on a larger scale and higher level by adopting an innovative approach to implementation.

(2) Promote improved fertilization methods. New types of business entities, including large-scale grain farms, family farms, cooperatives, etc., will play exemplary roles in order to strengthen technical training and guidance services, popularize advanced and applicable techniques, and promote improved fertilization methods.

(3) Promote application of new fertilizers and new techniques. Scientific research, education, promotion, and corporate resources will be integrated for joint research based on the needs of agricultural production, with increases in R&D investment and channels to obtain international advanced techniques.

(4) Promote the use of organic fertilizers. An effective model for the use of organic fertilizers that is adapted to the needs of modern agriculture development and the characteristics of China's agricultural system will be identified and farmers will be encouraged and given support to increase organic fertilizer use.

(5) Improve cropland quality. The development of high-standard cropland will be accelerated, and actions to protect and enhance cropland quality will be implemented to improve soil fertility. By 2020, the fertility of cropland will rise by at least 0.5% in terms of grade, the organic matter content of soil will increase by 0.2%, and acidification, salinization, pollution and other problems with cropland shall be effectively controlled.

[1] This refers to fertilizer with a chemical balance formulated to meet local needs.

The key tasks to achieve zero growth of pesticide use are the "one build and three promotes":

(1) Build up a pest monitoring and early warning system. Automated, intelligent field monitoring networks will be built based on the principles of advancement and practicability to improve pest monitoring.

(2) Promote scientific pesticide use. The focus is the simultaneous enhancement of "pesticides, devices and farmers". First, efficient, low toxicity, low residue pesticides will be promoted. Second, new and efficient crop protection machinery will be promoted. Third, scientific knowledge of pesticides will be popularized.

(3) Promote green prevention. Government support will be consolidated and market mechanisms will come fully into play to accelerate the pace of green prevention, including the promotion of integrated technology methods, the construction of green prevention demonstration zones and the training of technical staff.

(4) Promote unified control. Professional unified control of pests will be promoted with an emphasis on expanding service scope and improving service quality, including enhancements to devices, technology and service content.

The above shows that the actions to realize zero growth of chemical fertilizer and pesticide use focus on source reduction, end to end monitoring of chemical fertilizer and pesticide use, and end-of-pipe control of the pollution that is generated. For example, organic fertilizers, slow-release fertilizers, bio-pesticides and other efficient new fertilizers and efficient low toxicity, low residue pesticides will be incorporated into production processes. Professional service organizations and agricultural materials production enterprises will be guided to participate in soil testing and formulated fertilization, and to undertake unified control and green prevention of pests, to achieve accurate application of chemical fertilizer and pesticide and to enhance the utilization rate. The government will procure the services of agricultural non-point source pollution control companies and market organizations to improve control efficiency, effectiveness and benefits of solid and liquid waste treatment.

3 Progress in zero growth in chemical fertilizer and pesticide use

To achieve zero growth in chemical fertilizer and pesticide use by 2020, multiple administrative, economic and legal measures will be adopted. This section of the paper analyzes the feasibility of the Actions in the areas of policy formulation, local practices, and technical support to achieve zero growth of chemical fertilizer and pesticide use, and looks at achievements to date.

3.1 Policy formulation

Agricultural non-point source pollution, which is a grave problem of concern today, can be divided into two types: the first is pollution due to the excessive input of certain substances at the front end of agricultural production, including pesticides, chemical fertilizers and other chemical inputs; the second is waste from the agricultural production process, such as straw, manure, etc. The government attaches great importance to the control of agricultural non-point source pollution. Six No.1 Documents of the Central Committee of the Communist Party of China (CPC) issued in 2008–2010 and 2013–2015 have each explicitly mentioned the problem. In 2014 and 2015, a number of measures, including laws and regulations, national plans and programs, and sectoral rules and regulations were put forward to control agricultural non-point source pollution and promote agricultural sustainable development (Table 2). These measures provide the legal and policy basis for the target of zero growth of chemical fertilizer and pesticide use. Control of agricultural non-point source pollution with a focus on reducing the input of chemical fertilizers, pesticides and other chemicals is a key task of China's 13th Five Year Plan.

(1) Laws and regulations

In April 2014, a revised Environmental Protection Law

Table 2 Agricultural non-point source pollution control policies since 2014

Type	Title	Issuer
Laws and regulations	Environmental Protection Law (2014)	NPC
National plans and programs	Integrated Reform Plan for Promoting Ecological Progress (2015)	CPC Central Committee, State Council
	Water Pollution Control Action Plan (2015)	State Council
	Agricultural Sustainable Development Program (2015–2030) (2015)	MOA, NDRC, etc.
	Integrated Plan on Agricultural Environment Outstanding Issues (2014–2018) (2015)	MOA, NDRC, etc.
Sectoral rules and regulations, action plans	Opinions on Implementing Control of Agricultural Non-point Pollution	MOA
	Action to Achieve Zero Growth of Chemical Fertilizer Use by 2020	MOA
	Action to Achieve Zero Growth of Pesticide Use by 2020	MOA
	Implementing Plan to Promote the Action to Achieve Zero Growth of Chemical Fertilizer Use by 2020 (2015)	MOA
	Management Method for Recycling Pesticide Packaging (draft) (2015)	MOEP

was promulgated. The revised law paid increased attention to agricultural non-point source pollution and included comprehensive provisions on agricultural pollution monitoring and early warning, chemical fertilizer and pesticide pollution prevention and control, and livestock pollution prevention and control. Other provisions required governments and agencies related to agriculture at all levels to guide agricultural producers and business operators in the use of scientific cultivation methods, in the scientific and rational application of chemical fertilizers, pesticides and other agricultural inputs, and in the scientific disposal of agricultural films, straw and other agricultural waste. With the goal of preventing agriculture non-point source pollution, the revised law laid the legal foundation needed to control such pollution.

(2) National plan and program

In April 2015, the Water Pollution Control Action Plan issued by the State Council called for implementing a national plan to control agricultural non-point source pollution. The plan proposed that by 2020 the coverage of soil testing and formulated fertilization shall be greater than 90%, the utilization rate of chemical fertilizers for principal crops shall be above 40%, and the utilization rate of pesticides on principal crops shall be above 40%. The plan also stipulated that Beijing, Tianjin, Hebei, and the Yangtze River and the Pearl River basin areas shall achieve these targets one year earlier.

In May 2015, the Agricultural Sustainable Development Program (2015–2030), jointly issued by eight ministries including the Ministry of Agriculture (MOA), the National Development and Reform Commission (NDRC), the Ministry of Science and Technology (MST), clearly defined the general requirements, tasks, and key regions for agricultural sustainable development. The program requires expanding soil testing and the use of formulated fertilization, improving fertilization methods, and encouraging the use of organic fertilizers, bio-fertilizers and green manuring. By 2020 the coverage of soil testing and formulated fertilization shall come to more than 90%, the utilization rate of chemical fertilizers for principal crops shall be above 40%, and zero growth of chemical fertilizer use shall be achieved. Moreover, the use of efficient low toxicity, low residue pesticides, bio-pesticides and advanced application machinery shall be promoted, and the unified control and green methods of pest prevention shall be popularized. By 2020 the coverage of national unified pest control shall reach 40%, and zero growth of pesticide use shall be achieved.

In September 2015, the Integrated Reform Plan for Promoting Ecological Progress issued by the CPC Central Committee and the State Council stipulated that various measures to support the management system for the rural environment and government procurement of services will be adopted, and that the development of market-based entities will be developed to control agricultural non-point pollution and dispose of solid and liquid waste in rural areas.

(3) Sectoral rules and regulations

On 10 April, 2015, Opinions on Implementing Controlling of Agricultural Non-point Pollution issued by the MOA proposed a target of "one control, two reductions, three basics"[2] to control agricultural non-point source pollution. The opinions clearly defined tasks and safeguard measures for controlling such pollution; and require that coverage of soil testing and formulated fertilization shall be more than 90%, coverage of green prevention methods for pests shall be more than 30%, the utilization rate of fertilizers and pesticides shall be more than 40%, and that zero growth of chemical fertilizers and pesticides use shall be achieved nationwide.

On 14 April, 2015, Management Methods for Recycling Pesticide Packaging (draft) issued by the Ministry of Environmental Protection (MEP) presented detailed provisions for recycling, transporting and disposing of pesticide packaging. It requires the phasing out of small capacity and non-standard packaging and encourages the use of large capacity packaging.

3.2 Local practices

To achieve zero growth of chemical fertilizer and pesticide use, central and local governments must work together. On the basis of the "Action to Achieve Zero Growth of Chemical Fertilizer Use by 2020" and the "Action to Achieve Zero Growth of Pesticide Use by 2020" issued by the MOA, Shandong, Liaoning, Zhejiang, and Sichuan developed detailed implementation plans that took advantage of local practices to promote zero growth of chemical fertilizer and pesticide use. Taking local practices into consideration when developing plans is conducive to the accumulation of experience, improving policies, and facilitating the achievement of zero growth in chemical fertilizer and pesticide use.

(1) Shandong

Shandong Province has formulated the 2016–2020 Action on Reduction of Chemical Fertilizer Use in Shandong Province stipulating that by 2020 fertilizer use shall drop to 5% less than the current use level, the application rate of straw, livestock and poultry manure shall reach 60%, the ratio of NPK in fertilizer shall be optimized at 1:0.5:0.45 with a compound rate of more than 50%, and the crop fertilizer utilization rate shall be over 35%. The Shandong program identifies vegetables, fruit trees, wheat and corn as the targets of efforts to reduce fertilizer use through various techniques.

The Shandong Province Action on Zero Growth of Pesticide Use by 2020 stipulates that by 2020 zero growth of overall pesticide use shall be achieved. The coverage of

[2] "One control" refers to strictly controlling the total amount of water used in agriculture, "two reductions" refers to reductions in the use of chemical fertilizers and pesticides, "three basics" refers to utilization of basic farming resources, i.e. manure, straw, etc.

biocontrol and physical control methods for pests on principal crops shall be more than 30%, with full coverage of vegetables and standard horticultural plots. Coverage of professional unified control of pests on principal crops shall be more than 40%, with full coverage on high yield demonstration fields for grain, cotton, and oil, and on standard horticultural plots. The utilization rate of pesticides on principal crops shall be more than 40%, with a significant increase in proportion of efficient low toxicity, low residue pesticides.

(2) Liaoning

Liaoning Province has developed an Action on Zero Growth of Chemical Fertilizer Use on Fruit Trees by 2020 and a Technical Plan to Reduce Chemical Fertilizer Use for Apples, both of which require that the annual growth rate of fertilizer use is less than 1% during the years 2015 to 2019 and that the zero growth of chemical fertilizer use target is reached by 2020. Measures to reduce fertilizer use and increase efficiency include increasing application of organic fertilizer, and encouraging farmers to use manure and commercial organic fertilizers in reasonable ways to replace chemical fertilizers when possible, using green manure in the fruit gardens, spraying trace-element foliar, and applying reasonable amounts of fertilizers in later stages. The Liaoning measures promote integrated irrigation and fertilization with a focus of spray (drip) irrigation, small tube fertilization and other water-saving and fertilizer-saving techniques, and the use of efficient slow-release fertilizers and formulated fertilizers to prolong effectiveness and reduce the need for labor.

The Action on Zero Growth of Pesticide Use by 2020 in Liaoning Province stipulates that the achievement of zero growth of pesticide use in Liaoning province shall be divided into three phases: in 2015–2016, the coverage of green prevention methods for pests on principal crops shall reach 24%, the coverage of professional unified control of pests on principal crops shall reach 33%, the utilization rate of pesticides shall reach 36%, and the growth rate of pesticide use shall be less than 1%; in 2017–2018, the coverage of green prevention methods for pests on principal crops shall reach 27%, the coverage of professional unified control of pests on principal crops shall reach 36%, the utilization rate of pesticides shall reach 38%, and the growth rate of pesticide use shall be zero; in 2019–2020, the coverage of green prevention methods for pests on principal crops shall reach 30%, the coverage of professional unified control of pests on principal crops shall reach 40%, the utilization rate of pesticide shall reach 40% and the reduction rate of pesticide use shall be more than 1%.

(3) Sichuan

Sichuan's full implementation of the Action on Zero Growth of Chemical Fertilizer Use centres on the principles "enhance, promote, adjust, change, replace, pilot". In 2015, Sichuan established a target of cultivating of 550 acres of high- standard cropland in 150 counties. The effort to achieve this target is being led by government departments for land resources and agricultural development. The scope of soil testing and the use of formulated fertilization on vegetables, fruit trees and tea trees shall be expanded on the basis of continuously deepening soil testing and formulated fertilization on grain and oilseed crops. In 2015, a total of 127 counties (units) implemented soil testing and formulated fertilization projects; these projects had funding of CNY 43 million, covered an area of 9000 mu, brought technology to 38,000 villages, and provided guidance for 12 million farmers. Fertilization methods will be improved with demonstrations of integrated irrigation and fertilization. A project on 3100 mu of land for integrated irrigation and fertilization using spray, drip and irrigation will be established in Nanchong city, Shehong county and Yuechi county. A portion of the chemical fertilizers used will be replaced by organic fertilizers and there will be pilot projects for livestock and poultry manure utilization. Pilot projects to reduce fertilizer use and increase efficiency in vegetable production have been established, including a demonstration field of 100,000 mu of garlic in Pengzhou city and one of 62,000 mu for vegetables in Guang'an district.

Sichuan Province has fully implemented the action on zero growth of pesticide use, proposing a target of reducing by 1% of pesticide use by 2020, and making green prevention an important part of modern agricultural base construction. In the first half of 2015, provincial and municipal financial departments paid out a total of CNY 100 million to promote the development of green prevention, and more than 30 technical standards for pest control techniques were issued by the Sichuan Province Quality Supervision Bureau, The efficiency of red mite control on citrus rose to greater than 75% by means of "using predatory mites to control pest mites", and the efficiency of corn borer control by means of "trichogramma + virus" rose to greater than 73%. In recent years, more than 5,000 green prevention technicians and 250,000 farmers have been trained, while pesticide use has been reduced by over 5000 tons on the 20 million mu of green prevention pilot project cropland.

3.3 Technical support

Zero growth in chemical fertilizer and pesticide use cannot be achieved without technical support. Reducing chemical fertilizer and pesticide use refers to reducing the amounts of chemical fertilizers and pesticides used, increasing the utilization rates of fertilizers and pesticides, realizing cost efficiencies in agriculture and minimizing agricultural non-point source pollution by deploying technologies that do not lower yields at the early, middle and late stages of agricultural production. Research shows that, if proper cultivation techniques are adopted and sound management methods in place, less chemical inputs can achieve higher yields (Jin *et al*., 2015).

Technologies that reduce the use of fertilizers and pesticides are employed during the early stage of agricultural

production. The use of slow-release fertilizer, water soluble fertilizer, liquid fertilizer, foliar fertilizer, bio-fertilizer, and soil conditioners and other new efficient fertilizers, bio-pesticides, and efficient low toxicity, low residue pesticides can increase the utilization rate of fertilizers and pesticides, and this allows the volume of products that is applied to be reduced. For example, water soluble fertilizer, a completely water-soluble polyhydric compound fertilizer, containing nitrogen, phosphorus, potassium, various trace elements, and all other nutrients needed for crop growth, has a utilization rate when applied to crops of 70% to 80%.

Technologies that reduce the use of fertilizers and pesticides are also employed during the middle stage of agricultural production. Efficient absorption of chemical fertilizers and pesticides can be achieved by changing the methods used to apply the products and their ingredients in such a way as to reduce losses. Appropriate methods include soil testing and formulated fertilization, deep application of fertilizer, straw use, integrated irrigation and fertilization, green prevention, and scientific pesticide application. For example, the deep application of fertilizer refers to applying certain amounts of fertilizer to crop roots underground so that the fertilizer can be fully absorbed and losses significantly reduced. Studies show that ammonium bicarbonate and urea deeply applied at 6–10 cm below the surface can raise the utilization rates of these substances by 115% and 35%, respectively, compared with surface application (Zhang,2006).

Technologies can also reduce the impact of fertilizers and pesticides used in agricultural production on the environment. There are a number of ways to minimize environmental pollution from fertilizer and pesticide use. Non-point source pollution control technology, eutrophication control technology and bioremediation degradation technology can absorb, enrich, degrade, and purify pollutants that result from the use of chemical fertilizers and pesticides. For example, one focus of non- point source pollution control technology is to absorb the nitrogen, phosphorus and other chemicals from fertilizers and pesticides that were not absorbed by crops. Major control technologies include ecological ditches, biochemical ponds, and artificial wetlands.

3.4 Achievements

Zero growth of chemical fertilizer and pesticide use is not the same as no use of chemical fertilizers and pesticides. Zero growth is an effort to reduce the amount of chemicals by improving product quality and changing application methods to increase utilization rates. Action to achieve zero growth in chemical fertilizer and pesticide use has resulted in the utilization rate of fertilizer on rice, corn and wheat rising to 35.2% in 2015, an increase of 2.2% over the rate in 2013. The amount of urea used has been reduced by 1 million tons and farmers spent CNY 1.8 billion less on fertilizers. The utilization rate of pesticides reached 36.6% in 2015, an increase of 1.6% over 2013. The amount of pesticides used was reduced by 152,000 tons and farmers reduced expenses for pesticides by CNY 800 million. It is estimated that a 2.2% increase in the fertilizer utilization rate results in a reduction in fertilizer use equivalent to reducing nitrogen emissions by 478,000 tons and saving one million tons of coal. This demonstrates that reducing fertilizer and pesticide use plays an important role in lowering costs and reducing environmental pollution. However, although efforts to reduce fertilizer and pesticide use in China have made progress, there is still much room for improvement[3].

4 Challenges in achieving zero growth of chemical fertilizer and pesticide use

China is a large agricultural country and this creates certain obstacles to achieving zero growth of chemical fertilizer and pesticide use. The impact of climate change and market uncertainty create additional challenges. The problems and challenges in achieving zero growth are discussed below.

4.1 Uncertainty of baseline data related to zero growth in chemical fertilizer and pesticide use

The plan to achieve the target of zero growth of chemical fertilizer and pesticide use aims to gradually reduce the annual growth rate of chemical fertilizer use to less than 1% from 2015 to 2019; and then strive to realize zero growth for principal crops in 2020. The use of pesticides per unit of land area should be below the average level for the previous three years, and an effort should be made to achieve zero growth in the total use of pesticides by 2020. The government has statistics for fertilizer use, but when it comes to pesticides, accurate baseline data is lacking. At present national statistics include data on pesticide production, which show that total annual production has been around 1.8 million tons in recent years. Meanwhile, the pesticide industry and the agricultural sector generally use the amount of active ingredients of pesticides, which has been about 30 tons, but no accurate official data is available. If the production amount is taken as indicator, the amount of pesticides used in 2013 decreased by 4000 tons compared to 2012. Considering the impact of pesticide use on the environment, health, and food quality and safety, it is important to improve monitoring and statistics of pesticide use to obtain more accurate data.

4.2 Inconsistency of statistics and findings

Currently, many provinces, cities and counties have developed local action plans to achieve zero growth in chemical

[3] Xinhua Net. Utilization rate of fertilizer and pesticide on rice, corn and wheat increasing significantly. 2 December 2015. http://news.xinhuanet.com/Fortune/2015-12/02/c_1117336011.htm.

fertilizer and pesticide use, and some have proposed targets that call for negative growth. This reflects the importance provinces and cities attach to the zero use effort and their determination to achieve the target. It should be noted that zero growth should not become a statistical numbers game; we must ensure that the reduction of fertilizer and pesticide use shows tangible improvements in the quality of the agricultural environment.

One path to zero growth in fertilizer and pesticide use is to achieve zero growth in each province, each county, each village and even on each plot of agricultural land, but this is not the only path, nor is it the optimal one. The purpose of zero growth policy is to promote more scientific and efficient use of fertilizers and pesticides and to eliminate excessive, unreasonable use by increasing the efficiency of agricultural production. Looked at from this point of view, zero growth is an opportunity to transform agricultural development methods and make agriculture more sustainable. Only by understanding zero growth from this perspective can we maintain enthusiasm for this work. Moreover, reducing fertilizer and pesticide use includes completing very specific tasks and should be carried out in actual production in accordance with the general direction of policy. Statistical data only reflect one aspect of fertilizer and pesticide reduction. What is more important is the improvement of the agricultural production environment, the ecological environment and the quality of agricultural products.

4.3 A complex mix of factors leads to heavy use of chemical fertilizers and pesticides

Farmers are owners and users of agricultural production resources and how they choose to use chemical fertilizers and pesticides (including the amount, type, technology, etc.) will directly affect the achievement of zero growth. A number of factors interact to affect the use of fertilizers and pesticides. The entities that produce and sell fertilizers and pesticides obviously have an economic interest in end-users buying more. But farmers need to pay for fertilizers and pesticides and, moreover, the work of applying these products is both difficult and dangerous, so there is no reason for farmers to use more than the amount that is necessary. Yet they do.

It seems that excessive use of fertilizers and pesticides happens under certain conditions(Jin *et al*., 2015; Fang & Liu, 2018; Wang & Zhang, 2018). The growing of crops and the damage caused by pests are complex and farmers often have insufficient knowledge to assess problems. Farmers want to ensure that yields increase or at least remain constant and so they are inclined to use large amounts of more types of fertilizers and pesticides to achieve the desired outcome. Farmers are also highly dependent on information provided by dealers who sell chemical fertilizers and pesticides and by agricultural technology extension workers. Dealers, motivated by a desire to increase sales, tend to exaggerate the amounts of fertilizers and pesticides that are needed, or in some cases, famers may use more than the recommended amount because they do not trust the dealers. Two other factors are climate uncertainty, and market uncertainty, for example, the overuse of fertilizers and pesticides on commercial crops that have been planted to generate more revenue.

Thus, the use of fertilizers and pesticides is influenced by the entities involved in the process of producing and selling these products as well as by the farmers who use them. The government must make this complexity more transparent and predict in advance the uncertainties that may arise, in order to manage the implementation of zero growth of chemical fertilizer and pesticide use.

5 Recommendations for promoting zero growth of chemical fertilizer

Zero growth of chemical fertilizer and pesticide use is a national development priority, the necessity and importance of which are both self-evident. Under current conditions, the achievement of zero growth is both practical and feasible but determination and confidence, as well as patience and perseverance, are indispensable. In dealing with the challenges to achieving zero growth of chemical fertilizer and pesticide use discussed above, we make the following recommendations.

First, conduct basic research. A full-range analysis of fertilizer and pesticide use by regions, crops and entities should be undertaken to make clear the impact of different factors such as production and sale have on fertilizer and pesticide use, and determine the main reasons for the overuse of fertilizers and pesticides under different conditions.

Second, improve the system for monitoring fertilizer and pesticide use and collecting statistical data. A set of credible, accurate baseline data on pesticide use over time is urgently needed. These data may be based on supply balance accounting or the monitoring of household behavior. It might be best to use the amounts of active ingredients of pesticides that impact the environment, health and the food quality and safety. A complete monitoring and statistical system would provide an important basis for evaluating the effectiveness of efforts to achieve zero growth of chemical fertilizer and pesticide use, and it can help prevent these efforts from becoming a statistical numbers game.

Third, make good use of demonstration projects to achieve the overall target. To put it in the most extreme terms, even if only one county or village achieves reductions in chemical fertilizer and pesticide use, while others remain at the status quo, zero growth of chemical fertilizer and pesticide is realized. Therefore, before research and management are in place, it is useful to experiment and set up demonstration areas to make progress in the short run.

Fourth, strengthen policies to reduce chemical fertilizer and pesticide use. Because agricultural non-point source

pollution that results from overuse of chemical fertilizers and pesticides is a public and social issue, as well as an agricultural issue, efforts to control this pollution are a type of public service. According to the principle of that the polluter pays and the theory of public economics, costs of agricultural non-point source pollution control cannot be borne by farmers alone, but should be paid for with public financing, and money from agricultural materials producers and farmers. To achieve zero growth of chemical fertilizer and pesticide use, the government should increase investment in agricultural pollution control facilities, integrate existing agricultural subsidy policies, and establish an agricultural subsidy system based on green ecology. Positive incentives and reward-based policies that encourage zero growth of fertilizer and pesticide use should be formulated. Although farmers make great contributions to society, they often have low incomes and limited purchasing power so policies should offer subsidies or financial incentives that encourage farmers to use fertilizer and pesticide saving technologies.

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中国的化肥、农药使用量零增长行动：目标、进展与挑战

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摘　要：实施化肥、农药零增长行动，迫在眉睫、刻不容缓，有利于防治农业面源污染，促进节本增效、节能减排，保障国家粮食安全、农产品质量安全和生态环境安全，实现农业可持续发展。本文基于化肥、农药零增长行动方案的主要内容，从政策创设、地方实践、技术支撑和已取得成效四方面分析了行动方案的可行性，探究了其存在的问题和面临的挑战，提出了推进化肥、农药零增长工作的建议，主要从做好基础研究工作、完善化肥农药使用监测和统计体系、做好试验示范、加强化肥农药减量的相关创设四方面进行。

关键词：化肥零增长；农药零增长；可行性