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Feeding Effects of *Halyomopha halys* (Hemiptera: Pentatomidae) on Fruit Drop and Decay Rate in Mandarin Citrus Orchards

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감귤원에서 썩덩나무노린재 감귤과실 흡즙이 낙과 및 부패에 미치는 영향

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ABSTRACT: This study was conducted to examine the feeding effect of *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) on the fruit drop and decay rate of Mandarin citrus fruits (*Citrus unshiu*). The feeding of *H. halys* before fruit coloring caused a severe fruit drop, while the feeding after fruit coloring induced a low level of fruit drop. However, the feeding of *H. halys* before or after fruit coloring did not induce significant fruit decay during cold storage. The results are expected to be useful in managing *H. hlays* of late season mandarine, because citrus farmers follow calendar spray to prevent fruit drop and fruit decay.

Key words: *Halyomorpha halys*, Citrus fruit drop, Fruit decay, Bug feeding effect

초 록: 본 연구는 만다린 감귤에 대한 썩덩나무노린재 흡즙이 낙과 및 저장 중 부패에 미치는 영향을 검토하기 위하여 실시되었다. 과실 착색 전 흡즙은 심한 낙과를 유발하였으나 착색 후 흡즙은 낙과율이 낮았다. 하지만, 부패유발 측면에서는 수확과실 및 착색전후 과실에 대한 썩덩나무노린재 흡즙이 저장 중에 부패를 유발하지 않았다. 많은 감귤농가에서는 썩덩나무노린재로 인한 낙과와 부패를 방지하기 위하여 생육후기 살충제를 자주 살포하고 있기 때문에 본 결과는 생육후기 이 해충 관리에 유용한 정보를 제공할 것이다.

검색어: 썩덩나무노린재, 감귤낙과, 감귤부패, 노린재 흡즙효과

The brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), is polyphagous insect pest, originated in East Asia including Korea, China, Japan and Taiwan (Hoebeke and Carter, 2003). This bug attacks leguminous crops, fruit trees and many ornamental trees. *H. halys* invaded recently U.S. and Europe (Hoebeke and Carter, 2003; Wermelinger et al., 2008), and has become a major agricultural threat in the mid-Atlantic region of U.S. In Jeju island, Korea, *H. halys* was considered as an occasional pest in citrus orchards and thought to typically inflict light damage on fruit (Kim et al., 2000). Recently, its' population is found far beyond economic level specially in harvesting season of organic citrus orchard following the pattern of arrowhead scale (*Unaspis yanonensis* (Kuwana)) and cottony cushion scale (*Icerya purchasi* Maskell) (Kim et al., 2011; Kim and Kim, 2013).

Many citrus farmers believe that the feeding punctures of *H. halys* cause fruit decay by providing the route for secondary infection during storage and distribution. Accordingly, some farmers spray insecticides aggressively in the late season, sometimes exceeding the MRL (maximum residue limit). Haphazard spray of synthetic chemical insecticides may induce serious problem in exported fruits. However, there is little

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information about damage of citrus fruits caused by *H. halys* feeding in late season, which serve as baseline knowledge for establishing the management guideline against *H. Halys*. This study was conducted with the aim to explore the feeding effect of *H. halys* on fruit drop and decay of Mandarine citrus.

Materials and Methods

Laboratory rearing of *H. halys*

Adult females and males (n = 10 pairs) of *H. halys* were originally collected from an organic citrus orchard of Jeju-city, Korea, during October and November, 2009. Adults were placed in an acrylic cage (1,100 × 700 × 550 mm) at 24 ± 1℃, 40-70% RH, and a photoperiod of 16:8 (L:D) h in the laboratory. The acrylic cage was mesh windowed (500 × 450 mm) on two narrow sides and closed by a sleeve of cloth mesh (Φ 140 mm) in the front with no holes at the back. Adult *H. halys* were fed on well dried peanuts (90%) and soybean bean seeds (10%) *ad libitum*. Twenty to thirty *Peperomia* plants in a flower pot (Φ 90 mm, 100 ml) were provided as a water source and oviposition substrate for adults and nymphs. The food sources were supplied every two to three weeks, and *Peperomia* plants were replaced whenever the plants were withered and died by the excessive feeding of *H. halys*. Wild population (n < 20) of *H. halys* were recruited a year after the first establishment in 2009. According to the rearing protocol, the population of *H. halys* was well established in the laboratory condition (see Appendix 1).

Feeding treatments in the laboratory and field

Effects of *H. halys* on harvested citrus fruits (2010). Mandarin citrus fruits, *Citrus unshiu* (Swingle) Marcow were obtained on 11 November, 2010, from citrus orchard of Seogwipo Agricultural Center. For feeding treatment of *H. halys*, citrus fruits were placed one by one in an insect rearing cage (Φ 90 mm, height 80 mm). One or two adults of *H. halys* collected from the laboratory colony were introduced into each cage. After 24 h., *H. halys* adults were removed and the fruits were place in a standard paper box (upper side opened, capacity of 15 kg) for transportation aboard. The decay rate of fruits in paper boxes were examined after 40 d cold storage at 4℃. Citrus fruits which had been kept for 24 h in cages without the introduction of *H. halys* were used as untreated control. Each treatments were replicated thrice (10 fruits per replicate).

Feeding effects of *H. halys* on citrus fruits before and after fruit coloring (2011). Citrus branches of dia. 1 - 2 cm including 9 - 10 fruits were caged using a plastic mesh sleeve (250 × 500 mm, # 1 mm) for feeding study of *H. halys* in the field. Before fruit coloring on 16 September 2011, 0, 1, 2 or 10 of *H. halys* adults (laboratory population; sex was not considered) were introduced into each sleeve cage, resulting in 0, 0.1, 0.2 and 1.0 adult per fruit, respectively. Rate of fruits drop was checked on 17 November, 2011 and undropped fruits were harvested. And then the fruits were stored at 4℃ as the same method above, and the decay rate was checked after 50 d. This experiment was replicated 10 times in an experimental orchard block of Mandarin citrus at Jeju National University, Jeju city.

To examine the feeding effect of *H. halys* on citrus fruits after fruit coloring, 5 adults (0.5/fruit) were introduced into sleeve cages on 6 October, 2011 in an orchard block at Seogwipo Agriculture Center, as the same method above. Fruits were harvested and examined on 17 November, 2011 as the same manner above. This experiment was replicated 9 times.

Statistical analysis. The data sets were subjected to the analysis of variance (ANOVA) to determine statistical differences among treatments (SAS Institute, 1999). Differences in means were then analyzed using Tukey's studentized range test at P = 0.05.

Results

Effects of *H. halys* feeding on harvested fruits

The feeding of *H. halys* on harvested citrus fruits did not induced a significant fruit decay during cold storage (F = 1.00, df = 2, 8, P > 0.05), which was based on the data sets obtained after 40 d cold storage at 4℃ after feeding treatment. The decay rate was 0.0, 0.03 and 0.0% in the treatment of 0.0, 1.0, and 2.0 adults per fruit, respectively (Table 1).

Effects of *H. halys* feeding before and after fruit coloring

The feeding of *H. halys* before fruit coloring significantly

Table 1. Fruit drop and decay rates (%, Mean ± SD) caused by the feeding of *H. halys* adults

No. *H.halys* introduced per fruit	n	Fruit drop	Fruit decay[1]
Feeding treatment on 16 September (2011): before fruit coloring[2]			
1.0	101	76.1 ± 18.14a[3]	2.0 ± 6.32a
0.2	99	19.1 ± 9.84b	11.6 ± 11.76a
0.1	106	5.2 ± 8.14c	3.8 ± 4.99a
0.0	101	3.0 ± 4.83c	13.9 ± 16.58a
Feeding treatment on 6 October (2011): after fruit coloring[2]			
0.5	91	7.8 ± 13.02	8.4 ± 13.21
Feeding treatment on 11 November (2010): on harvested fruit[4]			
0.0	30	-[5]	0.0
1.0	30	-	0.03 ± 0.03
2.0	30	-	0.0

[1]The results are based on 50 d after colds storage at 4℃ (harvested on 17 November).
[2]Sample size indicates total number of citrus fruits included in 10 replicates.
[3]Means with same letters in a column are not significantly different by Tukey test at $P = 0.05$.
[4]Sample size indicates total number of citrus fruits included in 3 replicates with each 10 fruits. The results are based on 40 d after colds storage at 4℃ after feeding treatment of *H. halys*.
[5]No data available.

affected citrus fruit drop (Table 1). The rate of fruit drop was significantly increased in accordance with increased number of *H. halys* introduced (F = 91.00, df = 3, 39, P < 0.05). Most citrus fruits were dropped in plots where *H. halys* was introduced in the rate of one adult per fruit, resulting in 76.1% fall. When 0.1 adult was introduced per fruit, the fruit drop rate was not significantly different with that of untreated control. The feeding of *H. halys* before and after fruit coloring did not affect significantly fruit decay rate during cold storage (F = 2.81, df = 3, 39, P > 0.05).

The feeding treatment of *H. halys* after fruit coloring (0.5 adult per fruit) resulted into a low fruit drop rate, being slightly higher than that of 0.1 adult introduction before fruit coloring.

Discussion

The feeding of *H. halys* on citrus fruits showed different results according to fruit developmental stage. The fruit drop rate in the plot of feeding treatment after fruit coloring (0.5 adults per fruit) was much lower than that in the plot of feeding treatment before fruit coloring, in spite of higher number of *H. halys* introduced. Lee et al. (2009) reported a similar result in sweet persimmon orchards. The feeding of *H. halys* during July caused severe fruit drop of sweet persimmon, while it was negligible during September feeding, just leaving pitting spot damage on the fruits. Fruit drop caused by *H. halys* has not been reported yet in apple, pear and peach orchards (Rings, 1957; Funayama, 2002; Gyeltshen et al., 2005; Kim, 2012). The response of fruits to the feeding of *H. halys* seems to be different according to fruit ages and the types of fruit trees. For this aspect, further researches are required.

Insect feeding punctures can provide a route for secondary infection for various airborne diseases (Broembsen and Pratt, 2013). This knowledge has been accepted widely by agricultural researchers and extensionists in citrus industry. As a result, late season sprays against plant bugs including *H. halys* have been justified to prevent the decay of citrus fruits during the storage and distribution in fruit markets. However, this study showed no effect of *H. halys* feeding on the decay of citrus fruits as well as on fruit drop in late season. The present study can provide baseline to reduce insecticide use against *H. halys* especially in late season, although fruit quality should be tested further when such sprays are not applied.

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Appendix 1. Comparison of morphological characters[1] between laboratory-reared and wild population of *H. halys* adults (mm, Mean ± SD)

Sex	Population	n	Body length	Body width	Tibia of hind legs
Female	Laboratory	15	15.3 ± 0.44ns[2]	7.8 ± 0.31ns	4.9 ± 0.25ns
	Wild	12	15.3 ± 0.46	8.0 ± 0.38	4.9 ± 0.27
Male	Laboratory	11	13.8 ± 0.30ns	7.2 ± 0.25ns	4.8 ± 0.27**
	Wild	11	13.4 ± 0.58	7.1 ± 0.34	4.3 ± 0.35

[1]The morphological measurements of body length, body width and tibia of hind leg were compared between laboratory and wild populations of *H. halys*. Wild population of 23 *H. halys* adults (12 females and 11 males) was collected in citrus orchards in Seogwipo-city, Jeju, during October, 2012. Total 26 adults of *H. halys* (15 females and 11 males) were randomly selected on 20 October, 2012, in the laboratory colony. An image analysis software (ImagePro 5.1, Media Cybernetics) was used for the measurement, which was operated with stereomicroscope (SMZ-1500, Nikon), ocular micrometer (MBM 12100, Nikon) and digital camera (Micropublisher 3.3 RTV, Q imaging).

[2] Two sample t-test: ns, not significant; ** significant at $P = 0.01$.