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# Do rice water weevils and rice stem borers compete when sharing a host plant?*

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**Abstract:** The rice water weevil (RWW) *Lissorhoptrus oryzophilus* Kuschel (Coleoptera: Curculionidae) is an invasive insect pest of rice *Oryza sativa* L. in China. Little is known about the interactions of this weevil with indigenous herbivores. In the present study, adult feeding and population density of the weevil, injury level of striped stem borer *Chilo suppressalis* (Walker) (Lepidoptera: Pyralidae) and pink stem borer *Sesamia inferens* (Walker) (Lepidoptera: Noctuidae) to rice, as well as growth status of their host plants were surveyed in a rice field located in Southeastern Zhejiang, China, in 2004 with the objective to discover interspecific interactions on the rice. At tillering stage, both adult feeding of the weevil and injury of the stem borers tended to occur on larger tillers (bearing 5 leaves) compared with small tillers (bearing 2~4 leaves), but the insects showed no evident competition with each other. At booting stage, the stem borers caused more withering/dead hearts and the weevil reached a higher density on the plants which had more productive tillers and larger root system; the number of weevils per tiller correlated negatively with the percentage of withering/dead hearts of plants in a hill. These observations indicate that interspecific interactions exist between the rice water weevil and the rice stem borers with negative relations occurring at booting or earlier developmental stages of rice.

**Key words:** *Chilo suppressalis*, Interspecific interaction, *Lissorhoptrus oryzophilus*, *Sesamia inferens*, Stem borer, Weevil
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## INTRODUCTION

The rice water weevil (RWW) *Lissorhoptrus oryzophilus* Kuschel (Coleoptera: Curculionidae) is an important insect pest of rice in the US (Way, 1990; Tindall *et al*., 2004; Zou *et al*., 2004), and also has emerged as a pest of rice in Eastern Asia (Lee and Uhm, 1993; Zhai *et al*., 1997; Saito *et al*., 2005). Adults feed on leaf epidermis of rice plants leaving longitudinal scars on leaves; larvae cut roots resulting in stunting of plants, delayed maturity and grain yield loss. Adult damage is generally of minor importance, and it is the larval feeding that causes economic losses (Zou *et al*., 2004).

Interactions between RWW and other insects in rice have been studied in the US (Way *et al*., 1983; Tindall and Stout, 2001). In California, RWW damage can reduce competing ability of rice plants towards weeds *Monochoria vaginalis* Presl and *Sagittaria montevidensis* Cham. & Schltdl., leading to increased growth of these weeds, which subsequently favors build-up of the aster leafhopper, *Macrosteles fascifrons* (Stål) (Homoptera: Cicadellidae) which favors ovipositing on *M. vaginalis* and *S. montevidensis* (Way *et al*., 1983). In the greenhouse, when rice plants are shared by RWW and the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), severe defoliation by the armyworm can decrease RWW densities by 32% and reduce larval weight by 48%. Meanwhile, RWW damage can reduce growth rate of the armyworm by 9%~37% (Tindall and Stout, 2001).

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However, in Asia where RWW has occurred as an invasive species, little is known about interactions between RWW and indigenous insects. The striped stem borer, *Chilo suppressalis* (Walker) (Lepidoptera: Pyralidae) is one of the most serious pests of rice in temperate and subtropical Asia. Larvae bore leaf sheaths and stems, causing dead hearts, white heads, reduced plant vigor and tillering, unfilled grains and plant lodging (Dale, 1994). The pink stem borer *Sesamia inferens* (Walker) (Lepidoptera: Noctuidae) is a much less destructive pest of rice in Asia (Dale, 1994) which causes damages similar to those by *C. suppressalis*. In some areas of China such as Zhejiang, both RWW and *C. suppressalis*/*S. inferens* are important pests of rice and they co-occur on the first crop of rice. Therefore, competitions possibly exist between RWW and rice stem borers when sharing a host plant.

In the present study, RWW adult feeding and population density, *C. suppressalis*/*S. inferens* injury level, and growth status of rice plants were surveyed in a rice field in Southeastern Zhejiang, China. Our objective was to discover possible competitions between RWW and rice stem borers to increase our knowledge on RWW population biology.

## MATERIALS AND METHODS

### Experimental site

The experimental field was located at Yueqing (28°8′ N, 120°56′ E), Southeastern Zhejiang, China, where rice is planted consecutively for two seasons. Two generations of RWW occur annually which attack first- and second-season rice, respectively, and normally only the first generation has high densities (Zhai *et al*., 1997; 1999; Shi *et al*., 2007). In transplanted fields, overwintered RWW adults, first-generation larvae and pupae occur from early to mid-May, mid-May to late June and mid-June to early July, respectively (Zhai *et al*., 1997). The first generation of *C. suppressalis*/*S. inferens* attacks first-season rice from tillering to booting stages (mid-May to late June) with *C. suppressalis* being more important comparatively. Other rice stem borer species rarely occur in this area.

The experimental field (0.08 ha) was adjacent to a hill which is a major overwintering site of RWW (Zhai *et al*., 1997) and had serious natural RWW infestations during our study. The field was seeded (cv. Zhongsi-2) and transplanted in early April and early May, 2004, respectively. Transplanted plants were spaced 18~20 cm with three plants per hill. Normal water management and fertilization were conducted without insecticides applied throughout the season.

### Interactions of RWW with stem borers at tillering stage

Two weeks after transplantation six plant blocks (55~60 cm wide, 3.5~3.8 m long) were randomly sampled with 80 hills (4 lines, 20 rows) of plants in each block; each block was vertical to longitudinal levees, 60 cm apart to the nearest levee and 5 m apart to neighboring block(s). For each hill of plans, length of each RWW feeding scar on leaves was measured by a ruler and later accumulated (RWW feeding scar is morphologically specific and can be easily distinguished from those by other rice defoliators). Then, stem borer injury was inspected carefully depending on the presence of young *C. suppressalis*/*S. inferens* larvae inside leafsheaths, tunneling trace and excreta, and numbers of stem borers-injured tillers and total tillers were recorded. Correlations among length of RWW feeding scars, number/percentage of stem borer-injured tillers and total number of tillers within a hill were analyzed.

Stem borer injury and weevil feeding/oviposition on tillers of different sizes (indicated by the number of leaves) were also observed. To inspect stem borer injury, 54 plants were randomly sampled from the experimental field with one plant per hill; the numbers of total leaves and the leaves displaying stem borer injury symptoms on each plant were counted. To observe RWW feeding/oviposition response, 25 6-week-old plants (5 lines and 5 rows) bearing 1~3 tillers were transplanted in a plastic basin (72 cm diameter, 20 cm height, containing clay ca. 10 cm depth and water ca. 5 cm depth), and kept in a climate controlled chamber maintained at (27±1) °C and 70%~80% RH (relative humidity) with a photoperiod of 16:8 (light:dark) h. After 24 h, 50 ovipositing RWW adults (collected from the experimental field in mid-May) were released to the basin and the plants were enclosed with a cylindrical mylar enclosure (56 cm diameter). After two days, leaves of each tiller were counted, and length of RWW feeding scar on each tiller was measured. Each tiller was examined under a binocular microscope for eggs deposited by RWW. Correlations between the data of insects and tiller size were analyzed.

**Interactions of RWW with stem borers at booting stage**

Observations were performed at seven weeks after transplantation when RWWs were dominantly at pupal stage and a few at mature larval or early adult stage. Three plant blocks (55~60 cm wide, ca. 4.5 m long) were randomly sampled with 75 hills (3 lines, 25 rows) of plants per block; each block was vertical to longitudinal levees, 60 cm apart to the nearest levee and 5 m apart to neighboring block(s). Plants were cut at the base and numbers of productive tillers (bearing developing panicles), non-productive tillers and the tillers with withering or dead hearts due to stem borer injury in each hill were counted, and height of each tiller was measured. The stem borer injury was verified by presence of *C. suppressalis*/*S. inferens* larvae, pupae or puparia in stems and leafsheaths, tunneling trace and excreta. To survey RWW density, rice roots together with surrounding clay were dug out from each sampled hill and washed gently in water until all clay was separated from the roots. During washing, RWW larvae free from roots/clay normally floated at water surface and could be discovered easily. The few larvae and pupal cocoons washed down to water bottom were discovered by additional sifting and rinsing operations. Lastly, pupal cocoons attached to the roots were counted. All of the RWWs discovered from the same sampled hill were polled and taken as the density of this insect. Washed roots of each hill of plants were dried at 60~65 °C and weighted on an electronic balance (the dried weight was referred as root biomass later). Correlations among RWW density, stem borer injury and plant growth status were analyzed at the hill and tiller levels.

**Data analyses**

Data were analyzed using SPSS for windows (SPSS Inc.; 2002). Bivariate correlations among variables of insects and plants were calculated, and Spearman correlation coefficients (SCCs) were used to test the significance of correlations at the 0.05 and 0.01 levels (2-tailed). Prior to analyses, outliers in the data were excluded.

RESULTS

**Interactions of RWW with stem borers at tillering stage**

At two weeks after transplantation, on average 2.3 tillers (39.0%) per hill were injured by *C. suppressalis*/*S. inferens*. Both the number of stem borer-injured tillers (Fig.1a) and length of RWW feeding scars per hill (Fig.1b) correlated significantly positively with number of tillers (*SCC*=0.157, *n*=470, *P*<0.01 for stem borer-injured tillers; *SCC*=0.109, *n*=460, *P*<0.05 for weevil feeding scars). Neither the correlation between number of stem borer-injured tillers and length of weevil feeding scars (*SCC*=0.040, *n*=453, *P*=0.394) nor the correlation between percent of stem borer-injured tillers and length of weevil feeding scars per tiller (*SCC*=0.058, *n*=478, *P*=0.204) was statistically significant.

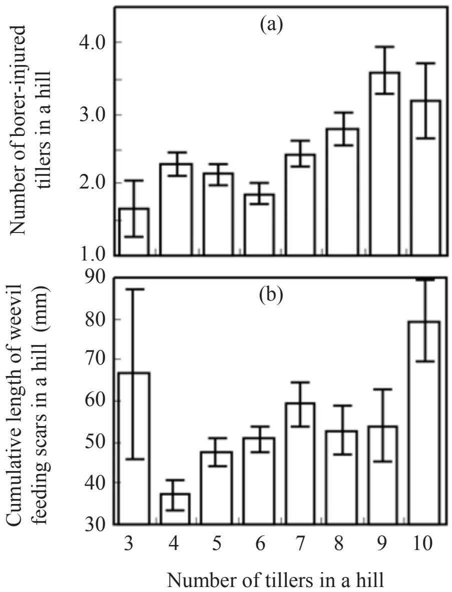


**Fig.1 Correlations of number of tillers injured by rice stem borers (*Chilo suppressalis*/*Sesamia inferens*) (a) and length of *Lissorhoptrus oryzophilus* adult feeding scars (b) in rice hills with different numbers of tillers at tillering stage**

Stem borer injury level (i.e., the number of leaves with the sheath injured by stem borers per tiller) correlated significantly positively with tiller size (i.e., the number of leaves per tiller) (*SCC*=0.296, *n*=100, *P*<0.01) with more injury occurring on larger tillers (Table 1). No significant correlation was observed between length of RWW feeding scar and tiller size

(*SCC*=0.238, *n*=45, *P*=0.116), but apparently tillers with 5 leaves were much more fed than those with 3 or 4 leaves. The number of eggs deposited by the weevil correlated significantly negatively with tiller size (*SCC*=−0.356, *n*=40, *P*<0.05) with more eggs deposited on smaller tillers (Table 1). These results show that at tillering stage both stem borer injury and RWW adult feeding tended to occur on larger tillers, but these insects had no evident competition with each other.

**Interactions of RWW with stem borers at booting stage**

Stem borer injury level and RWW density at booting stage were depicted in Fig.2. On average 2.5 rice tillers (14.0%) per hill were injured by stem borers and 3.4 weevils inhabited on roots per hill. Number of withering/dead hearts caused by stem borers correlated significantly positively with number and height of productive tillers, number of non-productive tillers, and root biomass (Table 2). However, percent of withering/dead hearts in a hill correlated significantly negatively with percent of productive tillers and root biomass per tiller (Table 3). RWW density correlated positively with number of productive tillers and root biomass (Table 2). Number of RWW per tiller correlated significantly positively with root biomass and negatively with percent of withering/dead hearts (Table 3, Fig.3). These results suggest that at booting stage both stem borer injury and RWW (the stages at rice roots) tended to occur on the plants which had more productive tillers and larger root biomass, and they may compete with each other to some extent.

**Table 1 Injury level by stem borers, feeding scar length and number of eggs deposited by *L. oryzophilus* on rice tillers of different sizes**

| Tiller size | Number of leaves with the sheath injured by stem borers per tiller | Weevil feeding scar length per tiller (mm) | Number of weevil eggs deposited per tiller |
|---|---|---|---|
| 2 | 0.6±0.1 (25) | – | – |
| 3 | 0.8±0.1 (47) | 53.5±8.1 (17) | 9.2±1.7 (15) |
| 4 | 1.3±0.2 (24) | 57.8±9.0 (13) | 4.5±1.4 (13) |
| 5 | 1.5±0.6 (4) | 87.0±16.0 (15) | 3.9±0.8 (12) |

Values expressed as mean±*SE* (standard error); Numbers in parentheses indicate the number of tillers observed

**Table 2 Correlations among stem borer injury, *L. oryzophilus* density and rice plants at booting stage (at the hill level)**

| | Number of withering/dead hearts in a hill | | | Number of weevils in a hill | | |
|---|---|---|---|---|---|---|
| | *SCC* | *P* | *n* | *SCC* | *P* | *n* |
| Number of productive tillers | 0.278** | 0 | 210 | 0.137* | 0.049 | 207 |
| Number of non-productive tillers | 0.522** | 0 | 216 | 0.099 | 0.152 | 210 |
| Height of productive tillers | 0.154* | 0.025 | 212 | 0.057 | 0.408 | 216 |
| Height of non-productive tillers | 0.103 | 0.139 | 208 | 0.055 | 0.423 | 212 |
| Root biomass | 0.166* | 0.014 | 216 | 0.360** | 0 | 222 |

* and ** indicate significant correlations at the 0.05 and 0.01 levels, respectively

**Table 3 Correlations among stem borer injury, *L. oryzophilus* density and rice plants at booting stage (at the hill and tiller levels)**

| | Number of weevils per tiller | | | Percent of productive tillers in a hill | | | Root biomass per tiller | | |
|---|---|---|---|---|---|---|---|---|---|
| | *SCC* | *P* | *n* | *SCC* | *P* | *n* | *SCC* | *P* | *n* |
| Percent of withering/dead hearts in a hill | −0.135* | 0.047 | 215 | −0.135* | 0.046 | 217 | −0.246** | 0 | 214 |
| Number of weevils per tiller | – | – | – | 0.070 | 0.305 | 215 | 0.329** | 0 | 214 |

* and ** indicate significant correlations at the 0.05 and 0.01 levels, respectively

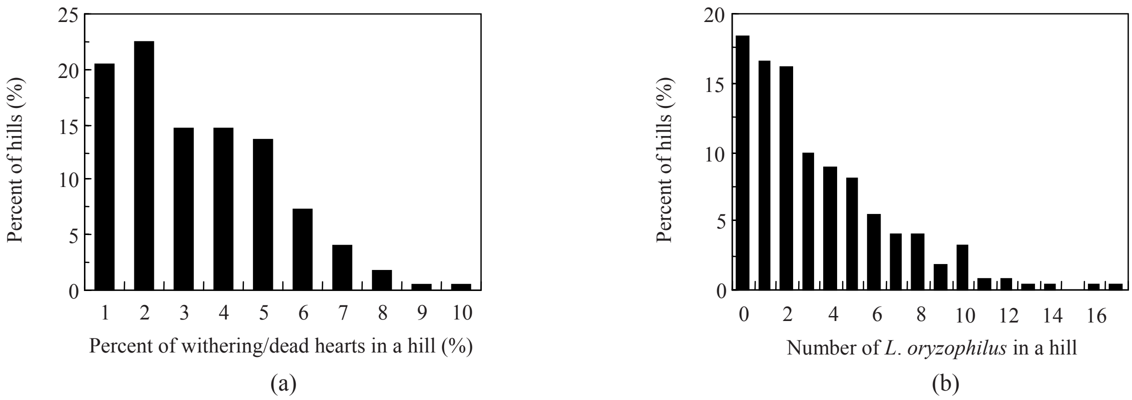


**Fig.2 Percent of hills of rice plants that suffered different levels of injury by stem borers *C. suppressalis* and *S. inferens* (a) and had different densities of *L. oryzophilus* (b) at booting stage**

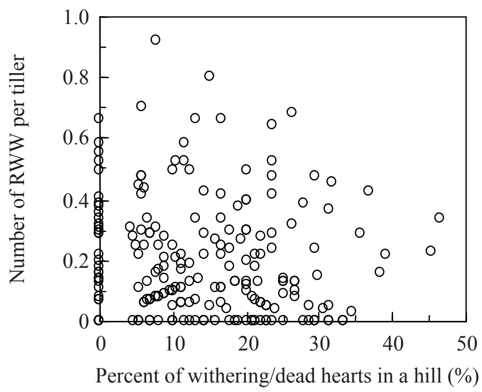


**Fig.3 Correlations between *L. oryzophilus* density and stem borer injury level at booting stage of rice**

# DISCUSSION

Our observations were performed during co-occurring of RWW and rice stem borers and the time when damage symptoms became visible. During the week prior to survey at tillering stage, RWW adults were in ovipositing stage and feeding actively, at the same time plants had been infested by stem borers and injured leafsheaths were yellowing. At the survey at booting stage, most of RWWs and stem borers had developed to pupal and later stages, and plants had experienced the most serious feeding damage and probably had undergone some physiological and growth changes. Therefore, competition between RWW and stem borers, if any, can be discovered by the two surveys performed at tillering and booting stages.

Our results suggest that little competition exists between RWW and stem borers at tillering stage. Although both RWW feeding and stem borer injury tend to occur on larger tillers, RWW is probably little impacted by stem borers as adult weevils can move, if necessary, to tillers less infested by stem borers. Nutritional changes in plants due to stem borer infestation and suitability of such plants for RWW are to be studied.

Positive correlations were discovered between plant growth status (number and height of tillers and root biomass) and stem borer injury at booting stage. These correlations might have resulted from growth or/and physiological compensations in the injured plants. Compensation in rice plants due to stem borer attack has been well documented in earlier studies (Lu, 1987; Sun and Du, 1992; Rubia *et al*., 1996; Jiang and Cheng, 2003). They might also have resulted from preference of stem borers for infesting larger plants where higher injury levels consequently occurred, or from some other unmeasured plant attributes to which stem borers respond. Based upon the significantly positive correlation between RWW density and plant root biomass, we speculate that if root biomass can be increased from plant compensation due to stem borer injury, stem borer infestations might be advantageous to RWW occurrence.

Surprisingly, as RWW density increased, rice root biomass did not decrease at booting stage, and they displayed a positive correlation. There are several possible reasons for this phenomenon. Firstly, new roots might have been produced after the original roots were pruned by RWW larvae, that is, some compensation might have occurred in host plants as a response to RWW injury. Secondly, as described above, root biomass might have been increased from plant compensations due to stem borer injury and thus more RWW larvae could be supported. Thirdly, similar to stem borers, RWW might also prefer to infest larger plants or to infest plants with some unmeasured attributes.

The negative correlation of RWW density with stem borer injury level at booting stage implies that competition might exist between RWW and stem borers. That is, the higher population density of the weevil may be disadvantageous to the population increase of the stem borers, or *vice versa*. However, mechanisms behind these interspecific interactions are not clear. One possibility was that high RWW densities had impaired the growth of rice plants, which, in turn, depressed stem borers and lowered the injury level by the latter. However, it should be noticed that although this correlation between the animals was statistically significant, it was not strong statistically ($P$=0.047, Table 3). Further investigations are required at the booting and earlier stages of rice to discern these interactions. Unfortunately, such field or laboratory work is likely difficult to carry out, because the arrival of such years when each of the target insects would occur in high numbers is uncertain, and as a quarantine insect in China the weevil is restricted for its rearing in uninvaded areas of the country.

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