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Development Ideas of Meteorological Index Insurance for Crop Pests and Diseases

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Abstract Pests and diseases are one of the most important disasters facing crops in China. In order to solve the limitations of the existing pests and diseases insurance products in the aspects of fuzzy definition of insurance liability, different setting of claim points, and the design and operation of moral hazard and adverse selection, this paper puts forward a new idea of applying meteorological index insurance to the risk management of pests and diseases, which can be summarized as the following four parts: acquisition and collation of data, determination of the production reduction caused by the pests and diseases, the selection of meteorological factors of pests and disasters and the construction of index, and the setting of the pure rate of insurance. In the future, in the study of meteorological index insurance for crop pests and diseases, we should strengthen the cooperation among meteorology, plant conservation, insurance and agronomy, and other interdisciplinary fields, scientifically quantify the production reduction caused by pests and diseases, and pay attention to the information exchange among the government, the insurance company and the farmers.

Key words Pests and diseases insurance, Meteorological factors, Meteorological index of pests and diseases, Yield loss

1 Introduction

Crop pests and diseases are one of the most important agricultural biological disasters in China, with the characteristics of many types, great influence and frequent outbreaks. There are more than 1 000 common pests and diseases in China, and nearly 100 major pests and diseases can cause serious risks all year round. Each crop often suffers from 3 to 4 kinds of pests and diseases at the same time[1]. Since the 21st century, the occurrence area of crop pests and diseases in China, the types of outbreaks, and the losses of disasters have been increasing year by year. According to statistics, from 2006 to 2015, the annual occurrence area of crop diseases, pests and rodents in China ranged from 460 million to 508 million ha, with an average of 481 million ha, an increase of 20.8% over the average of 1996 to 2005, which is 3.55 times that of the whole country's cultivated land. Of the ten pests, such as rice planthopper, corn borer and wheat aphid, which threaten the food security of our country most seriously, the outbreak of any kind can cause more than 2 million t of grain loss, accounting for about 12% of the total grain output of this kind[2]. In a word, the area of crop pests and diseases in China continues to expand, and the agricultural production is facing the increasingly serious threat of pest and disease disasters.

In order to effectively reduce the loss of pests and diseases to farmers, China is actively taking measures to prevent and control pests and diseases, while constantly exploring the establishment of insurance system. Since exploring the establishment of policy-oriented agricultural insurance system was proposed in the Third Plenary Session of the 16th CPC Central Committee in 2003, agricultural insurance has entered a new stage of historical development. At the national level, the Central Document No. 1 of 2007 emphasized the need to strengthen the construction of the prediction, forecasting and early warning system for natural disasters and major animal and plant pests and diseases, so as to improve the ability of agricultural disaster prevention and mitigation. In 2008, the *Central Financial Measures on the Administration of Premium Subsidy for Insurance in Planting Industries* included the disease, pest and rodent in the types of insurance subsidized by finance. In 2015, the *Notice on Further Improving the Drafting of the Clause of Subsidized Agricultural Insurance Products from the Central Financial Premiums* included the disease, pest and rodent as the mandatory insurance liability. At the local level, various provinces gradually expand the scope of crop cultivation insurance and increase the liability for pests and diseases insurance. For example, in 2014, Jiangxi Province added eight kinds of pests and diseases insurance liability for rice planting insurance, such as rice blast, and sheath blight; in 2015, Jilin Province expanded the scope to cover all the pests and diseases on the basis of the original five kinds of pest and disease liability.

2 Existing problems and solutions for traditional pests and diseases insurance

In recent years, with the popularization of pests and diseases insurance products in Jilin Province, Shandong Province, Anhui Province and other places, the pests and diseases insurance has made great progress, and has become an important means to reduce the risk of crop pests and diseases and ensure food security. However, from the product design and product operation, there are still many problems in the traditional pest and diseaseinsurance.

2.1 Problems in traditional pest and disease insurance

2.1.1 Design of pest and disease insurance products. (i) The

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definition of insurance liability is vague. Although crop insurance liability has been expanding in recent years, an increasing number of areas or insurance companies no longer consider pests and diseases as an exclusion. However, most of the insurance clauses generally define the insurance liability for pests and diseases as "pests and diseases", "pests and rodents" or "epidemic pests, diseases and rodent". For example, the corresponding insurance provisions of Anhua Agricultural Insurance Co., Ltd. on the planting of corn, rice and other crops in Jilin Province are simply stipulated as "diseases, insects, and rodents". Only a handful of advanced agricultural insurance areas have set a relatively clear and accurate range of pests and diseases liability for the agricultural insurance policy with local characteristics. For example, the *Trichosanthes* planting insurance clauses of Guoyuan Agricultural Insurance Co., Ltd. implemented in Anhui Province clearly stipulate that the pest and disease insurance liability mainly covers *Aulacophora femoralis*, *Aphis gossypii*, tetranychid and other pests as well as anthracnose, wilt and other diseases. The ambiguous definition of pest and disease insurance liability greatly increases the work burden and operational risks of insurance companies.

(ii) The setting of claim point is inconsistent, and the threshold of payment is high. In order to protect the interests of the insured farmers, the China Insurance Regulatory Commission stipulates that insurance companies are prohibited from setting absolute deductible rates. Compared with the insurance liabilities of hailstorms, wind disaster, waterlogging disaster and so on, high claim points (relative franchise) is set on the pest and disease insurance liability in many areas. For example, the insurance provisions of Anhua Agricultural Insurance Co., Ltd. on the planting of corn, wheat and other crops in Shandong Province stipulate that when the loss rate of pest and disease insurance accident reaches 50% (not included), it should be paid, but for rainstorm, flood insurance liabilities, only 10% (included) claim points are set. Similarly, the corn and cotton insurance clauses implemented by PICC in Shandong Province stipulate that for losses caused by insurance accidents such as fire and hail, if the loss rate is more than 20% (included), the proportion of compensation to be paid shall be determined according to the proportion of reduction in production; for corn borer, cotton *Verticillium* wilt and other important epidemic pests and diseases, a reduction of production of 50% (included) is required before compensation can be made. Excessive compensation standards are not conducive to improving the sustainable production capacity of agriculture, and also greatly reduce the enthusiasm of farmers to insure.

(iii) Premium rates are consistent and risk differences are ignored. In agricultural production activities, the occurrence frequency and intensity of pests and diseases will be different because of the influence of different natural and man-made factors on the same crop in different regions or different crops in the same region. However, at present, the premium rate of crop pests and diseases in our country is mostly determined and implemented uniformly by provinces or municipalities, without considering the difference of the risk of pests and diseases among different underwriting regions. For example, the current rate standard in Shandong Province is unified as follows: the insured amount of wheat per hectare is 5 625 yuan, and the premium rate is 4%; the insured amount of maize per hectare is 5 250 yuan, and the premium rate is 4.29%; the insured amount of cotton is 7 500 yuan per hectare at a premium rate of 6%. The policy design of unified rate is easy to induce adverse selection behavior. Farmers in pest-prone areas buy it in succession because they can make profits by purchasing pest and disease insurance. Farmers in less pest-prone areas choose not to buy insurance, which leads to higher risk of indemnity payment by insurance companies.

(iv) Part of the insurance liability is still in the form of additional risks. Although the insurance types in many areas have expanded the liability of pest and disease insurance on the basis of the original main insurance liability, some areas still include the liability of disease and pest in the scope of additional risk liability. For example, Guoyuan Agricultural Insurance Co., Ltd. add pest and disease insurance liabilities on the basis of tobacco planting insurance, providing that only the policyholder who has insured tobacco leaf planting can insure against this additional risk. Consequently, the pest and disease insurance can only depend on the main insurance, and it can not be solely insured. This brings a lot of inconvenience to farmers whose crop yields are mainly threatened by pests and diseases, and also increases the burden of state financial subsidies.

(v) The guarantee level is low, and only cost is guaranteed. In the United States, Canada, Japan and other developed countries, the level of agricultural insurance security can reach 70% to 80% of the production income, which includes material cost, labor cost, land rental cost and part of the profits. However, in order to enlarge the coverage of agricultural insurance, the central government and all levels of government have given 80% high premium fiscal subsidy due to the different actual situation in our country. This also determines that the current agricultural insurance in China is mainly the production cost insurance, the insured amount can only include the direct costs of seeds, fertilizers, pesticides, utilities and machinery, and the insured amount can only reach 30% to 40% of the actual income of crop production. When the pests and diseases disaster occurs, the insurance company determines the amount of compensation in proportion according to the degree of crop loss and the stage of growth in which it is located. The lower level of insurance security, to a certain extent, limits the agricultural insurance loss compensation function, and also affects the enthusiasm of farmers to apply for insurance.

2.1.2 Operation of pest and disease insurance products. (i) The problems of adverse selection and moral hazard are ubiquitous. The premium rate for traditional pest and disease insurance does not take into account differences in the risk of pests and diseases hazards between different regions. This urges farmers to give up insuring low-risk varieties or plots that are not prone to pests and diseases, and instead choose high-risk varieties and plots to

be insured. The information asymmetry between the insurer and the insured will inevitably lead to the problem of adverse selection. In addition, compared with meteorological disasters, the degree of damage caused by pests and diseases will be greatly affected by the behavior of farmers' self-rescue. If farmers take the way of waiting for claims after insurance, neglecting control and even neglecting the occurrence and development of pests and diseases, it will aggravate the occurrence of moral hazard.

(ii) It is difficult to determine the loss and the efficiency of claim settlement is low. The characteristics of pests and diseases make them different from the common meteorological disasters in that they are easy to be explored. It is very difficult to define the extent of crop damage and the extent of losses because of the inconsistency of the outbreak time and the uneven degree of damage. When large area of pests and diseases disaster is encountered, the capacity of post-disaster investigation and loss determination is limited, and there are many problems, such as large workload, flawed investigation and loss determination, limited representativeness and accuracy, and so on. In addition, the complex investigation and loss determination procedures make claims inefficient, and the insurance claims can not act on the post-disaster reconstruction of pests and diseases in time, which greatly reduces the sustainable production capacity of agriculture and the enthusiasm of farmers for insurance.

(iii) The management cost is high and the management difficulty is big. In order to prevent moral hazard and adverse selection caused by information asymmetry, the underwriting company must establish the corresponding supervision and information management system of agricultural production risk. In view of the fact that traditional pest and disease insurance policies pay out on a household-by-household basis. Therefore, it is necessary to investigate and determine the losses of the insured crops in the field, or to establish corresponding model fields as the basis of compensation to determine the actual losses caused by different crops in the event of pests and diseases disaster. This will inevitably lead to a large number of manpower and material resources consumed by the insurer, and the cost of operation and management is stubbornly high.

2.2 Solutions to traditional pest and disease insurance problems

2.2.1 Meteorological index insurance is an effective scheme to solve the problem of pest and disease insurance. With the disadvantages of traditional pest and disease insurance gradually exposed, innovative pest and disease insurance products have become the inevitable measures of agricultural pests and diseases disaster risk management. As a new agricultural risk management tool, meteorological index insurance can alleviate the inherent problems of traditional pest and disease insurance to a great extent. First of all, the meteorological index insurance for pests and diseases is not based on the actual crop yield as the standard of insurance payment, but on whether to reach the agreed trigger value of meteorological index, which is not affected by the subjective behavior of farmers and ensures the enthusiasm of farmers in the prevention and control of crop pests and diseases, and effectively evades the moral hazard. Moreover, meteorological information is public information, and the insurer and the insurer will not benefit from the asymmetric information, which reduces the occurrence of adverse selection problem. Secondly, insurance companies do not have to go to the field to conduct on-site surveys. The insurance company only needs to base its claim on the difference between the actual meteorological data measured by the meteorological department and the underwriting index. The loss checking rate is increased by nearly three times, and the compensation is more timely, which ensures that the insurer can make use of the indemnity to remedy the disaster and reproduce at the same time while reducing the operating cost of the insurance company. In addition, meteorological index insurance uses objective and independent meteorological data to manage the risk of pests and diseases. It overcomes the drawback that traditional pest and disease reinsurance product index is difficult to inspect, makes the insurance contract with standardized design have natural reinsurance advantage, and it is easy to bind with other financial products to realize many kinds of functions. It can help to spread the risk of agricultural system on a larger scale.

2.2.2 Feasibility analysis of meteorological index insurance for pests and diseases. (i) Typical meteorological characteristics of pests and diseases. In addition to its own physiological characteristics, crop pests and diseases are also affected by crop varieties, cultivation systems, fertilization and irrigation levels, especially by meteorological conditions. Under other conditions, meteorological conditions are often the critical factors that determine the occurrence and prevalence of pests and diseases, the occurrence, development and prevalence of almost all large-scale epidemic, unexpected and destructive pests and diseases are closely related to meteorological conditions[3]. Firstly, temperature is an important factor affecting the growth and development of pests and diseases. Chen Huailiang, et al. point out the incubation period of crop pests and diseases is generally shortened with the increase of temperature in the range of onset temperature, and the degree of onset is aggravated with the increase of temperature[4]. Secondly, as the dominant factor of crop diseases, rainfall-humidity condition can not only induce the propagation and diffusion of pathogens, but also create the way for their infection and transmission. The studies of Zhang Xuhui *et al.* show that wheat scab is a typical "meteorological" disease, and in the heading and flowering period, if there is continuous rain or continuous fog or relative humidity of more than 85%, it is easy to cause scab to occur in a large area[5]. In addition, wind not only affects the release and transmission of fungal spores, but also creates wounds and creates conditions for pathogen infection. (ii) The meteorological index insurance research accumulates rich experience for the product design. Since 2005, domestic scholars have begun the exploration of meteorological index insurance. Up to 2016, the agrometeorological index insurance gradually developed from the exploratory theo-

retical research stage to the mature and detailed product design stage. The design object covers corn, wheat, rice and other staple grain crops as well as fruits, vegetables and other cash crops, the insurance products tend to unify the design ideas, and the research methods are constantly being optimized. Meteorological index insurance for pests and diseases and traditional meteorological index insurance have consistency in principle, relying on the existing research results of meteorological index insurance, the research progress of meteorological index insurance for pests and diseases will be greatly accelerated. (iii) Meteorological technology developments provide the basis for the access to data. China has more than 2 200 provincial weather stations and 700 national weather stations, which can obtain high quality historical weather data of 40 to 50 years[6]. In addition, with the application of remote sensing (RS) and geographic information system (GIS) in agrometeorological operation, the access to data is more convenient. In particular, the application of satellite remote sensing technology to monitor vegetation cover and further predict crop yields greatly reduces data costs, improves data accuracy, reduces basis risk, and provides convenient conditions for designing more accurate meteorological index products.

3 Future development ideas of meteorological index insurance for pests and diseases

3.1 Design ideas of meteorological index insurance for pests and diseases Based on the existing research ideas of meteorological index insurance, the design of meteorological index insurance for pests and diseases can be divided into four steps, namely, data acquisition and sorting, determination of production reduction caused by pests and diseases, selection of meteorological factors for pest and disease disasters and index construction, and setting of pure premium rate.

3.1.1 Data acquisition and sorting. The product design and operation of index insurance is highly dependent on the data, and the accuracy of the data directly affects the quality level of the product. First of all, the data should have enough time to meet the modeling requirements, the time series data should be not less than 30 years, so that the t test can accurately reflect the distribution of the variables. Secondly, because of the different meteorological conditions faced by crops in different regions, the number of pests and diseases and the number of pathogens are different, the probability of occurrence of pests and diseases, the types and degrees of prevalence of pests and diseases will be also different. Therefore, when selecting data, we should select the data within 20 km of the weather station as far as possible. In addition, data sorting is an important means to improve the accuracy of data. Because of the remote location or limited technology, the data acquisition is incomplete in some areas. We can use smoothing method or MATLAB and other measurement softwares for smoothing and supplementing and curve fitting to solve the problem of interpolation, so that we can effectively deal with the missing data. For the problem of inconsistency of data standards, the weighted approximation method in Fuzzy mathematics can be used to normalize the process[7]. If change of varieties and change of tillage system are found in time series data, it must be analyzed and classified before it can be used[8].

3.1.2 Determination of production reduction caused by pests and diseases. Based on the existing research results of meteorological index insurance, crop yields (Y) are divided into trend yields (Y_t), yield reduction by pests and diseases (Y_{pd}), nutrient yields (Y_n) and random yields (ε), namely $Y = Y_t + Y_{pd} + Y_n + \varepsilon$. The increase of crop yield caused by the enhancement of productivity and science and technology often shows a trend change, so this kind of yield is defined as the trend yield Y_t; the decrease of crop yield caused by the disaster of diseases and pests arising from meteorological factors is called the reduction of crop yield caused by pests and diseases, which is expressed in Y_{pd}. Nutrient yield refers to the change of yield caused by the change of soil fertility and crop management level, which is expressed in Y_n. Random yield ε indicates fluctuations in crop yields due to other factors. Because of the stability of soil and management in different years, Y_n can be ignored in most of the studies. Specifically, we can verify the correlation coefficients between the two years of $(Y - Y_t)/Y_t \times 100\%$ sequence[9]. Thus, the formula for actual production can be changed to: $Y = Y_t + Y_{pd} + \varepsilon$. Based on the statistical fitting of the trend yield Y_t by moving average method, regression analysis method, HP filtering analysis method and autoregressive integral moving average model (ARIMA model), the detrend yield Y_w was obtained by de-trend treatment with $Y_w = Y - Y_t$, and then the reduction of yield Y_{pd} caused by pests and diseases is separated .

3.1.3 Selection of meteorological factors for pest and disease disasters and index construction. Firstly, whether meteorological factors are suitable for selection, is directly related to the accuracy of the model fitting. Therefore, on the basis of in-depth analysis of the meteorological conditions required for the growth and development period of the pests and diseases and the degree of occurrence of the pests and diseases, we use correlation analysis, coupled with principal factor selection and path analysis, select the meteorological factors with high degree of correlation with the occurrence and development of pests and diseases[8], such as ten-day precipitation and average daily air temperature, and set the weights of factors, to initially establish the pest suitability meteorological index or disease promotion index. Secondly, by comparing the historical data of epidemic degree of pests and diseases (such as diseased panicle rate, diseased plant rate, disease index, pest density, area of occurrence of pests and diseases) with meteorological index setting value, the initial index value is revised, and the critical value of meteorological index under different epidemic levels of pests and diseases is obtained. Finally, based on the analysis of the correlation between the epidemic degree of pests and diseases, and crop losses, the corresponding relationship between pest and disease meteorological index and crop losses is established, and then the compensation value of pest and

disease meteorological index is determined.

3.1.4 Setting of pure premium rate. Generally speaking, the premium rate refers to the gross premium rate, which includes the net insurance rate and the surcharge rate, while the calculation of the net insurance rate is at the core of the agricultural premium rate. The calculation methods of net insurance rate are mainly divided into two categories: experience rating method and unit yield distribution model method. The experience rating method is to use the average value of the historical loss rate as the predicted loss rate, the accuracy of the rate is high, and it is suitable for the long-term continuous, complete and accurate situation of the historical data. The unit yield distribution model method sets the rate by determining the probability density function of crop yield fluctuation. It has strong mathematical reasoning and is suitable for the low quality of historical data. The unit yield distribution model method is divided into parametric method and non-parametric method. Parametric method mainly uses normal distribution, logarithmic normal distribution, Gamma distribution and Weibull distribution to estimate the parameters, while non-parametric method mainly chooses kernel density estimation method[10]. Restricted by the per-unit yield data of our country, the study on the meteorological index insurance for diseases and pests is to adopt the unit yield distribution model method, then the premium rate is the expected loss rate, namely the sum of the product of the yield reduction rate of diseases and pests and the probability of occurrence of the meteorological index of diseases and pests. It is expressed in the following formula:

$$R = \frac{E\ (loss)}{\lambda\mu} E\ (loss) = \sum_{i=1}^{n} X_i \times P_i$$

where R is the premium rate; λ is the guarantee ratio; μ is the expected yield; $loss$ is the yield loss; $E(loss)$ is the expectation of the yield loss; X_i is the crop yield reduction rate at all levels; P_i is the probability of the yield reduction rate at all levels.

3.2 Problems to be noticed in the design meteorological index insurance for pests and diseases Although the conditions of developing the meteorological index insurance for diseases and pests have been very mature and complete, the following problems should be paid attention to in product design and application.

3.2.1 Selection of the insured object. The selection of the insured object should pay special attention to the occurrence of pests and diseases of crops. Firstly, not all pests and diseases will cause significant losses to crops. Of more than 1 000 pests and diseases common in China, only about 10% of sudden, epidemic and devastating pests and diseases will cause serious risks, such as maize crude dwarf disease(MRDV). In general, production will be reduced by 20% to 30% in the epidemic year, and more than 50% in severe cases, or even there is crop failure[11]. Secondly, the disaster mechanism of pests and diseases can be summed up as follows: meteorological factor-pest and disease disasters-crop reduction-farmer loss. It is not difficult to see that the causal relationship between meteorological factors and pests and diseases is the basis of the design of insurance products. Therefore, when choosing the insured object, we should not only ensure the contribution rate of pest and disease disaster to crop production reduction, but also ensure the high correlation between pest and disease disaster and meteorological conditions.

3.2.2 Calculation of crop losses. Compared with the meteorological disasters, the damage caused by pests and diseases has certain complexity. The meteorological factors that induce pests and diseases on the one hand will also affect the crop yield synchronously as direct meteorological disasters. On the other hand, different from the pure yield loss characteristics of meteorological disasters, the types of losses caused by crop pests and diseases often vary according to different types of pests and diseases. The loss types include not only the pure loss of yield, but also the decrease of crop quality, for example, the yield reduction is not serious under the mild wheat scab conditions, and the toxin produced by pathogen affects the quality of wheat, which is the main cause of the loss to farmers. In addition, the management of pests and diseases will directly affect the probability of occurrence of pests and pests and the degree of damage. These conditions increase the difficulty of obtaining the damage rate caused by pests and diseases. How to determine the contribution value of pests and diseases in crop loss will be a technical difficulty in future research. At present, we can use the method of field experiment in natural science for reference, and establish control group to measure the crop loss under the epidemic condition of pests and diseases.

3.2.3 Meteorological excitation and suppression. Appropriate meteorological conditions will stimulate the occurrence and development of pests and diseases, and when the meteorological conditions exceed the adaptability of pests and diseases, it will have a inhibitory effect. For example, the suitable temperature of cotton *Verticillium* wilt is 22 – 28℃, and it develops slowly when it is higher than 30℃, and there is masked symptom when it is more than 35℃ (masked symptom refers to a temporary phenomenon that the original symptom gradually decreases or even disappears due to the change of environmental conditions). When the relative humidity is above 90% and the temperature is 27°C, the hatching and survival rate of the larvae is over 97%, but excessive precipitation will seriously inhibit the pupation and emergence of the larvae. Therefore, in the process of product design, we should fully understand the physiological indexes of various life stages of pests and diseases, determine the correct meteorological indexes of pests and diseases, and scientifically and reasonably apply the stimulating and inhibiting effects of meteorological factors to the products.

3.2.4 Cross-cutting issues between plant growth cycle and pest and disease life cycle. The prerequisite for crop yield reduction caused by pests and diseases is the overlap of the stage of plant pests and diseases with the stage of crop susceptibility. For example, the larvae of the first generation of corn borer mainly harm the spring corn and cotton, the second generation of larvae harms the heart leaf and spring corn panicle in the middle and late July, and the third generation of larvae reach the peak in the middle and late August, harming the ears and stems of summer corn. In addition, due to the difference of interannual sowing time and meteorological

conditions, the growth cycle of crops and the life cycle of pests and diseases will change accordingly. Aiming at this problem, the meteorological index insurance products of pests and diseases should adjust the time period of the index products, and select the suitable insurance period on the basis of interdisciplinary cooperation, to ensure the overlap between the growth period of crops and the damage period of pests and diseases.

3.2.5 Other factors affecting the occurrence of pests and diseases. The design of meteorological index insurance for pests and diseases should also consider the influence of other related factors on pests and diseases. It includes direct factors and indirect factors, among which, the direct factors include crop varieties, their own disease resistance, the number of insects or pathogens and so on. The indirect factors include meteorological factors, the influence of natural enemies' growth and reproduction, low temperature, rain, drought and gale and other unfavorable meteorological conditions, which will obviously reduce the resistance of crops to diseases and pests. These influence factors will affect the occurrence and development of pests and diseases.

4 Conclusions and discussions

The meteorological index insurance for pests and diseases creatively integrates the correlation between meteorological factors and pests and diseases into meteorological index insurance, and opens up a new field of meteorological index insurance research. In practice, there is still a long way to go from product design to popularization of meteorological index insurance for diseases and pests because of the physiological complexity of diseases and pests and the difficulty of calculating the data of output reduction caused by diseases and pests. However, the unique technical advantages of the meteorological index insurance for pests and diseases can help to effectively solve the bottleneck problem of the traditional pest and disease insurance, enhance the ability to resist the pests and diseases, and ensure the national food security to a greater extent. All of these determine that the meteorological index insurance for pests and diseases will inevitably have broad prospects for development.

In the future, in order to solve the limitations of the design and operation in the research of meteorological index insurance for pests and diseases, and apply it to the risk management of pests and diseases, we should pay more attention to the following problems: first of all, it is necessary to strengthen the cooperation among meteorology, plant protection, insurance and agriculture and other interdisciplinary fields, profoundly study the meteorological pathogenic conditions and harm mechanism of pests and diseases, and determine the correct meteorological index for pests and diseases on the basis of accurately defining the physiological indexes of pests and diseases at each life stage. Secondly, there is a need to quantify the output reduction caused by pests and diseases. There are many types of pests and diseases and they can be prevented, making the quantification of the production reduction caused by pests and diseases become the top priority of this study. In view of the limitations of high cost and long duration of traditional field trials, it is necessary to continuously innovate the collection methods of crop data, and adopt new methods and techniques to obtain efficient and accurate yield and loss information. Finally, we should pay attention to the information exchange among the government, insurance companies and farmers, deeply understand the management problems of insurance companies and farmers' demand for pests and diseases avoidance, constantly innovate insurance products, and better achieve the supply and demand balance of insurance.

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