Research Article

Risk Evaluation of Solar Greenhouse Cucumber Low Temperature Disaster in Tianjin, China

Sining Chen[1]*, Fang Liu[1], Zhenfa Li[1], Shenbin Yang[2], Ming Li[3], Tie Wang[1] and Shumei Liu[1]
[1]Tianjin Climate Center, China
[2]Nanjing University of Information Science and Technology, China
[3]China National Engineering Research Center for Information Technology in Agriculture, China

***Corresponding author:** Sining Chen, Tianjin Climate Center, China

Received: June 09, 2016; **Accepted:** August 25, 2016; **Published:** September 01, 2016

Abstract

The energy-saving type solar greenhouse is the main carrier for facility agriculture in northern area of China. Compared with developed countries with advanced facilities and equipment, the energy-saving type solar greenhouses are generally not equipped with environment regulation and control equipment, therefore, the growth and development of greenhouse crops are still influenced by the greenhouse outside weather conditions to some extent. Tianjin is one of the main urban modern agricultural planting regions in China, and cucumber is one of the main greenhouse fruit vegetable crops in Tianjin. In recent years, the low temperature disaster of overwintering greenhouse cucumber happens frequently which has an important influence on the cultivation and production of cucumbers in Tianjin. Considering the different disaster characteristics of cucumbers suffering low temperature disaster at different development stages and for different types of greenhouses with different heat-preserving capacity, this research takes the three typical solar greenhouses with different heat-retaining capacities in Tianjin as the facility carriers, and takes solar greenhouse cucumber as the study object, and uses the meteorological observation data in and out of greenhouse, the cucumber growth observation data, the low temperature disaster experiment results and field investigation data accumulated by the research group as the data basis. The objective of this investigation is, firstly, to study the correspondence relationship between microclimate factors in the greenhouse and meteorological factors out of the greenhouse based on the assurance rate method in order to calculate the cucumber low temperature disaster indexes in and out of the greenhouse for different development stages in different types of greenhouses. Second, based on the natural disaster risk evaluation theory, to construct the risk evaluation model for greenhouse cucumber low temperature disaster and to calculate the cucumber low temperature disaster risk probability. Finally, the low temperature disaster risk region-division of cucumber is realized and the time series variation situation of low temperature disaster risk is analyzed for different development phases of different greenhouse types by utilizing GIS (Geographic Information System) spatial analysis function to evaluate the low temperature disaster risk of cucumber in a comprehensive way. Based on the comprehensive evaluation of the low temperature disaster risk of cucumber, the scientific advice can be given about how to construct the appropriate greenhouses or reform existing greenhouses according to the climate conditions and how to avoid or reduce the low temperature disaster risk to ensure the cucumbers' yield and quality.

Keywords: Solar greenhouse; Cucumber; Low temperature disaster; Risk evaluation; Tianjin

Introduction

In recent years, with the breakthrough in technology of controlled agricultural environmental engineering, the large-scale modern facility agriculture develops rapidly, and a kind of modern agricultural production technique with relatively high intensification is formed. Greenhouse culture has become the important part of facility agriculture. The ecological system in the facility provides necessary conditions for the growth and development of the crop, and the main environmental restrictive factors for the crop production in greenhouse include illumination, temperature, humidity and ventilation conditions, where temperature is one of the most important environmental factors [1]. Suitable temperature and humidity conditions not only contribute to the growth and development of crops, but also contribute to reduce disease of greenhouse crops and usage of insecticide, which is helpful for obtaining high quality agricultural products.

The greenhouse crops culture is distributed widely all over the world, and the areas with the temperature of 30°C-40°C is suitable for greenhouse crops. The cooling cost of greenhouse will increase with the decrease of latitude under 30°C, on the contrary, the heating cost will increase with the increase of latitude above 40°C. According to the latitude and the greenhouse culture technology, the greenhouse can be divided into the following three categories: 1) cool climate zone, with representatives of Holland, Britain and Germany; 2) temperate

Citation: Chen S, Liu F, Li Z, Yang S, Li M, Wang T, et al. Risk Evaluation of Solar Greenhouse Cucumber Low Temperature Disaster in Tianjin, China. Austin Food Sci. 2016; 1(4): 1017.

climate zone, with representatives of Mediterranean sea coast, Spain, Italy, Turkey, Greece, Israel and Egypt; 3) mixed climate zone, the zone with the climate characteristics of both of the above two climate zones, with representatives of America and Japan [2].

With the permeating of modern industry to agriculture and the application of microelectronic technique, the intensive facility agriculture has rapidly developed in some developed countries such as Holland, America, Spain and Japan, and a powerful pillar industry is formed. In the past 20 years, the importance of greenhouse in agricultural production is increasingly prominent, and the purpose of using greenhouse is to guarantee for the optimal heat quantity in each crop growth stage, to provide agricultural products with large quantity and high quality crop out of growth season [3,4]. Countries, in which facility agricultural is highly developed, as in Holland, have a high degree of agricultural facility standardization. Most are connected and intelligent greenhouses which have standard planting techniques and cultivation techniques, as well as advanced techniques for plant protection, facility environment comprehensive adjustment and control technology and agriculture mechanical technique. Also, they are on the way to automation, intelligent and networking orientation [5]. Therefore, the greenhouses of these countries are little influenced by meteorological disasters. Since 1980s, the facility agriculture with the representative of solar greenhouse and vinyl house has been developed rapidly in China, especially, the energy-saving solar greenhouse which adapts to the economic technical level in rural areas in our country is very common in areas of the middle and lower reaches of the Yellow River including Huang-Huai Plain, Liaodong Peninsula as well as Peking and Tianjin region [5]. At present, the facility culture in China occupies more than 85% of the whole world, and the total area and total production rank the first in the world. Facility agriculture has been the leading industry of agricultural production and income increase of peasants in China. Although there has been great progress in the facility agriculture in recent 30 years, the overall level is lagged behind developed countries. According to researches, the crop production will be increased by 20% when the greenhouse temperature increases by 10°C [2]. Therefore, heating of greenhouse is essential under insufficient radiation conditions. Because of the high cost of heating equipment, not each facility agriculture area will adopt it, and many facility agriculture areas still choose the non-heating and energy-saving greenhouses. As the basic carrier of facility agriculture, neither vinyl house nor solar greenhouse is equipped with microclimate control equipment in China because of the construction cost, which makes the facility crops influenced by the outside weather condition to certain extent and the disaster risks related to these adverse conditions are relatively serious. Therefore, compared with the countries with advanced facility cultivation techniques, the solar greenhouse crops and vinyl house crops are easier to be influenced by the disastrous weather in China, with relatively high meteorological disaster risks, and with relatively high risks of facility crop disease and insect attack derived from meteorological disaster [6]. It is essential to develop research on 1) meteorological disaster risk evaluation for facility crops based on the relationship between outside world meteorological condition and facility crops, 2) evaluation of the occurrence regularity and characteristics of facility crop meteorological disaster, and 3) analysis of the conditions that lead to possible losses for facility crop and to provide a scientific basis for the prevention of disaster and reducing damage in facility agriculture.

Many scholars at home and abroad have conducted a large number of researches aiming at the risk evaluation on the meteorological disaster of facility agriculture. In consideration that the facility agriculture in developed countries has characteristics of perfect facility, mature technique, standard production, stable output and high quality, as table industrial system has been formed. They can conduct an automatic environment control in the facility for optimum ecological conditions for crop growth, which is not influenced by climatic conditions. Therefore, the emphasis of risk evaluation is often on the researches of economic risk, social risk and environment risk [7,8]. And it pays more attention to the pest and disease damage caused by an adverse inside microclimate of the facility, for example, the downy mildew of greenhouse cucumber [9-11]. And the bemisiatabaci of greenhouse tomato [12]. Many scholars in China have worked a lot on facility agriculture meteorological disaster, for example Wei et al. studied the indexes and grade for low temperature and sunlight shortage disaster of greenhouse vegetables of Hubei Province in China, and obtained the suitable meteorological factor for vegetables in solar greenhouse by consideration of the meteorological conditions needed for growth of vegetables as well as the crop yield loss after low temperature &sunlight shortage disaster, and determined the appropriate regions for vegetables in solar greenhouse [13]. Conducted risk grade division to three main meteorological disasters (sunlight shortage disaster, low temperature disaster and high temperature disaster) in the facility agriculture area in Jiangsu Province [14]. Studied the quantitative criteria for solar greenhouse wind disaster grading and conducted evaluation on the time and space change of wind disaster of solar greenhouse [15]. Constructed solar greenhouse meteorological disaster risk evaluation model based on accelerating genetic algorithm with real number encoding [16]. We can find out from the above researches (especially those from Chinese scholars) that they have consistent results on meteorological disaster evaluation indexes of facility agriculture, the influence of multiple disaster indexes to facility agriculture can be taken into consideration and the critical values for disaster indexes of different disaster can be determined according to local practical situations. Some achievements have been applied in business, but there are still some problems: 1) Different from field crops which are totally exposed to the outside natural environment, the greenhouse crops, which are directly influenced by the microclimate in the greenhouse, are also influenced by the outside world environment in a indirect way. Most of existing researches determine the meteorological disaster factors out of the greenhouse in the way of experience and spot investigation; it ignores the relationship between the factors in the greenhouse and out of the greenhouse and the direct influence of the meteorological factor in the greenhouse to crops; 2) Most of existing researches take the whole growing period of greenhouse crops as the research object; in fact, there are different meteorological disaster influencing factors and influencing results for greenhouse crops in different developmental phases. Therefore, it is necessary to evaluate the meteorological disaster risks of greenhouse crops aiming at different development phases; 3) Most researches ignore the influence of different greenhouse types on greenhouse crop meteorological disaster evaluation, and there are obvious differences

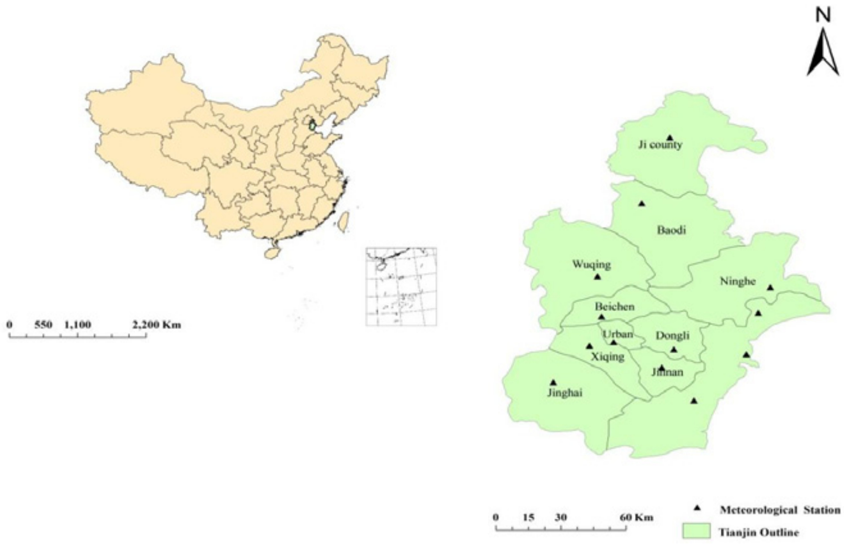

Figure 1: Study area.

in temperature preservation abilities between different greenhouse types, therefore, it is not proper to evaluate the greenhouse crop meteorological disaster by ignoring the influence of greenhouse type on greenhouse crops.

Tianjin is the typical urban facility agriculture planting region in China, and cucumber is one of the most typical solar greenhouse crops in Tianjin. Cucumber is suitable to grow in warm but not high temperature conditions, and it is sensitive to low temperature. In the cucumber production in over winter period of recent years, the temperature conditions in the protection facility cannot meet the requirement for the normal growth of cucumber, and there are frequent low temperature disasters which has been the common meteorological disaster for greenhouse cucumber. Besides, different characteristics in low temperature disaster in different development periods of cucumbers were observed. When encountering with low temperature during sprouting, germination is inhibited or slowed down; when encountering with low temperature during seeding stage, the seed grow slower, with shortened internodes and a dark green color; when encountering with low temperature during blossom and fruiting period, the growth of the cucumber is obviously restrained, with shortened internodes and lamina and the fruit grows slowly [17]. This research takes the three typical solar greenhouses with different heat-retaining capacities in Tianjin as the facility carriers, and takes solar greenhouse cucumber as the study object, and uses the meteorological observation data in and out of greenhouse, the cucumber growth observation data, the low temperature disaster experiment results and field investigation data accumulated by the research group as the data basis. Firstly, study the correspondence relationship between microclimate factors in greenhouse and meteorological factors out of greenhouse based on the assurance rate method to construct the cucumber low temperature disaster indexes in and out of greenhouse for different development stages in different types of greenhouse. Then, based on the natural disaster risk evaluation theory, to construct the risk evaluation model for greenhouse cucumber low temperature disaster strengthen to calculate the cucumber low temperature disaster risk probability. Finally, the low temperature disaster risk region-division of cucumber is realized and the time series variation situation of low temperature disaster risk is analyzed for different development phases of different greenhouse types by utilizing GIS (Geographic Information System) spatial analysis function to evaluate the low temperature disaster risk of cucumber in a comprehensive way.

Study Area and Data

Study area

Tianjin is located in the northeast part of North China Plain in China (116°43'-118°04'E, 38°34'-40°15'N). It is near to Yanshan Mountain to the north, and near to the Bohai Sea to the east, and is located in the transition region from mountain to strand plain; mountains and hills, plains and costal mud flat are distributed in Tianjin, with the coastline of more than 150 km. The diversified topographies and abundant climate resources form the agricultural planting industry, breeding industry and forestry and fruit growing industry of Tianjin. In recent years, because of the emerging facility agriculture as well as the increase of area and production of facility vegetables and flowers, Tianjin becomes one of the main urban facility agriculture planting regions in China. The lowest temperature in Tianjin is present in the middle ten days of December and the first ten days of February (with the average lowest temperature of under -5ºC). The lowest temperature value of one year is present in the middle ten days of January (the average value of the lowest temperature for many years is -8.5ºC), and the historical extreme lowest value of Tianjin is -23.3ºC (the above data is provided by Tianjin Climate Center). Between the middle ten days of December and the first ten days of February, the ground temperature is low and the duration of possible sunshine is little, in conditions of poor heat preservation or unreasonable crop rotation matching, it is easy for greenhouse crops to suffer from low temperature disaster. It can be seen that the heat condition is the main restrictive condition for solar greenhouse crop in winter and spring, and it is the most important meteorological disaster preventive measure during over winter period of Tianjin to conduct low temperature disaster risk evaluation for greenhouse crops (Figure 1).

Table 1: Error analysis of hourly air temperature simulation result of xiqing traditional second generation greenhouse.

Maximum error (°C)	Minimum error (°C)	Average error (°C)	Relative error (%)	Standard deviation (°C)
-1.92	0.07	-0.35	4	3.03

Table 2: Basic conditions of three types of solar greenhouses with different heat retaining abilities.

Greenhouse type	Length (m)	Span (m)	Spine height (m)	Back wall height (m)	Back roof projection (m)	Side wall thickness (m)	Side wall material	Back wall thickness (m)	Back wall material	Back slope thickness (m)	Back slop material	Heat Curtain thickness (m)	Heat retaining performance
Xiqing traditional Second generation greenhouse	80	6.5	3.1	2.5	0.67	0.37	Brick	0.5	Brick	0.15	Cement	0.08	Poor
Wuqing new type greenhouse	65	9.97	5.22	3.72	1.65	0.5	±	0.5	Brick + polyphenyl board	0.2	Cement	0.1	Moderate
Baodi traditional cob wall greenhouse	85	9	4.5	4.2	0.88	0.9	±	2.05	Soil	0.5	Soil	0.09	Excellent

*Thermal conductivity of wall material: brick-0.75 W/m·K; soil-0.23 W/m·K; polyphenyl board-0.04 W/m·K; cement-1.28 W/m·K

Study data

Meteorological data outside greenhouse: The hourly meteorological data outside greenhouse of 2005 – 2014 of 13 meteorological observation stations in Tianjin provided by Tianjin Climate Center, included temperature, sunshine duration, relative humidity, wind speed and wind direction.

Microclimate data inside greenhouse: The microclimate data inside greenhouse includes the inside greenhouse microclimate observation data (including air temperature, ground temperature, relative humidity and radiation) which is observed each 10 minutes of the over winter period (October –February of the next year) of 2011-2012, 2012-2013 and2013-2014 for three typical solar greenhouses of different heat retaining capacity (the three typical solar greenhouses are Xiqing traditional Second generation greenhouse, Wuqing new type greenhouse and Baodi traditional cob wall greenhouse, and the basic situations of various greenhouses such as material structure will be introduced in details in “2.3 Solar greenhouse introduction”). In order to be in accordance with the time scale of greenhouse outside air temperature, this research adopts the greenhouse inside air temperature of integral point time (for example, 0, 1, 2,……23 o’clock) to make correspondence with the greenhouse outside air temperature. Because of the lack of the microclimate data in some greenhouses, and the temperature in greenhouse is the key meteorological factor for low temperature disaster of greenhouse cucumber, the BP neural network based solar greenhouse air temperature simulation model [18,19]. Is adopted in this research to simulate the hourly air temperature in the greenhouse to fill up for the deficiency of greenhouse inside temperature. The model utilizes hourly outside temperature, outside daily sunshine duration, outside relative humidity and relative time to simulate the hourly air temperature inside the greenhouse. In consideration of the data integrity, the data of 2012 -2013 is taken as the modeling data, and the data of 2011-2012 and 2013-2014is taken as the verification data to test on the hourly temperature simulation result of the three solar greenhouses. (Table 1) is the error analysis on hourly air temperature simulation result of Xiqing traditional Second generation greenhouse. We can see from (Table 1) that the maximum error between hourly air temperature simulation value and the measured value is -1.92^{0}C, and the minimum error value is 0.07^{0}C, and the average error is -0.35^{0}C, and the relative error value is 4%, and the standard deviation is 3.03^{0}C. Generally, the hourly air temperature simulation accuracy can meet the requirement of the research. The hourly air temperature simulation results of the other two types of greenhouses are similar with that to the Xiqing traditional Second generation greenhouse (Table 1).

Other data: In recent years, the research group has accumulated a large amount of experimental data on greenhouse cucumber low temperature disasters well as field investigation data. In consideration of the different

Morphological characteristics of cucumber in different development phases, this research adopt cucumber low temperature disaster data for different development phases to reflect the affected situation of cucumber. The research group developed low temperature disaster tests on greenhouse cucumber potting during seeding stage in October 2011 – November 2011 in the 6th port village, Xiqing District and Shengrenzhuang village, Baodi District in Tianjin respectively. The test designed four low temperature levels of 6°C, 8°C, 10°C and15°C, with the low temperature processing time of 1 – 5 days and recovery time of 1- 5 days as described by Yu [20]. The low temperature disaster situation of cucumber during flowering phase and fruiting phase were based on the field investigation during the wintering periods of 2011 –2012 and 2012 –2013 of the above two areas. After the end of the seeding phase, there was a special manager conduct low temperature disaster investigation to the assigned greenhouse each day, with the same person. The investigation position was at the southwest, northwest, middle, southeast and northeast corners of each greenhouse, presenting in X-shape. 3 cucumbers are investigated for each position. The investigated items included the microclimate conditions of the plant (including air temperature, humidity, ground temperature and low temperature duration in greenhouse) and plant growth and development state (including plant height, leaf morphology, if there was damage and the degree, if the young fruit fell off, if the mature fruit deformed and the biomass).

Solar greenhouse introduction: By adopting three typical solar greenhouses with different heat retaining capacities, this research conducts comparison and analysis on the low temperature disaster risk of cucumber for different development phases in three typical

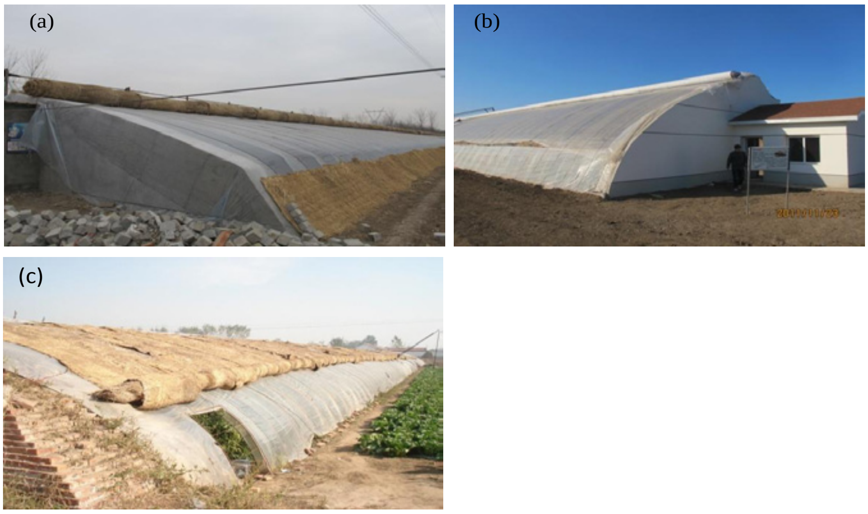

Figure 2: Xiqing traditional second generation greenhouse (a), wuqing new type greenhouse (b) and baodi traditional cob wall greenhouse (c).

solar greenhouses. The three types of greenhouses are Xiqing traditional Second generation greenhouse, Wuqing new type greenhouse and Baodi traditional cob wall greenhouse; the material, structure and related parameters of various types of greenhouses are shown in (Table 2). What shall be illustrated is that, compared with other two types of greenhouses, Baodi traditional cob wall greenhouse has obvious construction features, which shall be constructed in places of relatively wide land area, low-lying and low underground water level, i.e., a part of the greenhouse is buried underground, therefore, although there is no heating equipment, it has the optimal heat retaining capacity (Figure 2) (Table 2).

Methodology and Model

Growth and development period of greenhouse cucumber

According to the growth and development data of greenhouse cucumber, the greenhouse cucumber in Tianjin City is often planted before October 1st of each year; the seeding stage lasts for about 23 days; the stage of flowering without fruit lasts for about 10 days; the stage of flowing and fruiting lasts to May or June of the next year, but there is almost no low temperature disaster after the end of February; therefore, the growth and development phase of greenhouse cucumber growth phase is determined as (Table 3).

Low temperature disaster indexes for greenhouse cucumber

Tianjin has a large solar greenhouse planting area, but it fails to realize to install. The equipment of microclimate real-time monitoring system in each greenhouse. There are more than 200 meteorological automatic observation stations in Tianjin, and the evenly distributed and real-time monitored meteorological factor observation network is basically formed. Therefore, obtaining greenhouse outside low temperature disaster index of cucumber has more practical significance for the regional disaster risk evaluation. In consideration that there are different morphological characteristics of cucumber in different development phases, different determination methods of disaster indexes are adopted aiming at different development phases: the cucumber seeding phase disaster index is based on the past test results of this research group [19], the flowering phase and fruiting phase disaster index is based on the field investigation information of greenhouse cucumber planting region of Tianjin [20] and greenhouse cucumber growth cultivation data is taken for reference [21-23]. To determine the cucumber greenhouse inside low temperature disaster index of different developmental phases. Based on the unified cucumber greenhouse inside low temperature disaster index, the assurance rate method is adopted to obtain the greenhouse outside low temperature disaster index of cucumber for three types of greenhouses. The assurance method refers to the reliability of certain meteorological factor value is less or larger than some value, usually expresses with the accumulated frequency of some meteorological factor less or larger than some value in long period. As for the lower limiting value of greenhouse inside disaster index (i.e., greenhouse air temperature), rank the corresponding greenhouse outside disaster index (i.e., the greenhouse outside air temperature) from low to high to obtain the average value of 80% of the greenhouse outside air temperature at the back of the sequence, and take it as the lower limit of greenhouse outside disaster index which is corresponding to the lower limit of greenhouse inside disaster index; as for the upper limiting value of greenhouse inside disaster index (i.e., the greenhouse inside air temperature), rank the corresponding greenhouse outside disaster indexes (i.e., the greenhouse outside air temperature) from low to high, to obtain the average value of 80% of the greenhouse outside air temperature in front of the sequence, and take it as the upper limit of greenhouse outside disaster index which is corresponding to the upper limit of greenhouse inside disaster index.

Table 3: Development phase of solar greenhouse cucumber in Tianjin.

Development phase	Time
Seeding phase	October 1st– October 25th
Flowering phase	October 26th– November 5th
Fruiting phase	November 6th–February 28th

Method for low temperature disaster risk probability evaluation of cucumber in solar greenhouse

This research determines the low temperature disaster risk probability by the probability of low temperature disaster of greenhouse cucumber for different development phases. Firstly,

Table 4(a): Greenhouse inside disaster indexes of cucumber low temperature disaster based on different development phases.

Development phase / Disaster degree	Seeding phase (duration)	Flowering phase (duration)	Fruiting phase (duration)
Mild	11°C<=T<=15°C(72h)	10°C<=T<=14°C(72h)	9°C<=T<=13°C(72h)
Moderate	8°C<= T<=11°C(48h)	6°C<=T<=10°C(48h)	5°C<=T<=9°C(48h)
Severe	T<8°C(24h)	T<6°C(24h)	T<5°C(24h)

Table 4(b): Low temperature disaster greenhouse outside disaster indexes of cucumber of xiqing traditional second generation greenhouse.

Development phase / Disaster degree	Seeding phase(duration)	Flowering phase(duration)	Fruiting phase(duration)
Mild	11°C<=T<=15°C(72h)	9.2°C<=T<=12.6°C(72h)	0.4°C<=T<=4.4°C(72h)
Moderate	8°C<= T<=11°C(48h)	5°C<=T<=9.2°C(48h)	-3.1°C<=T<=0.4°C(48h)
Severe	T<8°C(24h)	T<5°C(24h)	T<-3.1°C(24h)

Table 4(c): Low temperature disaster greenhouse outside disaster indexes of cucumber of wuqing new type greenhouse.

Development phase Disaster degree	Seeding phase(duration)	Flowering phase(duration)	Fruiting phase(duration)
Mild	11°C<=T<=15°C(72h)	/	-2.8°C<=T<=1.6°C(72h)
Moderate	8°C<= T<=11°C(48h)	/	-3.4°C<=T<=-2.8°C(48h)
Sever	T<8°C(24h)	/	T<-3.4°C(24h)

Table 4(d): Low temperature disaster greenhouse outside disaster indexes of cucumber of baodi traditional cob wall greenhouse.

Development phase Disaster degree	Seeding phase(duration)	Flowering phase(duration)	Fruiting phase(duration)
Mild	11°C<=T<=15°C(72h)	/	/
Moderate	8°C<= T<=11°C(48h)	/	/
Severe	T<8°C(24h)	/	/

take the greenhouse outside air temperature of the wintering period (October 1st of the year to February 28th or 29th) of the next year is taken as the greenhouse cucumber wintering period in this research) of 2005-2006, 2006-2007, 2007-2008, 2008-2009, 2009-2010, 2010-2011, 2011-2012, 2012-2013, 2013-2014 of 13 meteorological observation stations in Tianjin as the basis to construct cucumber low temperature disaster indexes sequence. Then it conducts different theoretical probability density function (such as Beta, Exponential, Gumbel, Gamma, Generalized Extreme Value, Inverse Gaussian, Logistic, Log-Logistic, Lognormal, Lognormal2, Normal, Pareto, Pareto2, Pearson Type V, Pearson Type VI, Weibull, etc.) fitting tests to disaster indexes sequence for different development phases and different disaster grades to select the optimal theoretical probability distribution function and calculate the risk probability value for different cucumber development phases and various disaster level of 10 wintering periods of 13 stations. Finally, calculate the average value of the 10 wintering periods probability of each station to obtain the risk probability of cucumber low temperature disaster for different development phases and different disaster levels, and the greenhouse cucumber low temperature disaster risk grade is determined as per the risk probability.

Results

Low temperature disaster indexes of solar greenhouse cucumber

(Table 4(a)) gives the greenhouse inside disaster indexes of cucumber low temperature disaster for different development phases, and (Tables 4(b)-4(d)) gives the cucumber low temperature disaster indexes in different three typical greenhouses for different development phases. It should be noted that most solar greenhouses in Tianjin are covered with film on October 20th, and it is regarded that the greenhouse inside and outside air temperatures for cucumber seeding phase are the same, i.e., the greenhouse inside and outside disaster indexes of cucumber low temperature disaster for seeding phases are the same, as well as the low temperature disaster indexes for three typical solar greenhouses during cucumber seeding phase are the same (Table 4**).**

According to (Tables 4(b)-4(d)), we can see that there are different levels of low temperature disaster of cucumber during all the development phases in Xiqing traditional Second generation greenhouse; there are low temperature disaster during seeding phase and fruiting phase of cucumber in Wuqing new type greenhouse with lower greenhouse outside air temperature during fruiting phase compared to Xiqing traditional Second generation greenhouse (because the heat retaining ability of Wuqing new type greenhouse is better than that of Xiqing traditional Second generation greenhouse); the low temperature disaster to cucumber in Baodi traditional cob wall greenhouse often happens during seeding phase, and there is no low temperature disaster during flowing phase and fruiting phase (because Baodi traditional cob wall greenhouse has the best heat retaining ability in the three typical greenhouses).

Risk division of greenhouse cucumber low temperature disaster

Taking the average value of cucumber low temperature disaster risk probability of 10 wintering periods of 13 meteorological observation station in Tianjin, and in virtue of the spatial interpolation function of Arg CIS software (the normal Kriging interpolation method is adopted in this research) to obtain the risk special distribution result for low temperature disaster of cucumber for different development

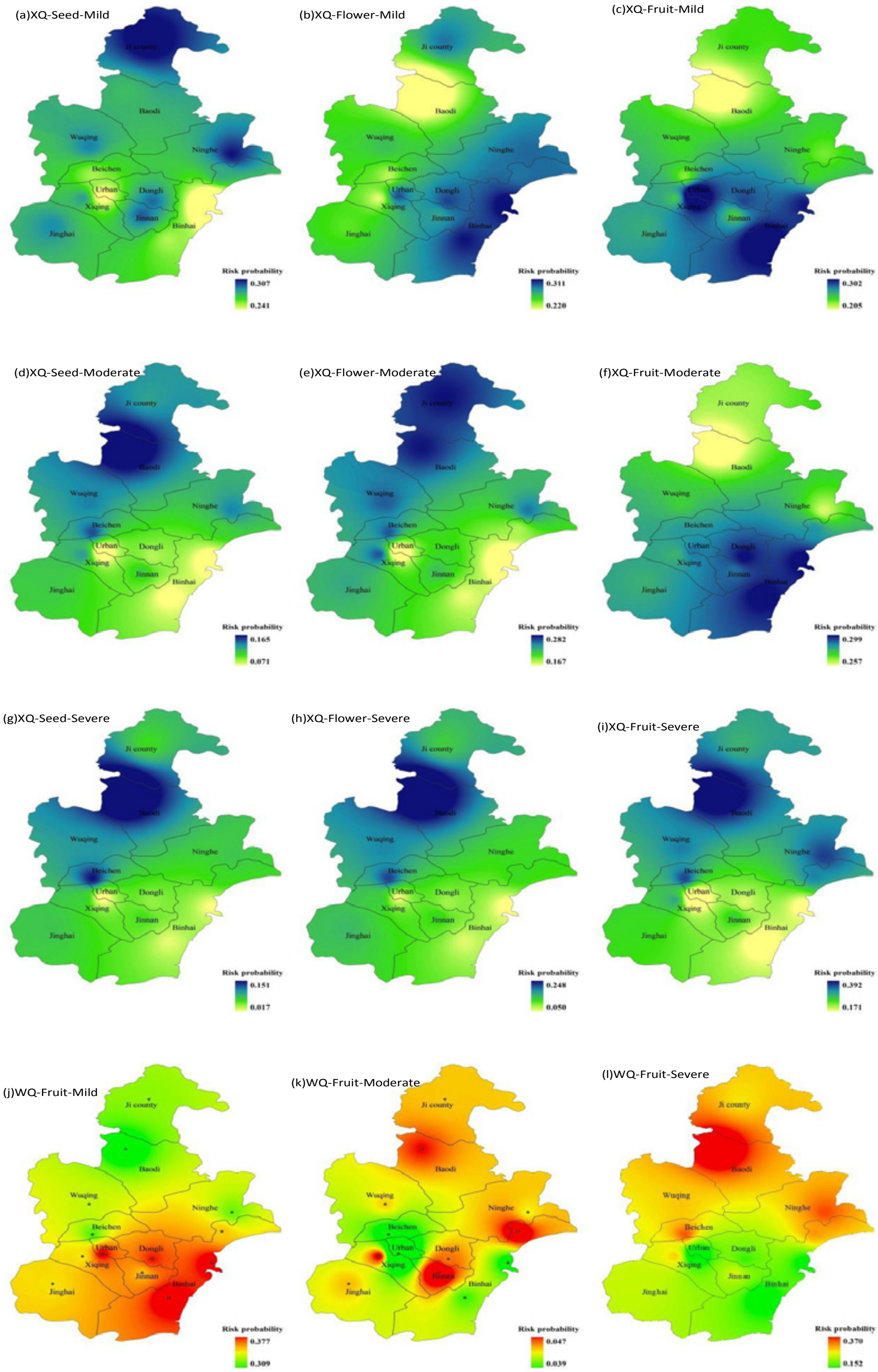

Figure 3: Risk special distribution result of low temperature disaster of cucumber for different development phases and different types of greenhouses.
*XQ represents Xiqing traditional second generation solar greenhouse.
WQ represents Wuqing new pattern solar greenhouse.
Seed, flower and fruit represent different development phase of solar greenhouse cucumbers respectively.
Mild, moderate and severe represent different severity of chilling injury of solar greenhouse cucumbers.

phases and different disaster strength of different types of solar greenhouses in Tianjin (Figure 3). What shall be illustrated is that because of the same low temperature disaster indexes during seeding phase for three typical greenhouses, the risk special distribution result of cucumber low temperature disaster of different disaster strength for the three typical greenhouses during seeding phase are almost the same, consequently this article only takes the risk special distribution result of cucumber low temperature disaster during seeding phase in Xiqing traditional Second generation greenhouse as the example. Besides, there is no low temperature disaster of cucumber during flowering phase in Wuqing new type greenhouse, and there is no low temperature disaster of cucumber during flowering phase and fruiting phase in Baodi traditional cob wall greenhouse, therefore, as for the two types of greenhouses, this article only gives the risk special distribution result of low temperature disaster for cucumber fruiting phase of Wuqing new type greenhouse; as for the risk special distribution result of low temperature disaster during seeding phase, please take reference of Xiqing traditional Second generation greenhouse (Figure 3).

According to (Figure 3) we can see that the risk special distribution situations of cucumber low temperature disaster for different solar greenhouse types, different development phases and different disaster grades are different in Tianjin. As for Xiqing traditional Second generation greenhouses: during seeding phase, the high risk area of mild low temperature disaster is located in Ji County; and the high risk area of severe low temperature disaster is located in northwest part of Baodi and the southwest edge of Ji County; and the low risk area of three-level low temperature disaster during seeding phase is located in urban areas and Binhai New District, and the risk probability of mild low temperature disaster during seeding phase is obviously higher than that of the moderate and severe low temperature disaster, and the above risk special distribution result of low temperature disaster of cucumber during seeding phase is also applicable to Wuqing new type greenhouse and Baodi traditional cob wall greenhouse. During flowering phase, the high risk area of mild low temperature disaster is located in middle part of Binhai New District; and the high risk area of moderate low temperature disaster is located in northwest part of Baodi and Ji County; and the high risk area of severe low temperature disaster is located in northwest part of Baodi and the southwest edge of Ji County, and the mild low temperature disaster risk during flowering phase is obviously higher than that of moderate and severe low temperature disaster. During fruiting phase, the high risk area of mild low temperature disaster is located in urban areas and middle part of Binhai New District; and the high risk area of moderate low temperature disaster is locate in Dongli District and middle part of Binhai New District; and the high risk area of severe low temperature disaster is located in northwest part of Baodi and the southwest edge of Ji County, and the risk of severe low temperature disaster during fruiting phase is obviously higher than that of mild and moderate disasters. Making a general survey of the whole development phase of greenhouse cucumber, the severe low temperature disaster risk in fruiting phase is the highest in Tianjin, with the highest risk probability value of 0.392, and also the fruiting phase is the key phase which has direct influence on the final production and economic income of cucumber; the mild low temperature disaster risks during seeding phase, flowering phase and fruiting phase of cucumber are relatively higher, and the severe low temperature disaster during seeding phase is the lowest. As for Wuqing new type greenhouse, the low temperature disaster risk during seeding phase is the same as that of the Xiqing traditional Second generation greenhouse; there is no low temperature disaster during flowering phase; the high risk area of mild low temperature disaster during fruiting phase is located in urban areas, Dongli District and middle part of Binhai New District, and there is only slight difference of moderate low temperature disaster risk probability with generally low risk probability value as well, and the high risk area of severe low temperature disaster is located in northwest part of Baodi and southwest edge of Ji County. In addition, the moderate and severe risk probabilities of cucumber during fruiting phase in Xiqing traditional Second generation greenhouse are higher than that of Wuqing new type greenhouse, and this is because that the latter one has better heat retaining performance than the former. Besides, the northwest part of Baodi and the southwest edge of Ji County will generally become high risk areas under different disaster grades during different development phases which related to the geographical positions: this area is in low terrain and is located in the flat area under north mountainous region, and the south part of Baodi has a high altitude, also there is funneling effect caused by the northwest wind in winter, as a result, the temperature is low in this area.

Change situations of low temperature disaster risk of greenhouse cucumber in recent 10 years

Figure 4 shows the low temperature disaster risk change situations of cucumbers during different development phases in different types of greenhouses in recent 10 years. As for the Xiqing traditional Second generation greenhouse, the risk of mild low temperature disaster during seeding phase is obviously higher than that of moderate and severe damages, and the risk probability values of mild low temperature disaster during seeding phase are generally in 0.25-0.4; during flowering phase, the risk of mild and moderate low temperature disaster is generally higher than that of severe low temperature disaster; during fruiting phase, there are high risk of severe low temperature disaster, and then is the moderate ones, and the mild ones rank the last. As for the total development phase of cucumber, the severe low temperature disaster during seeding phase is the lowest, and the risk probability values in recent 10 years is no more than 0.1. As for Wuqing new type greenhouse, the risk change situations of low temperature disaster during seeding phase in recent 10 years is the same as that of Xiqing traditional Second generation greenhouse; there is no low temperature disaster during flowering phase; the mild low temperature disaster during fruiting phase in recent 10 years has the highest risk, and the risk probability values of 9 years are more than 0.3, and the moderate low temperature disaster during fruiting phase is the lowest, and the risk probability values of recent 10 years are never more than 0.05 (Figure 4).

Discussion and Conclusion

There are both “similarity” and “difference” between the researches on meteorological disaster risk evaluation of facility crops with that of field crops. 1) The growth and development of facility crop is directly influenced by the microclimate in greenhouse, and the indirect influence of the conditions out of the greenhouse;

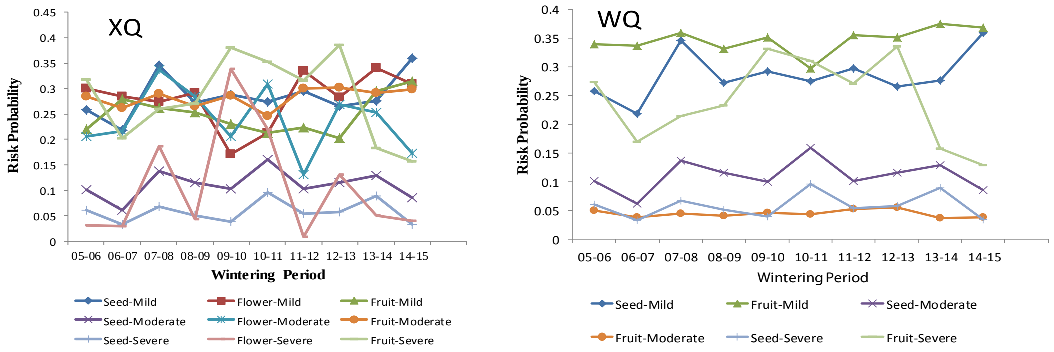

Figure 4: Risk probability change situations of low temperature disaster of recent 10 year's wintering periods of cucumber of different types of greenhouses.
*Meaning of XQ, WQ, seed, flower, and fruit, mild, moderate and severe is similar to Figure 3.

besides, there is great correlation between the greenhouse inside and outside meteorological conditions, therefore, it is the important basis for greenhouse crop meteorological disaster risk evaluation to take the correlation and the influence of both greenhouse inside and outside meteorological conditions to the growth and development of greenhouse crop into consideration. 2) Meteorological disaster has different influences on the greenhouse crop in different development phases, as well as the disaster expression and disaster loss; therefore, it is needed to conduct evaluations of greenhouse crop for different development phases. 3) The different factors of greenhouse, such as structure, material and geographical position, lead to different heat retaining abilities of greenhouses, and the same outside disaster weather condition may lead to different influence on greenhouse crops in different greenhouses; therefore, it is necessary to conduct disaster risk evaluation aiming at different greenhouse types.

Compared with the existing researches [13-16,20,23]. this research calculates the greenhouse outside disaster indexes with the assurance rate algorithm; based on natural disaster risk evaluation theory, it calculates the risk probability of low temperature disaster of greenhouse cucumber for different disaster grade during different development phases to obtain the risk change situation in recent 10 years and risk spatial distribution result of low temperature disaster. Besides, temperature is the main factor for greenhouse cucumber low temperature disaster, but because of the particularity of facility, the cucumber low temperature disaster is related to sunshine duration to some extent, which is not taken into consideration in this article, but will be supplemented in the future work.

This study was funded by the Youth Fund of Tianjin Science and Technology Committee (Project ID: 16JCQNJC14900), Doctoral Fund of Tianjin Meteorological Service (Project ID: BSJJ201505), Agro-Meteorological key laboratory Open Project in Jiangsu Province (Project ID: KYQ1305), and Climate Change Special Fund of China Meteorological Administration (Project ID: CCSF201521).

References

1. Yagcıoglu A. Greenhouse mechanization. Ege University, Faculty of Agriculture. Publication no: 562. 2005.
2. Murad C, Yasemin EN, Sefai B, Nuri C. Heating requirement and its costs in greenhouse structures: A case study for Mediterranean region of Turkey. Renewable and Sustainable Energy Reviews. 2013; 24: 483-490.
3. Bennis N, Duplaix J, Enea G, Haloua M, Youlal H. Greenhouse climate modelling and robust control. Computers and Electronics in Agriculture. 2008; 6: 96-107.
4. Sethi VP, Sharma SK. Survey and evaluation of heating technologies for worldwide agricultural greenhouse applications. Solar Energy. 2008; 82: 832-859.
5. Wang JL. Modern agricultural meteorology service. China Meteorological Press Beijing. 2010; 264-291.
6. Chen SN, Li ZF, Liu SM. Review of Facilities Agriculture Meteorological Disasters and Prospect of Associated Study Methods. Chinese Agricultural Science Bulletin. 2014; 30: 302-307.
7. Piers M, Jorissen RE, Stallen PJM. Methods and models for the assessment of third party risk due to aircraft accidents in the vicinity of airports and their implications for societal risk eds. Quantified Societal Risk and Policy Making. Dordrecht: Kluwer Academic Publishers. 1998.
8. Carter DA. The scaled risk integral-a simple numerical representation of Case Societal Risk for Land Use Planning in the Vicinity of Major Accident Hazards Loss Prevention in the Process Industries. Elsevier. 1995.
9. Shetty N, Wehner T, Thomas CE. Evidence for downy mildew races in cucumber tested in Asia, Europe, and North America. Scientia Horticulturae. 2002; 94: 231-239.
10. Colucci, Susan J. Host range, fungicide resistance and management of Pseudoperonospora cubensis, causal agent of cucurbit downy mildew. Raleigh, North Carolina State University Master of Science. 2008.
11. Arauz LF, Neufeld KN, Lloyd AL, Ojiambo PS. Quantitative models for germination and infection of Pseudoperonospora cubensis in response to temperature and duration of leaf wetness. Phytopathology. 2010; 100: 959-967.
12. Stanslya PA, Sánchezb PA, Rodríguezb JM, Cañizaresc F, Nietoc A, López Leyvad MJ, et al. Prospects for biological control of Bemisiatabaci (Homoptera, Aleyrodidae) in greenhouse tomatoes of southern Spain. Crop Protection. 2004; 23: 701-712.
13. Wei RJ, Zhao CL. Confirmation of most suitable area for developing fruit and vegetable solar greenhouse house in Hebei province by using GIS technology. Chinese Journal of Agricultural Resources and Regional Planning. 2005; 26: 35-38.
14. Cai B, Liu SD, Fei YJ, Yang ZQ, Huang HJ. The risk grading regionalization of meteorological disaster of facilities agriculture in Jiangsu Province. Chinese Agricultural Science Bulletin. 2011; 27: 285-291.
15. Huang, Chuanrong, Yang Zaiqiang, Liu Hong, Pei Daohao, Zhu Kai, et al. Risk analysis and regionalization of wind hazard to sunlight greenhouse in Beijing. Journal of Natural Disasters. 2012; 21: 43-49.
16. Zaiqiang Y, Yujuan F, Jing Z, Haijing H, Jing Z. Spatiotemporal distribution features of sparse sunlight disaster of facility agriculture in Jiangsu Province. Journal of Northeast Agricultural University. 2012; 43, 64-69.

17. Pang MD, Qiao LX. Disaster prevention and reduction technology of greenhouse vegetables. Hebei Science and Technology Press, Hebei. 2011; 54-55.

18. LIU Shu-mei, XUE Qing-yu, LI Zhen-fa, LI Chun, GONG Zhi-hong, LI Ning. An air temperature predicts model based on BP Neural networks for solar greenhouse in North China. Journal of China Agricultural University. 2015; 20: 176-184.

19. Li TL. Theory and practice on vegetable cultivation in solar greenhouse. China Agriculture Press. 2013; 163-174.

20. Yu H. The research on the disaster of low temperature and spare sunlight of vegetables seeding in Greenhouse - tomato and cucumber for example. Shenyang Agricultural University, Shenyang. 2012; 1-49.

21. Ling YX, Wang FC. Cultivation technology of cucumbers in solar greenhouse. Hebei Science and Technology Publishing House. 2009; 12-16.

22. Chen XY. One hundred questions about key technology of cucumber production in greenhouse. Chemical Industry Publishing House. 2013; 45-46.

23. Li Zhenfaa, Wang Tieb, Gong Zhihongc, Li Ningd. Forewarning technology and application for monitoring low temperature disaster in solar greenhouses based on internet of things. Transactions of the Chinese Society of Agricultural Engineering. 2013; 29: 229-236.

Austin Food Sci - Volume 1 Issue 4 - 2016
Submit your Manuscript | www.austinpublishinggroup.com

Citation: Chen S, Liu F, Li Z, Yang S, Li M, Wang T, et al. Risk Evaluation of Solar Greenhouse Cucumber Low Temperature Disaster in Tianjin, China. Austin Food Sci. 2016; 1(4): 1017.