

# The Influences of Phenology on the Order of 24 Solar Terms in Ancient China

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**Abstract** The 24 solar terms is an important part of the traditional Chinese calendar system. However, when studying the existing historical literature which contains the 24 solar terms, we find that, as dynasty altered, its name and order changed. Scholars commenced discussing the reasons of these changes from the Eastern Han 東漢 dynasty (A.D. 25—220), but it has still not been solved. In this paper, by analyzing the viewpoints of ancient scholars on this topic, we try to find out the reasons why they didn't break through. Based on these reasons, then we discriminate the editions of *Yizhoushu·Shixunjie* (逸周書·時訓解) and *Huainanzi·Tianwenxun* (淮南子·天文訓), the relations of Waking from hibernation (Qizhe 啓蟄) and Excited insects (Jingzhe 驚蟄), as well as tease out the evolution process of the names and orders of “Rainwater (Yushui 雨水) and Excited Insects”, “Grain rains (Guyu 穀雨) and Pure and bright (Qingming 清明)” recorded in the literature of the 24 solar terms. From the above we can come to the conclusion that the 24 solar terms has been changed four times in ancient China, and reveal that the order of solar terms is related to phenology, but it is not completely determined by the order of corresponding to phenology.

**Keywords** the order of 24 solar terms, Waking from hibernation, Excited insects, phenology

When studying the ancient Chinese calendars, we find that the names and orders of 24 solar terms recorded in the existing calendars were not uniform. Such as, in the *Taichu Li* (太初曆, 104B.C.) of the Western Han 西漢 dynasty (202 B.C.—9 A.D.) the records of 24 solar terms is: “立春、驚蟄、雨水、春分、穀雨、清明……”<sup>1</sup> in the early Tang 唐 dynasty (A.D. 618—907), Li Chunfeng 李淳風 recorded 24 solar terms in the *Linde Li* (麟德曆, 665A.D.) is: “立春、啓蟄、雨水、春分、清明、穀雨……”<sup>2</sup> the records of 24 solar terms in the *Shoushi Li* (授時曆, 1281A.D.) of the Yuan 元 dynasty (A.D. 1271—1368) is: “立春、雨水、驚蟄、春分、清明、穀雨……”<sup>3</sup>

Since these three calendars are all included in the official history of ancient China, they are reliable. However, we find that the names and orders of 24 solar terms in these three calendars are not exactly the same. Therefore, in this paper we want to solve such several questions as follows: Is this a transcription error? If not, so, which one is the real order of the 24 solar terms? And why did the order of 24 solar terms change in ancient China?

## 1 Background

### 1.1 The records of relevant literature

We divide the relevant literature into non-calendar literature and calendar literature. Non-calendar literature mainly include the relevant records in *Yizhoushu·Shixunjie* (逸周書·時訓解), *Huainanzi·Tianwenxun* (淮南子·天文訓), *Yitongguayan* (易通卦驗) and *Zhoubisuanjing* (周髀算經). The time span is about from the third century B.C. to the first century A.D. Calendar literature mainly include the relevant records in these existing calendars from *Taichu Li* to *Shoushi Li*. They are mostly presented in the form of astronomical tables. The time span is from 104 B.C. to 1281 A.D. Then we

will introduce them respectively.

In the non-calendar literature, *Yizhoushu-Shixunjie* was written in about the third century B.C. We can see that each solar term in the text corresponding to three phenology.<sup>4</sup> *Huainanzi-Tianwenxun* was written in 139 B.C. The text records the positioning principle of 24 solar terms and mentions that the interval between each solar term is 15 days.<sup>5</sup> In *Yitongguayan*, the text records the phenology and the length of the solar shadow corresponding to the 24 solar terms.<sup>6</sup> *Zhoubisuanjing* records the length of the solar shadow corresponding to the 24 solar terms.<sup>7</sup>

We sorted out the order of 24 solar terms in the above four non-calendar literature. The changing parts are shown in Table 1, the order of the other solar terms are the same, so, they are omitted here.

**Table 1 The comparison table of 24 solar terms in these non-calendar literature**

《逸周書·時訓解》 (about the third century B.C.)	《淮南子·天文訓》 (139 B.C.)	《易通卦驗》	《周髀算經》 (about 100 A.D.)
Excited insects (Jingzhe 驚蟄)	Rainwater (Yushui 雨水)	Rainwater (Yushui 雨水)	Rainwater (Yushui 雨水)
Rainwater (Yushui 雨水)	Excited insects (Jingzhe 驚蟄)	Excited insects (Jingzhe 驚蟄)	Waking from hibernation (Qizhe 啓蟄)
Spring equinox (Chunfen 春分)	Spring equinox (Chunfen 春分)	Spring equinox (Chunfen 春分)	Spring equinox (Chunfen 春分)
Grain rains (Guyu 穀雨)	Pure and bright (Qingming 清明)	Pure and bright (Qingming 清明)	Pure and bright (Qingming 清明)
Pure and bright (Qingming 清明)	Grain rains (Guyu 穀雨)	Grain rains (Guyu 穀雨)	Grain rains (Guyu 穀雨)

In addition, we also sorted out the order of 24 solar terms in all the existing calendars. Similarly, the changing parts are shown in Table 2. It should be noted that after *Donghansifen Li* (東漢四分曆, 85 A.D.) the order of the 24 solar terms remains unchanged until *Daye Li* (大業曆, 597 A.D.), and the order of the 24 solar terms in the calendars after the *Dayan Li* (大衍曆, 729 A.D.) has not changed till now.

**Table 2 The comparison table of 24 solar terms in the existing calendars**

《太初曆》 104 B.C. (《三統曆》)	《東漢四分曆》 85 A.D.	《大業曆》 597 A.D.		《皇極曆》 604 A.D.	《戊寅元曆》 619 A.D.	《麟德曆》 665 A.D.	《大衍曆》 729 A.D.
		入氣盈縮數表	日出、入時刻表				
Excited insects	Rainwater	Rainwater	Waking from hibernation	Rainwater	Waking from hibernation	Waking from hibernation	Rainwater
Rainwater	Excited insects	Waking from hibernation	Rainwater	Excited insects	Rainwater	Rainwater	Excited insects
Spring equinox	Spring equinox	Spring equinox	Spring equinox	Spring equinox	Spring equinox	Spring equinox	Spring equinox
Grain rains	Pure and bright	Pure and bright	Pure and bright	Pure and bright	Pure and bright	Pure and bright	Pure and bright
Pure and bright	Grain rains	Grain rains	Grain rains	Grain rains	Grain rains	Grain rains	Grain rains

To sum up, no matter in the non-calendar literature or calendar literature, the inconsistent order of 24 solar terms only on two groups: the first is Excited insects (Jingzhe, 驚蟄) and Rainwater (Yushui, 雨水); the second is Grain rains (Guyu, 穀雨) and Pure and bright (Qingming, 清明).

## 1.2 The views of past dynasties scholars

Firstly, as for the editions of *Huainanzi-Tianwenxun* and *Yizhoushu-Shixunjie*, previous scholars

have been talking differently but no conclusion. In *Wulitongkao* (五禮通考), Qin Huitian 秦蕙田 speculated that these two literature were changed by later generations, but no elaborated.

秦蕙田 (1702—1764) 《五禮通考》中言：“《時訓》一篇亦後人所託。惟《淮南子》係武帝時書，疑亦後人以時術追改之，非《淮南》之舊也。”<sup>8</sup>

Secondly, as for the relationship between Waking from hibernation (Qizhe, 啓蟄) and Excited insects (Jingzhe, 驚蟄), there are two main explanations:

One is that they were regarded as the 24 solar terms at the same time. Du Yu 杜預 said in *Chunqiuishili* (春秋釋例), in the first month, Beginning of spring (Lichun, 立春) as the nodal solar terms, Waking from hibernation (Qizhe, 啓蟄) as the medial solar terms. In the second month, Excited insects (Jingzhe, 驚蟄) as the nodal solar terms, Spring equinox (Chunfen, 春分) as the medial solar terms. In the third month, Clear and bright (Qingming, 清明) as the nodal solar terms, Grain rain (Guyu, 穀雨) as the medial solar terms.

杜預 (222—285) 《春秋釋例》中言：“正月節立春，啓蟄為中氣。二月節驚蟄，春分為中氣。三月節清明，穀雨為中氣。”<sup>9</sup>

The other explanation is that in the Han dynasty, to avoid the name of emperor Jingdi 漢景帝, scholars changed Waking from hibernation to Excited insects. In *Kunxuejiwen* (困學紀聞), Wang Yinglin 王應麟 believed that the reason for changing Waking from hibernation to Excited insects is to avoid the name of emperor Jingdi of the Han dynasty.

王應麟 (1223-1296) 在《困學紀聞》中言：“改啓為驚蓋避景帝諱”。<sup>10</sup>

Thirdly, the reasons for the change in the order of Excited insects and Rainwater.

Cai Yong's 蔡邕 opinion is that the order of the solar terms was determined by the corresponding phenology order.<sup>11</sup> However, Chen Xiangdao 陳祥道 didn't agree with Cai Yong's opinion. He believed that although phenology was related to solar terms, it was not a one-to-one relationship.<sup>12</sup> Ji Huang's 嵇璜 opinion is that the order of the solar terms should be better matched with climate.<sup>13</sup>

Therefore, by analyzing these scholars' views, we can tell why they were unable to completely solve the problem of the reasons of changing the order of 24 solar terms?

To begin with, they didn't correctly distinguish the editions of *Yizhoushu·Shixunjie* and *Huainanzi·Tianwenxun*.

Next, their explanations of the relationship between Waking from hibernation and Excited insects are inaccurate.

Finally, they mistakenly thought the order of Excited insects and Rainwater are entirely determined by the corresponding phenology order and believed that it was caused by a single factor, such as phenology or climate.

## 2 The reasons for the change of 24 Solar Terms

Based on these discussions, we analyze the reasons for the change of 24 solar terms from the following three aspects: discrimination of early literature editions; discrimination of the relationship between Waking from hibernation and Excited insects; phenology and solar terms.

### 2.1 Discrimination of early literature editions

Scholars still have disputes on whether the order of the 24 solar terms in *Yizhoushu·Shixunjie* and *Huainanzi·Tianwenxun* were changed by later generations. Here we will make a judgment by discussing whether the content in the text is consistent with the social background at that time.

We know the *Huainanzi* is a literature in the Western Han dynasty. At that time, the order of the

solar terms is Excited insects first, then Rainwater. But in the existing *Huainanzi-Tianwenxun*, the order is Rainwater first, then Excited insects.

*Yizhoushu-Shixunjie* is the pre-Qin literature. At that time, the solar term Waking from hibernation (Qizhe, 啓蟄) didn't need to be avoided the name of the emperor Jingdi 漢景帝, and the word Excited insects (Jingzhe, 驚蟄) has not yet appeared, but what we see in the existing text is Excited insects (Jingzhe, 驚蟄). Moreover, the records of phenology in *Yizhoushu-Shixunjie* are also different from that of the same period.

Therefore, we believe that the existing editions of these two literature are not original, that's to say, the order of the 24 solar terms has been changed by later generations. Here, we correct the order of solar terms in these two literature, as shown in red on Table 3.

**Table 3 The order of solar terms in the original editions of these two literature**

Name of literature	Time		the order of <b>Excited insects</b> and <b>Rainwater</b> and <b>Grain rains</b> and <b>Pure and bright</b>			
<i>Yizhoushu-Shixunjie</i> 《逸周書·時訓解》	about the third century B.C.	In the Pre-Qin Dynasty	Excited insects <b>Waking from hibernation</b>	Rainwater <b>Rainwater</b>	Grain rains <b>Grain rains</b>	Pure and bright <b>Pure and bright</b>
<i>Huainanzi-Tianwenxun</i> 《淮南子·天文訓》	139 B.C.	In the Western Han Dynasty	Rainwater <b>Excited insects</b>	Excited insects <b>Rainwater</b>	Pure and bright <b>Grain rains</b>	Grain rains <b>Pure and bright</b>
<i>Taichu Li</i> 《太初曆》	104 B.C.		Excited insects	Rainwater	Grain rains	Pure and bright

## 2.2 Discrimination of the relationship between Qizhe 啓蟄 and Jingzhe 驚蟄

In the history of Chinese agriculture, Waking from hibernation (Qizhe, 啓蟄) and Excited insects (Jingzhe, 驚蟄) are special. Waking from hibernation is the only one with dual concepts of phenology and solar terms, while Excited insects is the solar terms that replaces Waking from hibernation, but its corresponding phenology and time have changed.

**Table 4 The records related to Qizhe in the ancient classical literature**

<i>Xiaxiaozheng</i> 《夏小正》 about the 11th century B.C.	正月啓蟄。 故以啓蟄為建寅之月。
<i>Zhouli-Kaogongji</i> 《周禮·考工記》 about the 6th century B.C.	凡冒鼓，必以啓蟄之日。 康成注：啓蟄乃孟春中氣也。
<i>Zuozhuan</i> 《左傳》 about the 4th century B.C.	啓蟄而郊，郊而後耕。 啓蟄為建寅之月。
<i>Guoyu-Luyushang</i> 《國語·魯語上》 about the 3rd century B.C.	古者大寒降，土蟄發，水虞于是讲罴罝。 韦昭注：土蟄發，謂孟春建寅之月，蟄始振也，皆以啓蟄為正月。
<i>Liji-Yueling</i> 《禮記·月令》 about the 3rd century B.C.	孟春之月，蟄虫始振。 是啓蟄在正月。

At the beginning, Waking from hibernation (Qizhe, 啓蟄) appeared as a phenology, such as in *Xiaxiaozheng* (夏小正), “正月啓蟄”, means the first phenology in the first month.<sup>14</sup> By the time of *Zhouli-Kaogongji* (周禮·考工記), Waking from hibernation appeared as the medial solar terms in the first month.<sup>15</sup>

The above Table 4 collects the records related to Waking from hibernation (Qizhe, 啓蟄) in the ancient classical literature. We can see that whether it is a phenology or solar term, it is in the first month, and the corresponding natural phenomenon is that insects begin to wake up from hibernation. However, insects have not yet crawled out of the ground. Therefore, it is not easy to be observed. This phenomenon was confirmed by the literature of Xu Bozheng 许伯政.

清代许伯政 (1700—1784) 《全史日至源流》中云：“正月啓蟄，雉震响，《大戴》注云，‘正月必雷，雷不必聞，惟雉聞之。’盖三陽氣至雷，雖未出地，發聲而已，動于地下，故土氣震發，蟄蟲爲之昭蘇。”<sup>16</sup>

Through the study of *Liji·Yueling* (禮記·月令),<sup>17</sup> *lvshichunqiu·Shierji* (呂氏春秋·十二紀)<sup>18</sup> and other literature, we find that the ancients observed activities of insects in detail, and also defined activities of insects in different periods very clearly. In the early literature on phenology, there are four phenology involving the activities of insects, as follows: dormant insects begin to stir (蟄虫始振) in the first month; dormant insects all stir (蟄虫咸動) in the second month; hibernating insects close entrances to their burrows (蟄虫坯戶) in the eighth month; and hibernating insects all burrow in (蟄虫咸俯) in the ninth month.

Except for the *Yizhoushu·Shixunjie* and *Huainanzi·Tianwenxun*, which were changed by later generations. At present, Excited insects (Jingzhe, 驚蟄) first appeared in the *Taichu Li* (太初曆, 104B.C.) of Western Han dynasty. At that time, Excited insects as the medial solar terms in the first month, the corresponding phenology should be “dormant insects begin to stir (蟄虫始振)”. We can see, in *Shuowenjiezi* (說文解字), “啓, 開也; 驚, 馬駭也”, that is, Qi 啓 means begin, start; Jing 驚 means shock, shake.<sup>19</sup> So it seems that Waking from hibernation (Qizhe, 啓蟄) and Excited insects (Jingzhe, 驚蟄) have different meanings.

Thus, in *Taichu Li*, Excited insects as the medial solar terms in the first month, it is not matched with the corresponding phenology “dormant insects begin to stir (蟄虫始振)”. Later, in the *Donghansifen Li* (東漢四分曆, 85 A.D.), Excited insects was moved to the nodal solar terms in the second month, which matches the second month phenology “dormant insects all stir (蟄虫咸動)”.

Therefore, Waking from hibernation (Qizhe, 啓蟄) and Excited insects (Jingzhe, 驚蟄) are two solar terms with different essential meanings in different periods.

### 2.3 Phenology and Solar Terms

We can divide the period of phenology change into three stages by sorting out the existing relevant literature.

#### **The first stage, from about the third century B.C. to 139 B.C.**

Includes *Yizhoushu·Shixunjie* 《逸周書·時訓解》, *Liji·Yueling* 《禮記·月令》, *lvshichunqiu·Shierji* 《呂氏春秋·十二紀》 and *Huainanzi·Shizexun* 《淮南子·時則訓》. They are the early literature about recording the phenology corresponding to solar terms, or the phenology corresponding to month. Among them, *Yizhoushu·Shixunjie* is the earliest literature to record 24 solar terms and 72 phenology, that's to say, each solar term corresponding to three phenology. The other three literature do not refer to the name of solar term. It records the corresponding phenology of each month, and the number of phenology recorded each month is not same. There are nine at most, and only four at the least.

#### **The second stage, from 523 A.D. to 665 A.D.**

The phenology recorded in the four calendars of *Zhengguang Li* 《正光曆》, *Xinghe Li* 《興和曆》, *Huangji Li* 《皇極曆》 and *Linde Li* 《麟德曆》. *Zhengguang Li* is the first calendar to introduce phenology table (523 A.D.). We find that once the phenology was introduced into the calendar, it strictly followed the rules that each solar term corresponds to three phenology. However, compared with the order of

phenology in the first stage, it has the obviously tendency to move backward in this stage. For example:

Duckweed begins to grow “萍始生” and Hoopoe alight on the mulberry trees “戴胜降于桑”, the first stage was in the third month, while the second stage was in the fourth month;

Earth-worms curl up “蚯蚓結”, Elaphure sheds antlers “麋角解”, Streams and springs stir “水泉動”, the first stage was in the eleventh month, while the second stage was in the twelfth month and so on.

### The third stage, from 729 A.D. to 1281 A.D.

The phenology tables, included in all the existing calendars from the *Dayan Li* 《大衍曆》 to *Shoushi Li* 《授時曆》, are followed the phenological records of the *Yizhoushu-Shixunjie*, and have continued to today.

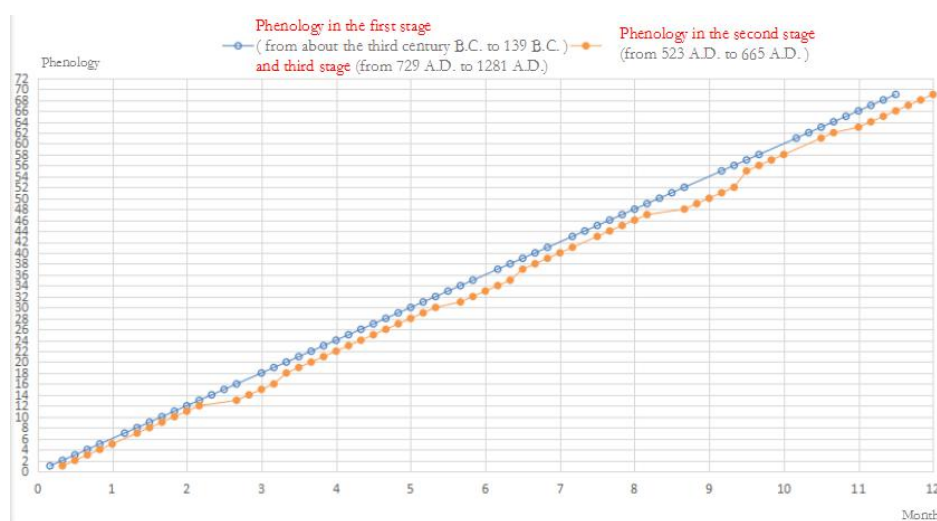


Figure 1 The comparison diagram of phenology order

In this figure above, we can see that the distance of these two curves reflect the degree of move backward of the phenology order in the second stage. In the first two months, these two curves are very close, it means that the phenology of the first two months move backward for only one position. But around September, these two curves are relatively far away, it means that the phenology of around September move backward for four positions, that is, nearly 20 days.

In previous studies, according to the phenology order of the second stage tends to move backward, and in the Great cold (Dahan, 大寒), there is no phenology of the coldest period, “Marshes are thick and solid 水澤腹堅”. Therefore, the scholars speculated that the climate during Northern Wei 北魏 dynasty (A.D. 386—534) has been warm all the time.<sup>20</sup>

On the basis, we know that the climate changes are not stable in history, and there were still great changes in the climate after the *Dayan Li* (大衍曆, 729 A.D.). However, the phenology tables are included in the calendar after the *Dayan Li*, they have not changed. So, our conclusion is that in the early period when phenology was introduced into the calendar, climate changes would cause the change in the phenology order, but after the *Dayan Li*, there is no correlation between climate change and phenology.

In the calendar, the solar terms were first introduced in the *Taichu Li* (太初曆, 104B.C.) of the Western Han dynasty, while the phenology were first introduced in the *Zhengguang Li* (正光曆, 523 A.D.) of the Southern and Northern 南北朝 (A.D. 420—589) dynasties. With a time interval of more

than 600 years. Since the introduction of phenology into the calendar, the order of the 24 solar terms in *Zhengguang Li*, *Xinghe Li*, *Huangji Li* and *Linde Li* was different, but the order of phenology recorded in these four calendars was exactly the same. Similarly, in the *Dayan Li* and the calendars after it, the order of 24 solar terms was different from that in *Yizhoushu·Shixunjie*, but the recorded order of phenology was exactly the same as that in *Yizhoushu·Shixunjie*.

Thus, the solar terms and phenology were introduced into the calendar successively. We find that the changes of the solar terms and phenology were out of sync. That's to say, the relationship between them tended to gradually separate from each other.

### 3 The changing process of 24 Solar Terms in ancient China

Based on the above research results, we summarize the changed part of 24 solar terms in historical records, as shown in Table 5. Here we can see, the names and orders of the 24 solar terms has been changed four times in ancient China.

**Table 5 The comparison table of 24 solar terms in ancient Chinese literature**

Name of literature	Time	the order of <b>Excited insects</b> (驚蟄) and <b>Rainwater</b> (雨水) and <b>Grain rains</b> (穀雨) and <b>Pure and bright</b> (清明)			
<i>Yizhoushu·Shixunjie</i>	about the 3rd century B.C.	Waking from hibernation	Rainwater	Grain rains	Pure and bright
① <i>Huainanzi·Tianwenxun</i>	139 B.C.	Excited insects	Rainwater	Grain rains	Pure and bright
<i>Taichu Li</i>	104 B.C.	Excited insects	Rainwater	Grain rains	Pure and bright
<i>Yitongguayan</i>		Rainwater	Excited insects	Pure and bright	Grain rains
② <i>Donghansifen Li</i>	85 A.D.	Rainwater	Excited insects	Pure and bright	Grain rains
<i>Zhoubisuanjing</i>	about 100 A.D.	Rainwater	Waking from hibernation	Pure and bright	Grain rains
<i>Daye Li</i> (入氣盈縮數表)		Rainwater	Waking from hibernation	Pure and bright	Grain rains
<i>Daye Li</i> (日出、入時刻表)	597 A.D.	Waking from hibernation	Rainwater	Pure and bright	Grain rains
③ <i>Huangji Li</i>	604 A.D.	Rainwater	Excited insects	Pure and bright	Grain rains
<i>Wuyinyuan Li</i>	619 A.D.	Waking from hibernation	Rainwater	Pure and bright	Grain rains
<i>Linde Li</i>	665 A.D.	Waking from hibernation	Rainwater	Pure and bright	Grain rains
④ <i>Dayan Li</i>	729 A.D.	Rainwater	Excited insects	Pure and bright	Grain rains

The first change is the *Huainanzi·Tianwenxun* in the Western Han dynasty. This time change only shows in the name, the order has not changed. In order to avoid the name of Emperor Jingdi of the Han dynasty, Excited insects (Jingzhe, 驚蟄) here replaced Waking from hibernation (Qizhe, 啓蟄).

The second change is the *Donghansifen Li*. We can see the order of Excited insects (Jingzhe, 驚蟄) and Rainwater (Yushui, 雨水) were exchanged, and the order of Grain rains (Guyu, 穀雨) and Pure and bright (Qingming, 清明) were also exchanged. Although the records of the 24 Solar Terms in the *Yitongguayan* are exactly the same as that in the *Donghansifen Li*, *Yitongguayan* as a *Wei Shu* 緯書, is often not accepted because its contents are mostly influenced by later generations and the time for writing is uncertain. Therefore, the time of this change is based on the *Donghansifen Li*.

As we know from the above discussion, Waking from hibernation has been in the first month, when it was changed as Excited insects. Initially, its order has not changed yet and it's still in the first month. However, the phenology of the first month doesn't match the solar term Excited insects. Excited insects was more closely matched with the phenology of the second month “dormant insects all stir (蟄虫咸動)”, so the second change moved it to the second month.

The third change are the *Daye Li* 《大業曆》, *Huangji Li* 《皇極曆》, *Wuyinyuan Li* 《戊寅元曆》 and *Linde Li* 《麟德曆》 during the Sui and Tang dynasties. This time was the chaotic period of the changes of the 24 solar terms. We can see, in the *Daye Li*, there are two records of solar terms in different orders. In addition, we also find that Waking from hibernation (Qizhe, 啓蟄) appeared again as a solar term in this period, and this may be related to the emperor's concept of governing the country at that time. This sign of restoring the ancient method is not only reflected in the change of the 24 solar terms, but also the measurement system in this period also restored the ancient method as standard. Therefore, in the Sui and Tang dynasties, the ancient method regained the attention by the calendar makers and it was introduced into the calendar at that time.

However, Zhang Zhouxuan 張胄玄 has not yet formed a unified understanding of how to restore the ancient method of the 24 solar terms in the *Daye Li*, so there are two different orders of the solar terms. When Liu Zhuo 劉焯 refuted the omissions of the *Daye Li*, he thought that Zhang Zhouxuan's calendar violated the destiny of heaven in terms of solar terms and it was inconsistent with the celestial phenomena. Therefore, he didn't adopt the order in *Daye Li*, but still followed the order in the *Donghansifen Li*. Until the early Tang dynasty, *Wuyinyuan Li* and *Linde Li* gradually reached a consensus, thus these calendars restored to the same order as the *Yizhoushu·Shixunjie*.

The fourth change is the *Dayan Li* of the Tang dynasty, which is changed to the same order as that in the *Donghansifen Li*. And Yi Xing 一行 creatively combined the 72 phenology of the *Yizhoushu·Shixunjie* with the 24 solar terms of the *Donghansifen Li*, which has been used till now.

We find that in the whole changing process of 24 solar terms, Waking from hibernation (Qizhe, 啓蟄) in *Zhoubisuanjing* (周髀算經), whether it was considered to restored the old name, or not to have avoided the name of Emperor Jingdi of the Han dynasty, it was a special case at that time.

## 4 Conclusions

From the above analysis, our main results consists of four parts:

Firstly, we clarify that the Waking from hibernation (Qizhe, 啓蟄) and Excited insects (Jingzhe, 驚蟄) are special solar terms, which are different in terms of their essential meanings and time. Waking from hibernation is the only solar term with dual concepts of phenology and solar terms. It first appeared as a phenology, and then evolved into the medial solar terms in the first month. At that time, other solar terms didn't appear completely. As a result of avoiding the name of emperor Jingdi 漢景帝 of the Han dynasty, Excited insects appeared as a solar term to replace Waking from hibernation. However, its meaning didn't match the corresponding phenology, which led to the change of the order of the 24 solar terms.

Secondly, we can divide the period of phenology change into three stages by sorting out the existing relevant literature, namely, the first stage (from about the third century B.C. to 139 B.C.), except for *Yizhoushu·Shixunjie*, the literature in this stage mainly records the correspondence between month and phenology, with early features in form and content, which were not completely unified; the second stage (from 523 A.D. to 665 A.D.), once the phenology was introduced into the calendar, it strictly followed the rules that each solar term corresponds to three phenology, and the recorded form became stable, mature and complete; the third stage (from 729 A.D. to 1281 A.D.), the phenology tables, included in all the existing calendars from the *Dayan Li* to *Shoushi Li*, are followed the records in the *Yizhoushu·Shixunjie*, and have continued to today.

Thirdly, the solar terms and phenology were introduced into the calendar successively, and then



participated in some specific calculations. We find that the changes of the solar terms and phenology were out of sync. That's to say, the relationship between them tended to gradually separate from each other. The phenology is stable in content and normative in form in the existing calendar. Although it reflects the climate change in a certain period, the overall performance is stable. After the *Dayan Li*, the solar terms and phenology continued in a fixed form.

Fourthly, we find that the names and orders of the 24 solar terms has been changed four times in ancient China, namely, the *Huainanzi·Tianwenxun* (淮南子·天文訓, 139 B.C.) in the Western Han dynasty; the *Donghansifen Li* (東漢四分曆, 85 A.D.) in the Eastern Han dynasty; from the *Daye Li* (大業曆, 597 A.D.) to *Linde Li* (麟德曆, 665 A.D.) during the Sui and Tang dynasties; the *Dayan Li* (大衍曆, 729 A.D.) in the Tang dynasty.

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