Correlation Analysis between Well-cellar Early Transplanting of Robust Seedlings and Diseases in Shiyan Tobacco-growing Area

Dingjun WANG[1], Aihua LI[1], Liguang CHAI[1], Dan LIU[1], Yixia LIU[2], Minggang LI[1], Jingyang PENG[1]

1. Hubei Tobacco Company Shiya Company, Shiyan 442012, China; 2. Shiyan Meteorological Bureau, Shiyan 442012, China

Abstract [**Objectives**] The paper was to investigate the relationship between the well-cellar early transplanting of robust seedlings and the prevalence of diseases in the Shiyan tobacco-growing area. [**Methods**] The relationship between disease occurrence and meteorological factors during the field growth period was examined by analyzing the prevalence of flue-cured tobacco virus diseases, brown spot, and total disease in the Shiyan tobacco-growing area before (2013 – 2017) and after (2018 – 2022) the well-cellar early transplanting of robust tobacco seedlings. [**Results**] The implementation of a well-cellar early transplanting technique of robust seedlings resulted in a reduction in the average incidence of tobacco virus disease, brown spot, and total disease by 0.83%, 8.85%, and 7.91%, respectively, in comparison to the incidence observed prior to early transplanting. These findings suggest that early transplanting can significantly reduce the incidence of flue-cured tobacco diseases. Prior to the well-cellar early transplanting of robust tobacco seedlings, there was a significant (including highly significant) positive correlation between the incidence of brown spot and total disease and precipitation in August and September. The incidence of brown spot and total disease in tobacco plants was found to be significantly positively correlated with May precipitation and significantly negatively correlated with May sunshine hours following the well-cellar early transplanting of robust seedlings. The advancement of the transplanting period by 20 d resulted in a reduction in the growing period of tobacco plants in the field under autumn rains (late August to November) in western China. This effectively circumvented the suitable conditions for disease occurrence and can reduce the incidence of disease. [**Conclusions**] This study offers a framework for enhancing the quality and efficiency of flue-cured tobacco production in the northwest tobacco-growing area of Hubei.

Key words Tobacco disease; Well-cellar early transplanting of robust seedlings; Meteorological factor; Correlation analysis; Shiyan tobacco-growing area

1 Introduction

The prevalence of tobacco disease represents a significant challenge to the potential benefits of tobacco planting. The objective of flue-cured tobacco production is the harvesting of leaves. Leaf damage reduces the value of the leaves and may result in no harvest if the disease is severe. Leaf spot diseases have a significant impact on tobacco production. The prevalence of flue-cured tobacco disease is found to be significantly influenced by meteorological conditions during the growth period. A number of studies have demonstrated that the appropriate adjustment of transplanting time can alter the climatic conditions of flue-cured tobacco at different growth stages[1]. To a certain extent, this attenuates the occurrence of pests and diseases and reduces the impact of diseases on tobacco yield and quality.

The majority of studies related to flue-cured tobacco diseases are focused on drug control, pathogen detection, and other aspects[2–5]. There is a paucity of studies on reducing disease losses by changing the growth period and cultivation methods. Kong Yinliang[6] demonstrated that the use of seedling transplantation under a membrane in tobacco can effectively circumvent the peak of aphid migration and reduce the probability of virus transmission. Feng Yuan *et al.*[7] have observed that medium- and short-wave ultraviolet radiation can inhibit the germination of pathogen spores and reduce the incidence of plant diseases. Conversely, long-wave ultraviolet radiation has been found to have an inducing effect on the germination of pathogen spores, which can consequently lead to an increase in the incidence of plant diseases. None of the aforementioned studies conducted a comprehensive analysis of the relationship between climatic conditions and disease occurrence during the growth period.

A team of researchers in Guizhou Province developed a novel seedling transplanting technology, which they termed the "well-cellar" method. In light of this, numerous scholars have commenced research into the well-cellar seedling transplantation technology of tobacco. Liu Dan *et al.*[8] analyzed meteorological data from the tobacco-growing area of Northwest Hubei and proposed that the optimal transplanting period for well-cellar robust seedlings in the high-quality tobacco-growing area of Northwest Hubei is around April 20. As a representative tobacco area in Northwest Hubei, the Shiyan tobacco-growing area has implemented a comprehensive program to promote the well-cellar early transplanting of robust seedlings since 2018. This study took the Shiyan tobacco-growing area as an example and analyzed the meteorological data and the occurrence of major diseases in the area from 2013 to 2022. The study also explored the dominant meteorological factors affecting the occurrence of diseases in the area with the aim of providing references for the enhancement of the quality and efficiency of the production of flue-cured tobacco in the tobacco-growing area of Northwest Hubei.

Received: March 10, 2024 Accepted: July 8, 2024
Supported by Research Program on Prevention and Control Technology of Tobacco Potato Virus Y Disease (SYK2023-06).
E-mail: 191787839@qq.com

2 Materials and methods

2.1 Disease and meteorological data

2.1.1 Sources of disease data. The incidences of tobacco virus diseases (tobacco mosaic disease and tobacco potato virus Y disease), brown spot (*Alternaria alternate*), and total disease in Shiyan City from 2013 to 2022 were obtained from the Shiyan Tobacco Monopoly Bureau.

2.1.2 Sources of meteorological data. The meteorological data of Shiyan City from 2013 to 2022 was obtained from the Shiyan Meteorological Bureau. The meteorological data and the planting season of flue-cured tobacco in Shiyan City were employed to select the precipitation, sunshine hours, and mean temperature during the field growth period of flue-cured tobacco (April – September) for analysis.

2.2 Data processing The IBM SPSS Statistics 20 software was employed for the purpose of conducting a correlation analysis.

3 Results and analysis

3.1 Changes in tobacco disease incidence before and after the well-cellar early transplanting of robust seedlings As illustrated in Fig. 1, the average incidence of tobacco virus disease, brown spot, and total disease were 3.18%, 18.48%, and 20.97%, respectively, prior to the well-cellar early transplanting of robust seedlings (2013 – 2017). Following the well-cellar early transplanting of robust seedlings (2018 – 2022), these values decreased to 2.35%, 9.63%, and 13.06%, respectively. It can be observed that the comprehensive promotion of the well-cellar early transplanting technique of robust seedlings has led to a notable reduction in the incidence of flue-cured tobacco diseases in the Shiyan tobacco-growing region. This is consistent with the findings of Kong Yinliang[6] and Tanwen[9].

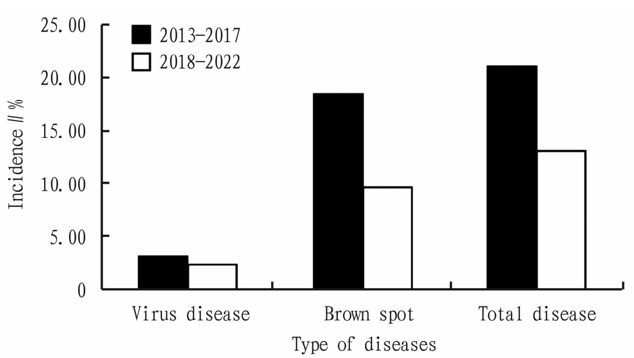

Fig. 1 Occurrence of tobacco diseases at different transplanting stages

3.1.1 Reasons for lower incidence of virus diseases. The tobacco virus disease can manifest throughout the entire period from seedbed to field planting. The 20 d period following transplanting to the bud stage represents the peak of the disease's onset, and the disease continues to spread in the field even after topping. The incidence condition of the disease is contingent upon a number of factors, including variety resistance, climatic conditions, soil factors, cultivation management, host plants, and the presence of aphids. The optimal temperature for the onset of tobacco common mosaic disease is 28 – 30 ℃. Temperatures above 38 ℃ or below 10 ℃ result in a lower incidence of the disease. Furthermore, climate droughts following transplanting, temperature fluctuations before and after the peak growth period, cold rain or hot winds, and other drastic changes in weather conditions have been observed to increase the probability of disease occurrence[10].

The process of well-cellar seedling transplantation involves the tobacco leaves wrapping the substrate and transplanting immediately after the root system has not extended out of the seedling trays in sufficient numbers. Following the transplantation of tobacco roots, they can be extended into the well cellar and exposed to fertilizer within 1 – 2 d, without the need for a seedling return process. This technology ensures the supply of essential nutrients, enhances the immunity of tobacco seedlings, and enables the non-destructive root transplantation process. The ground temperature of seedling transplanting at a depth of 15 cm in a well-cellar environment is 14.5 – 16.5 ℃. It has been demonstrated that the mulching effect can increase the ground temperature by 2 – 8 ℃. The temperature after transplanting is typically between 15.5 and 24.5 ℃, with optimal conditions for tobacco leaf growth, development, and disease resistance occurring at the midpoint of this range. In the Shiyan tobacco-growing area, temperature fluctuations during the months of May and June are minimal, creating a conducive environment for tobacco leaf growth. The practice of early transplantation of robust seedlings has been shown to promote robust root development in tobacco plants, enhancing their resilience to disease. Furthermore, early transplantation can circumvent the migration of aphids in agricultural production at the early growth stage, effectively reducing the incidence of virus diseases.

3.1.2 Reasons for lower incidence of brown spot. Tobacco brown spot is a disease that affects tobacco plants worldwide and is particularly prevalent in mature plants. The disease manifests following the topping of the tobacco plant and the subsequent maturation of the leaves. In suitable conditions, the disease will progress and worsen over time. The occurrence and spread of brown spot are closely related to the disease resistance of tobacco, the growth period of tobacco, the condition of relative humidity higher than normal temperature and humidity conditions, field density, and other factors. The occurrence of brown spot is contingent upon the relative humidity of the atmosphere over a 10 d period. When the average relative humidity exceeds 68.1%, brown spot will occur. Furthermore, an increase of 1% in relative humidity will result in a 0.366 6 increase in the disease index of brown spot. The temperature primarily influences the early and late onset of the disease, as well as the number of late re-infections. The disease can occur when the mean daily temperature is above 20 ℃, with the most suitable temperature range being 23.7 – 28.5 ℃[10]. The statistical results of temperature and humidity during the maturation of tobacco in the Shiyan tobacco-growing area between 2018 and 2022 are presented in Table 1.

As illustrated in Table 1, with the exception of the altitude range of 1 000 – 1 200 m, the temperature and relative humidity at each altitude within the Shiyan tobacco-growing area in August and September were all within the incidence interval for brown spot. The advancement of the transplanting period by 20 d resulted in a reduction in the growth time of tobacco plants in the field under the autumn rain in September in western China. This can facilitate the safe harvesting of tobacco leaves. By modifying the duration of the growth period, the onset of tobacco brown spot was accelerated and the prevalence of tobacco red spot disease was diminished.

Table 1 Temperature and humidity during tobacco maturation in the Shiyan tobacco-growing area from 2018 to 2022

Mature period	Below altitude 600 m		Altitude 600 – 800 m		Altitude 800 – 1 000 m		Altitude 1 000 – 1 200 m	
	Temperature//℃	Relative humidity//%	Temperature//℃	Relative humidity//%	Temperature//℃	Relative humidity//%	Temperature//℃	Relative humidity//%
Early August	22.38	81.90	21.19	84.06	20.58	85.18	19.41	87.58
Middle August	22.23	81.86	21.04	84.00	20.43	85.12	19.29	87.57
Late August	22.08	81.90	20.90	84.00	20.30	85.13	19.18	87.55
Early September	22.00	82.02	20.83	84.08	20.23	85.21	19.13	87.56
Middle September	22.01	82.27	20.85	84.25	20.25	85.37	19.15	87.54
Late September	22.15	81.96	20.98	83.97	20.37	85.11	19.27	87.24
Mean of August	22.23	81.89	21.04	84.02	20.44	85.14	19.29	87.57
Mean of September	22.06	82.08	20.89	84.10	20.28	85.23	19.18	87.45

3.2 Correlation between disease incidence and precipitation

3.2.1 Correlation between disease incidence and precipitation prior to early transplanting. As demonstrated in Table 2, prior to the well-cellar early transplanting of robust seedlings from 2013 to 2017, the incidence of tobacco brown spot and total disease exhibited a significant and positive correlation with precipitation in August and September. Additionally, the incidence of brown spot demonstrated a positive correlation with precipitation from April to September, reaching a significant level.

Table 2 Correlation between incidence of brown spot and precipitation from 2013 to 2017

Month	Incidence of virus disease	Incidence of brown spot	Incidence of total disease
April to September	–0.746	0.957*	0.873
April	–0.133	0.256	0.338
May	–0.237	–0.528	–0.700
June	–0.344	–0.213	–0.443
July	0.226	–0.021	–0.052
August	–0.653	0.970**	0.964**
September	–0.437	0.939*	0.967**

NOTE "*" indicates a significant correlation ($P<0.05$), while "**" indicates a highly significant correlation ($P<0.01$). The same below.

3.2.2 Correlation between disease incidence and precipitation following early transplanting. As demonstrated in Table 3, following the well-cellar early transplanting of robust seedlings in 2018 – 2022, the incidence of tobacco brown spot and total disease demonstrated a positive correlation with precipitation levels in May, reaching a highly significant level. *A. alternate* overwintered on the remains of the residual plant as mycelium and began to form new conidia under conditions of mean temperature (7 – 8 ℃) and relative humidity (50%) in early spring. As the temperature rose, the number of spores produced increased, and the surrounding tobacco plants were infected by wind and rain, becoming the source of the initial infection[10].

Table 3 Correlation coefficient between tobacco disease incidence and precipitation from 2018 to 2022

Month	Incidence of virus disease	Incidence of brown spot	Incidence of total disease
April to September	–0.325	0.032	0.018
April	–0.854	–0.075	–0.223
May	–0.268	0.997**	0.972**
June	0.876	–0.518	–0.361
July	–0.091	–0.197	–0.172
August	–0.357	–0.170	–0.196
September	–0.615	0.098	0.024

Consequently, from the moment the tobacco plants are transplanted, the tobacco leaves are persistently exposed to the infestation of *A. alternata* conidia. The study by Ma Guilong *et al.*[11] demonstrated that the lesions of tobacco brown spot were unable to produce spores when continuously moistened for less than 5 h. Furthermore, the relative spore production rate of the lesions was found to be positively correlated with the duration of continuous moistening when the lesions were continuously moistened for more than 7 h. The success of the infection of *A. alternata* is contingent upon the duration of the water film on the leaf surface, particularly under specific temperature conditions[12]. Precipitation has been demonstrated to markedly enhance the likelihood of a water film forming on the leaf surface, thereby facilitating the infection of conidia and the subsequent propagation of bacteria. Consequently, the precipitation levels observed in May can exert a considerable influence on the incidence of brown spot in the field.

3.3 Correlation between disease incidence and sunshine hours

3.3.1 Correlation between disease incidence and sunshine hours prior to early transplanting. As demonstrated in Table 4, the total disease incidence exhibited a negative correlation with the number of sunshine hours in August at a statistically significant level prior to the well-cellar early transplanting of robust tobacco seedlings from 2013 to 2017. The primary rationale for this phenomenon is that an increase in the quantity of sunshine hours is correlated with a reduction in precipitation and a diminished probability of leaf water film formation. This is not conducive to conidial infestation and reproduction.

Table 4 Correlation coefficient between disease incidence and sunshine hours from 2013 to 2017

Month	Incidence of virus disease	Incidence of brown spot	Incidence of total disease
April to September	0.283	-0.624	-0.694
April	-0.061	-0.486	-0.645
May	-0.355	0.004	-0.213
June	0.338	-0.043	0.039
July	-0.173	0.465	0.609
August	0.258	-0.792	-0.907*
September	0.533	-0.825	-0.796

3.3.2 Correlation between disease incidence and sunshine hours following early transplanting. As illustrated in Table 5, the total disease incidence exhibited a negative correlation with the number of sunshine hours in May at a statistically significant level following the well-cellar early transplanting of robust tobacco seedlings in 2018 - 2022. The primary rationale for this outcome was the increase in sunshine hours in May. This corresponded to the fact that less rain during the rooting period was conducive to the root development of tobacco plants. The strong root system may provide support for the enhancement of tobacco plants' resistance in the later stage. Concomitantly, the increase in sunshine duration was accompanied by a decrease in precipitation, which was unfavorable for the infection of conidia and the propagation of bacteria in the subsequent stages. The incidence of total disease was found to be negatively correlated with the number of sunshine hours in September, reaching a significant level.

Table 5 Correlation coefficient between disease incidence and sunshine hours from 2018 to 2022

Month	Incidence of virus disease	Incidence of brown spot	Incidence of total disease
April to September	-0.267	-0.280	-0.379
April	0.339	0.112	0.134
May	0.077	-0.881*	-0.888*
June	-0.655	0.140	-0.014
July	-0.805	-0.069	-0.247
August	0.527	0.305	0.377
September	-0.278	-0.836	-0.898*

3.4 Correlation between disease incidence and mean temperature In the study conducted by Gao Yuliang *et al.* [13], it has been determined that when the mean daily temperature exceeds 16 ℃, the conditions for the occurrence of tobacco virus disease are met. The occurrence of severe virus disease is found to be associated with high mean daily temperatures, a high number of days with more than 6 h of sunshine, and low precipitation in the 10 d prior to the onset of the disease. From 2013 to 2022, the mean temperature from April to September in the Shiyan tobacco-growing region was 19.37 ℃. Furthermore, the mean monthly temperature during the period from the onset to the peak incidence of virus diseases (May to July) was above 17.1 ℃, which met the conditions for virus disease incidence. As demonstrated in Tables 6 and 7, there was no discernible correlation between the incidence of virus disease and the mean temperature in April - July before and after the well-cellar early transplanting of robust tobacco seedlings. This suggests that mean temperature is not a limiting meteorological factor for the occurrence of virus disease in the Shiyan tobacco-growing area.

Table 6 Correlation coefficient between tobacco disease incidence and daily mean temperature from 2013 to 2017 (prior to early transplanting)

Month	Incidence of virus disease	Incidence of brown spot	Incidence of total disease
April	0.800	-0.303	-0.195
May	-0.621	0.201	-0.035
June	0.474	-0.394	-0.307
July	0.146	0.118	0.141

Table 7 Correlation coefficient between tobacco disease incidence and daily mean temperature from 2018 to 2022 (following early transplanting)

Month	Incidence of virus disease	Incidence of brown spot	Incidence of total disease
April	-0.144	0.455	0.399
May	0.296	-0.004	0.087
June	-0.451	-0.247	-0.366
July	-0.796	0.163	-0.012

4 Conclusions

This study aims to identify the dominant meteorological factors affecting the occurrence of flue-cured tobacco diseases in the Shiyan tobacco-growing area. The results of the study are presented in the following manner.

(i) Prior to the early transplanting of tobacco seedlings between 2013 and 2017, there was a significant positive correlation (including a highly significant correlation) between the incidence of tobacco brown spot and precipitation in the months of April to September. Following the early transplanting of tobacco seedlings between 2018 and 2022, there was a highly significant positive correlation between the incidence of tobacco brown spot and precipitation in the month of May, and a significant negative correlation between the incidence of tobacco brown spot and the duration of sunshine in the month of May.

(ii) Prior to the well-cellar early transplanting of tobacco seedlings, the incidence of total diseases exhibited a positive correlation with precipitation in August and September and a negative correlation with the duration of sunshine in August. Conversely, following the well-cellar early transplanting of seedlings, the incidence of total disease demonstrated a positive correlation with precipitation in May and a negative correlation with the duration of sunshine in May and September.

(iii) The advancement of the transplanting period by 20 d effectively shortened the growth time of tobacco plants in the field under the autumn rain in September in western China. This cir-

(To page 36)

ciency and increase the accuracy of certification and selection. A team that can accurately and efficiently complete the program is also necessary. Breeders must possess professional knowledge and skills, confidence and courage, and a clear understanding of the future needs of the industry. This knowledge must be integrated with research and development activities, and conveyed to those working at the front line. The unity of knowledge and action is of great benefit.

References

[1] LI W. Simulation study on spatial and temporal variation of water productivity of spring maize in northern dry crops[D]. Beijing: Chinese Academy of Agricultural Sciences, 2021. (in Chinese).

[2] ZHANG XC. Genomic variation and evolution of elite germplasm in the spring maize zone in Northern China[D]. Beijing: Chinese Academy of Agricultural Sciences, 2021. (in Chinese).

[3] ZHANG K. Development strategy of maize industry in Heilongjiang reclamation area[J]. Modernizing Agriculture, 2016(3): 15–17. (in Chinese).

[4] HU HL. Principles of selection of varieties for mechanisation of the whole maize production in Heilongjiang reclamation area[J]. Seed World, 2014(2): 5. (in Chinese).

[5] CAI Z, XU GL, ZHANG MT, *et al.* The advances in haploid breeding of maize[J]. Journal of Maize Sciences, 2008(1): 1–5. (in Chinese).

[6] LI YL. The breeding of higher efficient haploid inducer in maize[J]. Liaoning Agricultural Sciences, 2018(4): 37–39. (in Chinese).

[7] LI YL. New fresh corn variety Ken Sweet Glutinous 18A and cultivation technology[J]. China Seed Industry, 2022(4): 126–127. (in Chinese).

[8] ZHANG HS. Research advances on cytoplasmic male sterility and restorer genes in maize[J]. Guangxi Agricultural Sciences, 2022, 49(5): 1–9. (in Chinese).

[9] BAI YF. Technical points of field management of maize breeding[J]. Journal of Mudanjiang Normal University: Natural Sciences Edition, 2009(1): 46–47. (in Chinese).

(From page 24)

cumvented the climatic conditions suitable for disease occurrence and can effectively reduce the incidence of brown spot. By adjusting the transplantation period and improving cultivation methods to provide a favorable environment for the growth of tobacco plants, the disease resistance of tobacco plants has been enhanced, and the incidence of virus diseases has been reduced. Accordingly, in the context of the natural conditions of the tobacco-growing region in Shiyan, the timely and early transplanting of tobacco can serve to reduce the incidence of leaf spot diseases. Furthermore, in the cultivation management, reducing the overlap time of tobacco plants in the field and the precipitation period to a minimum can be an effective strategy for reducing the impact of brown spot. The prevention and treatment of brown spot disease should be combined with precipitation in May to prevent the disease in advance and reduce the source base of disease.

References

[1] LIU GS. Tobacco cultivation[M]. Zhengzhou: China Agricultural Press, 2016: 192. (in Chinese).

[2] GUO YG, ZHANG S, YANG HJ, *et al.* Control of tobacco cucumber mosaic virus disease by interfering viral RNA based on VIGS technology[J]. Shandong Agricultural Sciences, 2023, 55(6): 136–142. (in Chinese).

[3] LI SJ, WU WX, PENG YC, *et al.* Research on the application of green prevention and control technology of tobacco common mosaic virus disease in Guiyang County[J]. Modern Agricultural Science and Technology, 2022(10): 62–64. (in Chinese).

[4] TIAN L, GUO J, ZHANG XF, *et al.* Prevention and control effect of different chemicals on tobacco red star disease and target spot disease[J]. Agricultural Technology Service 2022, 39(5): 50–53. (in Chinese).

[5] CHEN YG, DONG NY, HUO ZW, *et al.* Effect of several pesticides against *Alternaria alternata* in tobacco field[J]. Journal of Zhejiang Agricultural Sciences, 2021, 62(12): 2490–2492. (in Chinese).

[6] KONG YL. Effects of Transplanting young tobacco seedlings under film on viral diseases prevention, growth, development, and economic characters of flue-cured tobacco[J]. Tobacco Science & Technology, 2011(9): 75–80. (in Chinese).

[7] FENG Y, GAO ZH, ZU YQ. The potential effects of UV-radiation on plant diseases[J]. Journal of Plant Protection, 2008(1): 88–92. (in Chinese).

[8] LIU D, LI A, WU Z, *et al.* Study on suitable transplanting period of well-cellar strong seedlings for high-quality flue-cured tobacco in northwest of Hubei Province[J]. Journal of Anhui Agricultural Sciences, 2020, 48(8): 215–219, 223. (in Chinese).

[9] TAN W. Pathogenesis of tobacco red star disease and comprehensive management[J]. Tobacco Science & Technology, 1993(2): 45–48. (in Chinese).

[10] ZHENG XB, LIU JL, LI GC, *et al.* Tobacco cultivation technician (three to five levels) professional knowledge[M]. Zhengzhou: Henan Science and Technology Press, 2019. (in Chinese).

[11] MA GL, WANG L, GAO J, *et al.* Studies on sporulation conditions of *Alternaria alternata* in tobacco[J]. Journal of Jilin Agricultural University, 2006(6): 610–612, 618. (in Chinese).

[12] GUAN BY. Study on the specific classification and the pathogenicity differentiation of tobacco brown spot pathogen in Chongqing[D]. Chongqing: Southwest University, 2007. (in Chinese).

[13] GAO YL, GAO C, ZHANG GF, *et al.* The relationship of tobacco virus disease and meteorological factors in Yanbian[J]. Agricultural Science Journal of Yanbian University, 2014, 36(1): 74–77, 87. (in Chinese).