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THE COLD AND HOT DAMAGES TO THE CITRUS IN THE THREE GORGES AREA OF THE CHANGJIANG RIVER

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ABSTRACT: Starting from the research on and collection of the damaging factors and index of the cold and hot damages to citrus, this paper systematically studies the apparent properties in temporal and spatial distribution, differences, relationship of the two kinds of disasters and their impact on citrus production in the Three Gorges area in Hubei. It also reveals the important fact that it is warmer in winter and hotter in spring since the 1980s, which is the cause of departing to two poles of the cold and hot damages, and discusses the alleviating effect to the disasters by the Three Gorges Project. Finally some countermeasures are proposed.

KEY WORDS: the Three Gorges of the Changjiang River, cold and hot damages, citrus, climatic change

I. INTRODUCTION

The Three Gorges of the Changjiang (Yangtze) River, lying in the mountainous parts of western Hubei and eastern Sichuan, is one of the main production bases of citrus and good oranges in China, and the leader of "the citrus belt along the Changjiang River".

The Three Gorges area in this pater is only limited in Yichang Prefecture and Badong County of Hubei Province, including ten counties and one city (Fig.1). In the area, cultivated area and yearly yield of citrus have made up a great amount of the whole province's total, 19.5% and 90.0% in 1976, 32.3% and 28.8% in 1990, and increased 2.5 and 5.1 times respectively in the last fifteen years. The good orange yield is 65%-85% of the citrus's total yield in the area. With the warming of climate and the beginning of the Three Gorges Project, citrus production will develop rapidly from now on.

This area is known for warmer winter and low freezing frequency, but freezing injuries to citrus have happened accidentally. For cultivated area expansion, ratio of tender species rising and orangery moving higher recently, same minimum temperature (T_{min}) now a days will lead more loss, such as in 1991.

Since 1978, citrus in the area have been hurt by abnormal high temperature in bloom and the yield decreased heavily. For example, maximum temperature (T_{max}) of Zigui and Xingshan got to 40.8℃ and 40.3℃ in 3rd of May, 1988, which lead serious dropping of flowers and fruits, even the yield (72.4%). Freezing and heating injuries have deciduous influences on citrus production and development, so research is very needed and urgent.

Fig.1 Geographic distribution of the Three Gorges area of the Changjiang River in Hubei Province

II. COLD DAMAGE TO CITRUS IN THE THREE GORGES AREA

1. Cause of Warm Winter in the Area

The area is defined as the most suitable region in the division of the citrus (climate) in China [1-2], for T_{min} here is mostly among −5℃ and 2℃, which is equal to north tropical belt, and make the area become one of the warmest centers in Hubei Province, even in China. This azonal phenomenon has been explained by researchers with three points [3-4]:

(1) Topography: there are several high mountains in north and south, which break the cold air from north and make air from south warm when dropping, and phenomenon of temperature version on slope exists. (2) Water: water coming from Sichuan is warmer and continuously give a great amount of heat and vapour to the air, "green house effect" is notable with high humid. (3) Weather: southeastern warm trough stretches just to the east edge of the area to protect it from cold air in winters of some years.

The area will be affected by cold air and bear freezing injury, if weather is not so good, like 1977 and 1991. Great differences of distribution of topography and water in time and space, adjustment of climate, way and strength of cold air [5], make outstanding change of temporal and spatial distribution of freezing injuries.

2. Selection of Damaging Factors and Index

Damaging factors to citrus includes meteorological, biological, geographic condition and managing level, etc., but the factor resulting cold damage to citrus in large scale is extreme T_m [6-7], the critical low temperatures to make serious loss for various species are different (*Citrus natsudaidai*: −5℃, *Citrus sinensis*: −7℃, *Citrus unshu*: −9℃).

3. Spatial Distribution of Cold Damage to Citrus in the area

3.1 Comparison of four times of serious freezing injuries

There are four times of serious freezing damages to citrus happening in Hubei Province even in the Changjiang River valley. The whole area bore freezing damage heavily only in 1977, and freezing damage were light inside the valley of the areaand heavy out of it in 1955, 1969, 1991, which shows that winter's warmness inside is clear.

In 1955, almost no injury happened inside the gorges (short for "inside"), for T_{min} of Badong was only −3.4℃ and major species was cold-hardy *C. unshu*. In the mouth of the Gorges (short for "mouth"), T_{min} of Yichang, only −6.2℃, might produce 0–2 grades of freezing damages to citrus. Outside the gorges (short for "outside"), little citrus were planted so the lose was little. In 1969 besides no harming to Zigui with T_{min}=−4℃, orange trees inside such as in Xinshan and Badong were surely injured; out of the gorges (short for "out"), citrus were seriously frozen, especially in Yuanan, Dangyang, etc.. In 1977, inside, T_{min} got −8.9℃ — −9.4℃; out side, T_{min} was −12.0℃ — −19.0℃. It is a kind of destroyed calamity to citrus which may reappear over a century, many grown-up and strong citrus trees were frozen to die. In 1991,in west of Yichang and Zhicheng(inside and mouth), T_{min} < −6.9℃, among them, Zigui and Changyang only −3.4℃ and −4.0℃, so harm was very

slight. Outside got −7.0℃ — −9.0℃, together with aridness and early coming of low temperature, freezing grades of most citrus got 3–4. The cultivated area has expanded times in last fifteen years, so the total loss exceeded any frozen years. Average interval between two heavy freezing accidents is eight to ten years (outside), over fifteen years (inside).

3.2 Division of cold damage to the citrus in the area

Division of freezing damage about the Three Gorges area has ever been discussed in the researches on national, subtropical, provincial and Yichang Prefecture [1-2, 8-10], but all of them were simple and rough. A detailed division of freezing damages of the area is given here (Table 1).

Table 1 Division of the cold damages to the citrus in the Three Gorges area and control cities

Average T_{min}(℃)	Extreme T_{min}(℃)	Frequency of $Tm<-5$℃	*Citrus natsu–daidai*	*Citrus sinensis*	*Citrus unshu*	Composite division: The gorges Grades	Composite division: The gorges Division	Control cities
>0.0		Rare	I	0	0	0	Near the river	
−0.1/ −1.5	>−9.0	>100	II	I	0	I	ZG	
−1.6/ −2.5	−9.1/ −11.0	10	III	II	I	II	BD	ES
−2.6/ −3.5		8–10	IV	III	I		XS, inside YC2	
−3.6/ −4.5	−11.1/ −13.0	5	V	IV	II	III	YC1, YC2, CY, west of ZC	
−4.6/ −5.5		3		V	III	IV	East of ZC, ZJ	
−5.6/ −6.5	−13.1/ −15.0	2			IV	IV	DY	YX, Y
<−6.6	<−15.1	1.5			V	V	WF, YA	WH

Note: 0–none, I–accidental, II–light, III–medium, IV–serious, V–very serious

It is clear from Table 1 that the area possesses all of six grades and differences of freezing injuries among regions and species are prominent: (1) the low part near the river in the valley of the gorges is the warmest place in the whole region and province, where freezing damage is slight, Zigui is the best place with almost no freezing damage if citrus of the various species were planted under limited height. *Citrus. natsudaidai*and *C. sinensis* in other parts and high orangeries need to be protected from freezing injuries. (2) As to mouth, average height of mountains in north and south and winter's warmness decreases

simultaneously, only *C. unshu* can be planted economically and safely. *C. sinensis*can only be experimentally planted, although it takes the secondary place in winter's warmness in the province. (3) Outside can be separated to two kinds of transition and edge region. The first is in the same level as northwest and southeast of Hubei Province called "freezing seriously" in which it was difficult to develop citrus before 1978, for frequency of critical low temperature is high. The second part is the most serious freezing area as Wuhan in plain, citrus shouldn't be treated as main fruit species.

3.3 Local difference

Because the height,direction and gradient of a slope, topography,water and so on have great impact on low temperature especially T_{min}, they can change the pattern of freezing injuries onmiddle and large scales.

1) Height. The freezing degree gets heavier as the orangery rises, so the structure of species, and cultivation method should be adjusted relevantly. Nowadays, the limited heights of *C. natsudaidai, C. sinensis*and *C. unshu* are correspondingly under 300m, 450–500m and 700–800m inside, and the heights for citrus (only *C. unshu*) out is under 400m. But there are some orangery got over the limited heights of species, with very instable and low even none yield. For example, in last several days of 1991, leaves and sprouts of *C. unshu* planted over 500m and *C. sinensis*over 300m were the first to be slightly harmed by low temperature, under the heights no harm to citrus; but in 1977, serious freezing damage happened in almost every corner of the area but the orangeries under 300m[11]. Through analysing the gradient data investigated in the valley of the Three Gorges, we found, in winter, inversion of temperature constantly exists in two layers of 250–370m and 500–800m above the sea level, the total depth of inversion gets 300–400m, difference of temperature in the inversion layer get to about 1.3℃ even to 4.0℃, because of this, navel orange and *C. unshu*trees have been planted successfully as high as about 600m and over 800m in Zigui.

2) Direction of a slope. The orange trees on a slope in south or directed to water get slighter freezing damage. It was investigated in Zigui after the serious freezing injury event in 1977 in the whole area that freezing index to *C. sinensis* was 0.414 and 0.536, correspondingly for slopes near and in the back of the Changjiang River (the direction of the slopes and heights are the same) and 0.4 and 0.53 respectively for upwind and downwind slopes (the height is the same).

3) Topography. Any site like a loudspeaker mouth that the cold air can easily enter but not easily get out will be injured heavier than others, and the site in the mouth of wind will

be injured heavily. There is a deep canyon in Shuitianba Village of Zigui near Xingshan with the direction of NS and the width of the northern part is wider than the southern, so the cold air is still easy to be stopped within it, after the attacking of low temperature and snow in December of 1991, 90% of the citrus leaves died and in summer and fall sprouts were injured heavily or died partly for the loss of water. In contrast, citrus trees in the low place of the Three Gorges weren't affected.

4) Water. The larger the water area, the warmer the winter, so the winter's temperature in valley of the Three Gorges will be higher than that in valleys of the Qingjiang River and the Xiangxi River. By calculating, we found that extreme low temperature in Zigui was 1.5℃ higher than that in Xingshan and freezing index in Zigui was lower than that in Xingshan. Another example is that citrus near Mudian reservoir in Dangyang had full green branches in March of 1992, citrus trees not protected by water got 2–4 grades of freezing injuries.

4. Temporal Changes of Cold Damage to Citrus in the Area

4.1 Changes between decades or years

It is easily seen from Fig.2 that the winter in last twenty years especially the last ten years is warmer than the former twenty years; and the colder the decade, the bigger the difference of low temperature index between years.

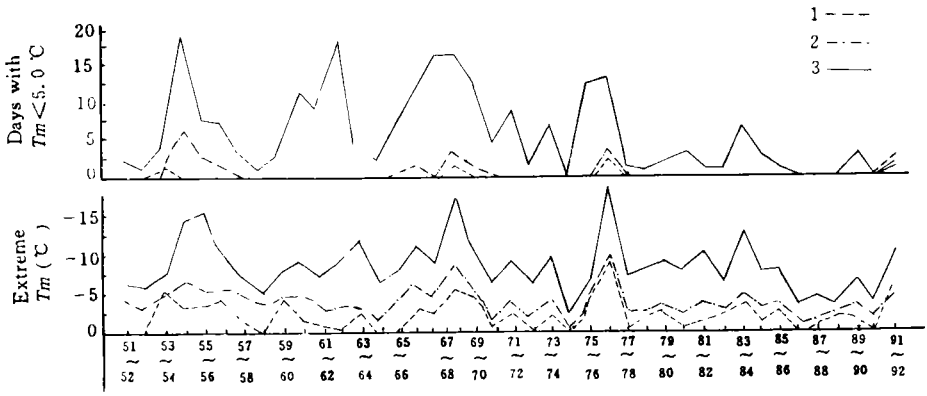

Fig.2 Temporal changes of index of low temperature in winter in the past forty years (1–Badong, 2–Yichang, 3–Wuhan)

4.2 The reappearing time of minimum temperature

There are many researches and different views on the problem of the periodicity of low temperature and freezing damage [4,12], but the results about the reappearing period of injury to citrus by all of research are the same, that is the serious injury event reappearing once every 8–11 years, medium once every 5–6 years. The result from of the gorges is just like these, but inside the serious and medium freezing injuries appear once every 40–100 years and 8–10 years. Since the beginning of the 1980s, the climatic pattern in large scale has changed greatly, that is warmer in winter, which makes the periods calculated using many methods become untrue and no use. We will not take any research about periodicity continuously, but obtain the reappearing years of some items of low temperature in the last forty years and last ten years for comparison, which may be referred by citrus development and improvement of species, etc.

By statistics, extreme $T_{min} < -5℃$ (at least once a year) will reappear more than 10 years inside and over 30 years even 100 years in Zigui; 6 years on the mouth; 2–3 years the outside(Wufeng and Yuanan are in the most frequent).

The event of extreme $T_{min} < -7℃$ only happened once (in 1977) inside in the last forty years, and will reappear every 10–20 years on the mouth, 2–6 years in others.

West of the mouth ever affected by $T_{min} < -9℃$ only once (in 1977),which may reappear over 100 years, outside 15 years even 5–8 years in Wufeng and Yuanan.

Enshi to the inside, northeast and southeast of Hubei to the mouth and outside, and Wuhan to edge (Yuanan), have the same reappearing periods for every kind of freezing grades.

4.3 Change of appearing dates of T_{min}

Appearing dates of the extreme T_{min} in winter have changed in the last four decades, average date in the 1960s was later than that in the 1950s, since then that date has got earlier and earlier, it shifted to 0–11 days earlier (0–3 days inside, 7–11 days out and in control cities) in the 1970s than in the 1960s, 2–14 days (only 0–2 days in Badong but 14 days in Xingshan) in the 1980s compared to the 1970s, especially, the date of T_{min} got as early as the end of December in Wuhan, that is to say, the coldest day is in "1st Nine" not "3rd Nine"(the third nine-day period after the winter solstice, Table 2).

If the extreme T_{min} comes too early, citrus trees do not get into the deepest dormancy,

and is easy to be injured by low temperature. That can better explain the fact that though not too low, T_{min} in December of 1991 had produced very heavy damage and loss.

Table 2 Evolution of appearing dates of T_{min}

Period	Gorges			Control cities	
	BD	XS	YC	Y	WH
1952–1962	17–18/ 1		16/ 1	15/ 1	18/ 1
1962–1972	20/ 1	18–21/ 1	25–27/ 1	21/ 1	23/ 1
1972–1982	17–20/ 1	19/ 1	18/ 1	12–17/ 1	12/ 1
1982–1992	17–18/ 1	5/ 1	12–22/ 1	17/ 1	31/ 12–3/ 1

III. THE HOT DAMAGE TO CITRUS IN THE THREE GORGES AREA

1. Hot Damage and Its Appearing Date [13]

Hot damage represented the high temperature in midsummer and its damage to citrus trees and green fruits before 1978, but now surely the high temperature in blossom and its damage to citrus (make flowers and young fruits drop abnormally).

Since 1978, citrus in the whole valley of the Changjiang River have experienced serious injuries of abnormal high temperature in flowering and fruit-growing periods (1978, 1981, 1985, 1988, 1990), and there were certain damages in 1979, 1984, 1986 in small scale. Yield in those years decreased heavily and frequently, which surpasses freezing damage.

A citrus tree has very large number of flowers, but most of them drop in development, especially in full bloom (as high as 75%–90%). Any abnormal dropping has decidable effect on fruit-seated percentage and yield. High temperature in full bloom mostly concentrate in last ten days of April to first ten days of May makes shortage of nutrient supply, but the nutrient in flowers and fruits is absorbed away by leaves and sprouts, the flowers and fruits have to drop.

A famous Japanese citrus scientist ever listed five kinds of causes leading flowers and fruits to drop,but no high temperature. This phenomenon was investigated in America early in the 1930s and the 1940s but the deep research on it was not carried on which may indicate the problem in U.S.A. is not serious.

2. Research on Harming Factors and Their Indexes

A research by Chen [14] systematically revealed the key periods and factors which were concerned with abnormal dropping of flowers and fruits of *C. unshu* in Yichang. (1) Key periodsrefer to the peak point of dropping or flowering (5 days early and 2–3 days later) or first ten days of May. (2) Key factors include high temperature, low humidity, continuous aridness, strong evaporation, southern wind like fire. The most important is high temperature. Strong sunshine and daily differences of air temperature etc. are also harming factors, but certain amount of rainfall can lessen the harm.

Wan(1992) got the same result in Zigui. Huang (1991) advanced that factors for division should be simple,which were daily T_{max} and its continuous days or accumulation of harmful high temperature (AT), evaluating factors should be overall, which include average and maximum temperature, relative humidity and wind velocity at 14:00.

Every factor's index determined or supplied by many researches differs greatly, such as T_{max} from 28℃ to 37℃ (mostly 30℃, 32℃, 35℃); Huang thought that damaging index of every factor in blossom and young fruit period should be different.

In consideration of the availability of data, we adopt AT proposed by Huang as identifying factors but critical temperature is 30℃ (not 28℃) and AT is 7.5℃ (not 6.0℃) and AT is divided into five grades <0℃, 0℃–7.5℃, 7.6℃–15.0℃, 15.1℃–30.0℃, >30.1℃, correspondingly to none,light,medium,serious,very serious damages; and once a day $T_{max}\geq 35$℃ and five days with $T_{max}\geq 30$℃ is referred as over medium damage.

3 Distribution of Hot Damages to Citrus in the Area

3.1 Comparison of several times of seriously hot damages in the 1980s

Greatly hot injuries to citrus happened in 1981, 1985, 1988 in China, but we discovered that hot injuries in the gorges even in the whole province were as serious as in the whole valley of the Changjiang River; but happened partly in 1985.

In 1981, extreme T_{max} in blossom got 38.9℃ and 39.5℃ in Zigui and Xingshan respectively , hot injuries inside were very serious; Wufeng and Enshi were in medium degree, other places bore serious damage.

In 1984, Only inside were affected by medium (Badong) to serious damage. T_{max} of

Xingshan got 35.3℃.

In 1985, West of mouth and southwest of Hubei Province endured medium to serious hot injuries, yield declined. But yield in the whole area increased 17%. Extreme T_{max} was only 34.8℃ (not over 35.0℃).

In 1986, Very serious damage appeared in the west of mouth and northwest of Hubei Province, medium in others.

In 1988, west of Yichang got very serious degree, outside and southeast of Hubei Province were seriously damaged, Wufeng and other control cities endured medium harm. Abnormal high temperature came in the end of April to the early May rapidly, which made the dropping rate of flowers and fruits as high as 95%–100%. Yield in the area and the whole province in 1988 decreased 72% and 94% compared to 1987, which was much worse than that in 1977 by cold damage.

So three times' serious hot damage in the Gorges should be at 1981, 1986, 1988, they all happened in the 1980s, the most serious year was 1988; regional difference are very clear, that is, hot injuries inside was heavier than out and, the damage centrewas just consistent with that of freezing damage. So we easily deduce that serious hot injury center formed in the valley of the gorges is concerned with topography, water and weather.

3.2 Division of hot damage in the area

According to Table 3 and above analysis, some conclusions are as follows: regional differences of hot injuries in the gorges is obvious; the low part of the river valley inside is the hot center in the whole area, provinces even China, and Xingshan is the most serious; hot injuries become lighter as getting out from inside equal to that of control cities (northwest is little bit heavier than others and equal to Badong); hot injuries in Wufeng is very tender because of its high altitude; regional disparity in hot and cold injuries to citrus in the gorges is inverse.

3.3 Local differences

There are local differences for hot injuries just as the cold ones.

1) Height. Generally the temperature (in blossom) drops and rain increase, hot injury get tender, if the height rises (Table 4), but in preceding days, the temperature falls as height rises, the peak flowering period postpone. Furthermore, inversion layers of temperature still exist in spring just as in winter, so the total heat and high temperature in the preceding and

flowing periods on the top of or in it are higher than that in the bottom, injury and lost are heavier.

Table 3 Division of the hot damage of citrus in the Three Gorges area and control cities

Grade	Degree	Average T_{max} every year(℃)	Yearly average days with T_{max} > 30℃	T_{max}(℃)	Division						
					Gorges				Control cities		
0	None	<28.0	0	<30	Inside, over 700 m						
I	Very light	28.1–29.5	<1, >0	30.0–34.0	WF						
II	Light	29.6–30.5	1.1–1,9	34.0–36.9	ZJ						
III	Medium	30.6–31.5	2.0–2.9	35.0–38.9	DY	ZC	YC	YA	ES	WH	YX
IV	Serious	31.6–32.5	3.0–3.9	38.0–	CY	BD			Y		
V	Very serious	32.6–33.5	>4.0	>40.0	ZG						
		>33.6			XS						

Table 4 Gradient of high tempreture with height during blossom in the valley of the Gorges (1983–1985)

Place	Height (m)	T_{max} (℃)		Yearly average AT (>30℃)	Days			
		Mean	Extreme		T_m>30℃	Total (%)	T_m>35℃	Total (%)
ZGM	150	34.8	35.8	16.6	15	26	1	25
XSM	272	35.3	35.7	19.9	24	42	3	75
XSH	460	33.5	33.8	9.0	15	26	0	0
QH	770	30.2	30.6	0.5	3	5	0	0
SCX	1050	29.1	29.9	0	0	0	0	0

Notes: ZGM—Zigui Meteorological Station; XSM—Xingshan Meterological Station;

XSH—Xingshan Husbandry Institute; QH—Qinghua Station; SCX—Shicaoxi Agricultural Institute

2) Local topography. Any lowland such as valley and basin especially the bottom of a basin is easily heated in daytime, which makes temperature rise rapidly and help that place

become "hot lake" (in contrast with "cold lake" in early morning or night in winter) , and hot harm is more serious than slope, mount or plain, such as Xingshan county, seated in the bottom of a steep basin, had recorded the highest T_{max} in the history in the whole province (43.1℃), and from Table 6, it is seen that all indexes of damaging factors (except for extreme T_{max}) are higher than Zigui.

3) Water body. Average air temperature around the big water body in winter and spring is higher, which makes the blossoming period come earlier and have lower frequency coming with abnormal high temperature. Therefore, daily T_{max} drop down just like the tendency in summer, and the orangery can be easily irrigated when it is high temperature.

4) Differences in small scale. It was investigated [15] that the temperature and hot injury to citrus on southwestern slope were higher than on northern slope in the gorges in 1988 and seated rate of fruits on shining southeast slope is lower than on northern slope in the orangery of meteorological observation of Yichang Prefecture in 1986 [16] . Hot injury is more serious on southwestern part of a tree than northern part or outside of a tree than inside of a tree or with green grasses under a tree than with bare land. The bad condition on citrus can be improved by irrigation and covering, such as the experiment orangery in Pengjiapo of Zigui didn't appear the phenomena of abnormal dropping of flowers and fruits in 1988, because of spraying water on trees.

4. Temporal Changes of Hot damage to Citrus in the Gorges

4.1 Yearly and decadal changes

It is obtained from Fig.3:

(1) Yearly index of harming high temperature in blossom vary greatly. For example, in Yichang the years with $T_{max} \geqslant 30$℃ lasting over 5 days are: 1953, 1960–1961, 1981, 1986, 1988 but none in 1955, 1957, 1959, 1962–1963, 1970, 1973–1977, 1980, 1987.

(2) The hot injuries may be heavy or light for several years continuously in Yichang, there were heavy injuries in 1951–1953, 1960–1961, 1966–1969, 1981–1988, and light ones in 1955–1959, 1962–1965, 1970–1980. The cold injuries don't have this property.

(3) Differences of yearly hot injury were big in the 1950s and the 1960s, and small in the 1970s and the 1980s.

(4) Hot injuring index between decades varies greatly, which were equally average level in the 1950s and the 1960s, hot injuries happen only in one or two years. In the 1970s, the

event of T_{max}>35℃ happened only in Yunxian two times among all stations. After entering the 1980s, temperature in blossom got high abnormally, hot injuries were serious.

4.2 Reappearing periods of hot injuries

By analysing the long series of high temperature and relative indexes, we think that hot injuries have certain periodicity and yearly differences; reappearing period with T_{max}>30℃ lasting over 5 days is 2–5 years inside (Xingshan the shortest, only 2 years); 6–8 years out (none in Wufeng for too high); <5 years in Yunxian, 6 years in Yangxian, 9 years in Enshi, 13 years in Wuhan.

The reappearing periods of high temperature have shorten greatly in the 1980s, < 2 years inside (only 1.3 years in Xingshan), 2 years in Yuanan and Yunxian, 2.5 years in Zhicheng and Dangyang, 3–4 years in others except Yunxian.

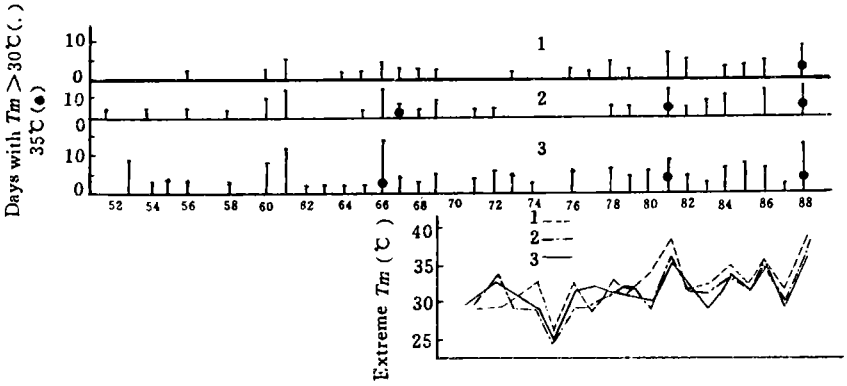

Fig.3 Temporal changes of indexes of high temperature in blossom (from 21st of April to 10th of May) in the past 40 years (• 30℃, ⊙35℃, others as Fig.2)

IV. CONCLUSION AND COUNTERMEASURES

1) Spatial distribution of freezing and heating damage are both very noticeable, and the pattern and gradient tendency of two harms are opposite, which is unique in the whole province and China. West of the mouth of the Three Gorges is the warmest in winter and the hottest in spring with the lightest freezing injury, and heaviest heating injury in the whole area and province. From the inside to the mouth and outside, cold and hot damages are getting more serious and lighter respectively; in the plain area, the cold damage is the most serious and hot damage is the lightest.

2) Temporal change of two harms is also apparent, which is as the same as the whole

province and China. Besides very serious freezing damage in 1977, the inside were affected only lightly in 1955, 1969 and 1991. Citrus production of the area were heavily damaged by abnormally high temperature in 1981, 1986, 1988 and 1990. In 1978, 1984 and 1985, hot injuries to citrus happened only in small area. Except for the yearly difference, there were changes between decades for the disasters. Freezing damage were very serious in the 1950s and the 1960s, very light in the 1980s (none inside), and medium in the 1970s. Hot damage appeared in some years in the 50's and the 1960s, almost none in the 1970s, frequently and heavily in the 1980s.

3) There were local differences for the two disasters. Height, slope direction and gradient, water, temperature inversion etc. can change their patterns, and the Three Gorges Project can reduce the disaster.

4) Winter and spring became warmer and hotter in the 1980s, which made the cold damage lighter and hot damage heavier.

Extreme T_{min} lower than critical injuring temperature appearedin a short time such as the serious cold injury in December of 1991, although the winter still keep warm in the early of the 1990s. Preventing citrus from freezing damage shall be paid attention in the future, including species arrangement, height selection, cold-relief cultivation and so on. Frequency and loss of hot damage to citrus in the area are so high that more attention should be paid to the research and preventing methods include irrigation project, biological controlling technique (the medicine keeping for flowers and fruits), breeding and selecting species flowering early or hot-resistant species and hot-relief cultivation, etc.

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