Occurrence and Distribution of *Rhinoncus sibiricus* (Coleoptera: Curculionoidea) and Its Preference for Two Buckwheat Species in China

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Abstract

*Rhinoncus sibiricus* Faust, a major pest of buckwheat, has invaded the buckwheat cultivation areas of China for years. This pest was first found in Russia in 1940, causing great damage during the entire buckwheat-growing season. In China, there are few records on *R. sibiricus*, and studies regarding pest damage on buckwheat are unknown. The occurrence and distribution of this species in China is still not clear. We therefore conducted field surveys for 6 yr to identify the distribution range and the degree of pest damage caused by *R. sibiricus* in the buckwheat-planting areas of China and tested its preference for two *Fagopyrum* species in common garden experiments. The results showed that *R. sibiricus* had a larger distribution range in the Northern rather than the Southern part of China, and that pest damage was more serious in northern China. The pest preferred *F. tataricum* (Tartary buckwheat, Polygonales: Polygonaceae) over *F. esculentum* (Common buckwheat, Polygonales: Polygonaceae), but caused damage to both, indicating its potential for distribution in southern China. This study clarified the occurrence, distribution, and damage traits of *R. sibiricus* in the buckwheat cultivation areas of China, which will help explain the pest attack traits and inform strategies for pest control and prediction.

Key words: buckwheat weevil, buckwheat, distribution, cultivation area, insect attack

Buckwheat is a broad-leaved, annual crop belonging to the family Polygonaceae, genus *Fagopyrum*, and origins from China with a long cultivation history which dates back about 4,000–5,000 yr (Ohnishi 1998, Skrabanja et al. 2004, Gondola and Papp 2010). It is widely used as a healthy food as well as a good medicinal plant (Li and Zhang 2001, Zhang et al. 2012, Giménez-Bastida and Zizi 2015). The cultivation area and export volume of buckwheat in China are the largest worldwide; 913,000 tons of annual output account for 40.2% of the total global production, and has been exported to many countries mainly including Japan, Russia, France, South Korea, Netherlands, and North Korea (Wang and Li 2004). Two major *Fagopyrum* species are planted in China: *F. esculentum* and *F. tataricum* (Chauhan et al. 2010). *Fagopyrum esculentum*, also called common buckwheat, is widely cultivated in Northeast China including Chifeng, Tongliao, Hinggan League, and Baicheng; in North China including Datong, Shuozhou, Zhangjiakou, Ulanqab, and Huhhot; and in Northwest China including Yulin, Dingxi, and Guyuan. *Fagopyrum tataricum*, also called Tartary buckwheat, is mainly planted in Southwest China including Yunan, Guizhou, Sichuan, and Tibet (Ohnishi 1993, 2009). The buckwheat is damaged by several pests such as *Chaetocnema concinna*, *Meligethes aeneus*, *Ramularia spp.*, *Peronospora ducometi*, and *Botrytis cinerea* (Rana et al. 2012). *Rhinoncus sibiricus* Faust (Ceutorhynchinae, Curculionidae) is a specific pest of buckwheat. This insect was first found in Russian Far East in 1940, and is widely distributed in Russia including Tuva, Amur, Khabarovsk, Sakhalin, and Kuril Islands (Mishchenko 1940, Safiullina 1959). Studies on this pest in China and even globally are rare. The pest causes great damage during the entire growing season of buckwheat, and gradually spread to Japan, South Korea, China, and Mongolia, with the stem damage rate by larva reaching up to 70% (Klykov et al. 2014). In 2013, pest damage caused massive production loss of buckwheat in Chifeng City of Inner Mongolia. When the insect attack occurred, the taxonomic status of this pest was not clear. We cooperated with local pest control workers to collect samples and stop the insect attack expansion in a timely manner; the pest

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was identified as *R. sibiricus* (Dong et al. 2014, Meng et al. 2014). Mishchenko (1940) and Klykov et al. (2014) reported *R. sibiricus* could attack *F. esculentum* and cause serious damage, but documented reports regarding *F. tataricum* being attacked by *R. sibiricus* are rather few.

In China, there are no studies regarding *R. sibiricus* damage on buckwheat. Its occurrence and distribution in China and how the insect attack dynamics change in cultivation areas are still not clear. As the pest *R. sibiricus* was first found in Russia near the Northeast of China, we hypothesize that the occurrence and distribution of this species might be heavier in the Northern part rather than the Southern part of China. This study examined the occurrence and distribution of *R. sibiricus* in the buckwheat cultivation areas of China. We investigated its occurrence, distribution range, and the degree of damage in buckwheat cultivation regions from 2013 to 2018, with a comparison of the pest damage between *F. esculentum* and *F. tataricum* by common field experiments in 2015 and 2016. The results would clarify the pest distribution and damage range in China and enable strategies for pest control for a theoretical basis for pest prediction.

### Materials and Methods

#### Pest Distribution and Damage Survey

This survey was conducted in the major buckwheat cultivation regions of China from 2013 to 2018 during the plant-growing season. The details on the survey sites are provided in Supp Table S1 (online only). The buckwheat plots were chosen randomly (10 m × 10 m), and five quadrats (1 m × 1 m) were chosen by a diagonal collecting method from one plot. The total plant number and damaged plant number in each quadrat were counted. Pest traits and damage symptom were recorded during the survey. The degree of sample damage was classified by the standard below: samples with no damage symptoms were considered as level 0; samples with 0.01–10.00% stem damage rate were considered as level 1; samples with 10.01–30.00% stem damage rate were considered as level 2; samples with 30.01–50.00% stem damage rate were considered as level 3; and samples with 50.01–100.00% stem damage rate were considered as level 4.

\[
\text{Stem damage rate (\%)} = \left(\frac{\text{Damaged plant number}}{\text{Total plant number}}\right) \times 100
\]

#### Pest Damage on *F. esculentum* and *F. tataricum* in Common Field Experiments

We conducted two common garden experiments to determine the pest preference in two buckwheat species. We grew *F. esculentum* and *F. tataricum* at five cultivation sites in 2015 and at three cultivation sites in 2016 and checked the pest damage under natural conditions. Details of the cultivation sites are shown in Table 1 and the survey method used was same as that described above.

| Sites (codes)        | Latitude  | Longitude | Years |
|----------------------|-----------|-----------|-------|
| Chifeng (CF)         | 118.87°N  | 42.30°E   | 2015, 2016 |
| Tongliao (TL)        | 122.55°N  | 43.74°E   | 2015, 2016 |
| Baicheng (BC)        | 122.82°N  | 45.44°E   | 2015   |
| Datong (DT)          | 113.31°N  | 40.08°E   | 2015   |
| Zhangjiakou (ZJK)    | 114.72°N  | 41.16°E   | 2015   |
| Hinggan League (XAM) | 122.10°N  | 46.07°E   | 2016   |

### Data Analysis

SPSS 13.0 (SPSS Inc., Chicago, IL) was used for data analysis. An independent sample *t*-test was used for common field experiments to test the pest preference. The mean values of damaged stem rate from two buckwheat species at each site were compared for the differences.

### Results

#### Pest Traits and Damage Symptoms of Buckwheat in China

The survey results indicate that *R. sibiricus* causes damage from germination to harvest during the entire growing season of buckwheat, and that insect attack was most serious from late June to mid-late August. The larvae lived in the buckwheat stem and their developmental duration lasted nearly 30 d. Adults turned dark quickly after eclosion, started to eat the buckwheat leaves, could fly, and hide in the floral organs, rachis, and soil block. Adults caused leaf damage, which had a negative effect on plant photosynthesis (Fig. 1). The damage symptoms were easily observed from the first to sixth joint of the stems; soft tissue was eaten and brown powdery metabolin was left inside (Fig. 1). Most larvae existed in the main stem and branch, causing crop transport channel damage and insect path formation, which resulted in nectar reduction, plant lodging, and reduced production by 17–40%.

#### Occurrence and Distribution of *R. sibiricus* in China

In total, 117 sites in the buckwheat-growing zone from 13 provinces were surveyed from 2013 to 2018 (Supp Table S1 [online only]). The results show that the insect attack occurred in Inner Mongolia, Hebei, Shanxi, Jilin, Shaanxi, Gansu, Ningxia, Sichuan, and Yunnan Provinces (Fig. 2). The insect attack was more serious in the Northeast of China, with 12 sites considered as damage level 3 accounting for 30.00% and 13 sites considered as damage level 4 and accounting for 32.50% in this area including Chifeng City, Tongliao City, and Hinggan League in Inner Mongolia and Baicheng City in Jilin. The sites considered as damage level 3 and 4 accounted for 37.84 and 13.51% of all sites, respectively, in North China including Hohhot City, Ulanqab City, and Baotou City in Inner Mongolia, Shanxi, and Hebei; for 29.41 and 23.53%, respectively, in Northwest China including Shaanxi, Gansu, Ningxia, and Qinghai. In contrast, sites without pest damage accounted for 81.82% in South China including Sichuan, Yunnan, Guizhou, and Tibet. The results showed that the insect attack only occurred in Qujing of Yunnan in 2016 and in Liangshan of Sichuan in 2017, which were both considered as damage level 1. In 2018, one site of Taizhou City in Jiangsu Province of Southeast China was surveyed, and no pest damage was found.

#### Dynamic Change in Insect Attack on Common Buckwheat in the Main Cultivation Areas

The survey results show that the insect attack patterns of *F. esculentum* differed in Ongniud Banner of Inner Mongolia, Tongwei County of Gansu, Yuzhou District of Shanxi, and Zhangbei County of Hebei (Fig. 3). In Ongniud, the damaged stem rate was decreased significantly in 2013–2015, rose rapidly in 2016, and remained stable in 2017 and 2018. The damaged stem rate in Tongwei increased significantly in 2014–2016, and decreased dramatically in 2017 and 2018. In Yuzhou, the damaged stem rate rose gradually year by year from 2013 to 2017. The damaged stem rate in Zhangbei was changed in a wave mode as it rose significantly in 2013–2015 and in
2016–2017, with the lowest in 2016. Multiple dynamic changes in the insect attack were observed during the survey years in different cultivation areas.

Pest Damage Differences in *F. esculentum* and *F. tataricum*

Field experiments were carried out in five cultivation sites including Chifeng (CF), Tongliao (TL), Baicheng (BC), Zhangjiakou (ZJK), and Datong (DT) in 2015 to compare the damage differences in *F. esculentum* and *F. tataricum*. The results showed significant differences in the pest damage of the two species in CF ($F_{1,4} = 0.373; P = 0.015$), TL ($F_{1,4} = 3.797; P = 0.014$), BC ($F_{1,4} = 2.642; P < 0.001$), and DT ($F_{1,4} = 0.695; P = 0.040$), except ZJK in 2015, which indicated that the pest preferred *F. tataricum* rather than *F. esculentum* (Fig. 4).

In 2016, the common garden experiment results from three sites including CF, TL, and Hinggan League (XAM) were in accord with those from 2015. The pest damage between the two species of buckwheat was significantly different in CF ($F_{1,4} = 4.912; P = 0.042$), TL ($F_{1,4} = 0.023; P = 0.040$), and XAM ($F_{1,4} = 0.348; P = 0.030$); the damage to *F. tataricum* in the field was greater than that to *F. esculentum* indicating the pest preference for *F. tataricum* (Fig. 5).

**Discussion**

As we assumed, *R. sibiricus* is chiefly abundant in the northern buckwheat cultivation areas of China including Northeast, Northwest, and North China, especially in the western part of Northeast China including Chifeng City of Inner Mongolia, whereas it was sporadically distributed in the southern part as in the Southwest of China indicating that the pest had a larger distribution range in northern part than in the southern part of China. As the survey proceeded, the pest damage aggravated in Northwest and North China, but lighter damage was observed in Southwest China.

The survey results showed that *R. sibiricus* caused damage during the entire host growing season, especially from late June to mid-late August, which was in accordance with previous results showing great harm to crop growth and production (Klykov et al. 2014). The insect attack showed varying patterns in different cultivation areas by the
Fig. 2. Distribution and occurrence degree of *Rhinoncus sibiricus* in China.

Fig. 3. Dynamic change in insect attack of buckwheat in main producing areas during 2013–2018.
years, which may be related to the geographical factors and climate change, indicating that the geographical and climate data should be combined with the survey results for further research.

We surveyed occurrence and distribution of *R. sibiricus* in buckwheat cultivation areas of China by years, while the dynamic spread pattern is still not clear and should be explored in next step. We found preference of the pest for two buckwheat species and cause damage, indicating that the pest has potential for distribution in the southern part of China in the future. It is thus necessary to take actions for pest control in order to limit its extension and damage. This study will help lay the theoretical foundation for pest control and prediction.

**Supplementary Data**

Supplementary data are available at *Journal of Insect Science* online.

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