Effect of Cherry Cultivar and Trapping Height on Population Dynamics of Drosophila Fruit Flies in Cherry Orchards in Northern China

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Research

Effect of cherry cultivar and trapping height on population dynamics of *Drosophila* fruit flies in cherry orchards in northern China

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Abstract

In recent years, fruit flies (*Drosophila* spp.: Drosophilidae) have become an increasingly serious problem for cherry production in northern China. In this study, we examined the species composition and dynamics of fruit flies in cherry orchards using lure-baited traps placed at different heights, and in 3 different cherry cultivars, from Apr through Sep 2014 to 2016 in Qingdao, Shandong Province, China. The total number of fruit flies increased from yr to yr. Four species were captured: *Drosophila melanogaster* Meigen, *Drosophila suzukii* Matsumura, *Drosophila hydei* Sturtevant, and *Drosophila immigrans* Sturtevant (all Diptera: Drosophilidae). The dominant species was *D. melanogaster*, with 66.7% of the total captured, followed by *D. suzukii* (29.7%). *Drosophila hydei* and *D. immigrans* accounted for only 3.0 and 0.6%, respectively, and for these last 2 species, no peak period in abundance was observed. In general, *Drosophila* spp. appeared in Apr, and peaked around mid-Jul. Over the 3 yr span of the study, peak fruit fly abundance occurred later each yr, being at the end of Jun in 2014, and in the middle of Jul in 2015 and 2016. There were significant differences in the number of *Drosophila* species among cherry cultivars, as well as in the number of *Drosophila* trapped at different heights. The cultivar maturing in the middle of the season (cv. 'Van') attracted the most fruit flies. The optimal height for trap placement was at 1 m above ground level, which is recommended as a standard height for *Drosophila* spp. population monitoring.

Key Words: insect traps; monitoring

Resumen

En los últimos años, las moscas de la fruta (*Drosophila* spp: Drosophilidae) se han convertido en un problema cada vez más grave para la producción de cerezas en el norte de China. En este estudio, examinamos la composición de especies y la dinámica de las moscas de la fruta en huertos de cerezas utilizando trampas cebadas colocadas a diferentes alturas, y en 3 diferentes variedades de cerezas, desde abril hasta septiembre del 2014 to 2016 en Qingdao, provincia de Shandong, China. El número total de moscas de la fruta aumentó de año a año. Se capturaron cuatro especies: *Drosophila melanogaster* Meigen, *D. suzukii* Matsumura, *D. hydei* Sturtevant, y *D. immigrans* Sturtevant (todos Diptera: Drosophilidae). La especie dominante fue *D. melanogaster*, con el 66.7% del total capturado, seguido de *D. suzukii* (29.7%). *Drosophila hydei* y *D. immigrans* representaron solo el 3.0 y 0.6%, y para estas 2 últimas especies, no se observó un período máximo en abundancia. En general, las especies de *Drosophila* aparecieron en abril y alcanzó su punto máximo a mediados de julio. Durante los 3 años del estudio, la abundancia pico de la mosca de la fruta fue más tarde cada año, siendo al final de junio en el 2014 y en el medio de julio del 2015 y 2016. Hubo diferencias significativas en el número de especies de *Drosophila* entre los cultivares de cereza así como en el número de *Drosophila* atrapado a diferentes alturas. El cultivar que madura a la mitad de la temporada (cv. 'Van') atrajo la mayor cantidad de moscas de la fruta. La altura óptima para la colocación de la trampa fue a 1 m sobre el nivel del suelo, que se recomienda como una altura estándar para *Drosophila* spp. monitoreo de la población.

Palabras Clave: trampas de insectos; supervisión

Cherry, *Prunus avium* L. (Rosaceae), is one of the most valuable orchard crops in northern China. Because of their high nutritional value, low levels of pesticide residues, and popularity with consumers, cherries are being produced on a rapidly expanding land area (Zhou 2016).

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However, in recent years, pest and disease pressure on cherry have grown, and *Drosophila* have become an increasingly serious problem. *Drosophila suzukii* Matsumura (Diptera: Drosophilidae) fruit flies were first recorded on cherry in 1916 in Yamanashi, Japan (Yu et al. 2013), and in China in the early 1930s (Kanzawa 1936). Subsequently, *D. suzukii* was recorded in North Korea, South Korea (Chung 1955; Kang 1968), India (Parshad & Duggal 1965), Russia (Sidorenko 1992), Pakistan (Amin et al. 2005), Bangladesh (Pansa et al. 2011), Myanmar (Toda 1991), and Thailand (Okada 1976). By the 1980s, *D. suzukii* was observed throughout Hawaii, and first appeared in North America in California in 2008 (EPPO 2010). *Drosophila suzukii* quickly moved east in the US, being observed in Florida in 2009 (Steck et al. 2009) and the Carolinas in 2010 (Burrack 2010). Since then, they have invaded much of North and South America, Europe, and many other regions, causing serious economic damage (Cini et al. 2012).

Adults of *Drosophila melanogaster* Meigen (Diptera: Drosophilidae) were discovered first in China in 1997 in the city of Tianshui, Gansu Province (Guo 2007). Presently, the species can be found in Heilongjiang, Shandong, Zhejiang, Guangxi, and the Guizhou provinces of China, in Tibet and Taiwan, and 22 other provinces and autonomous regions (Qian & Zhang 2006), reportedly causing increasing damage (Wang et al. 2008, 2013; Hui et al. 2010; Yang et al. 2011; Lu et al. 2015;). *Drosophila melanogaster* usually is not considered to be a primary fruit pest in many regions of the world. However, in China it is abundant in cherry orchards, and even if it attacks only overly ripe or damaged fruit, its presence is a concern to producers because it can be confused with *D. suzukii*. In Aba in Sichuan Province, the damage attributed to *D. melanogaster* has reached 60% (Guo et al. 2007). Similarly, in Guizhou Province, the damage to *Myrica rubra* (Lour.) Siebold and Zucc. (Myricaceae) attributed to *D. melanogaster* has risen from 38% to 57% (Li et al. 2011). In Gansu Province, *D. melanogaster* reportedly damaged 35% of cherry fruits, with some cultivars suffering as much as 80% damage. Without timely prevention and control, *D. melanogaster* fruit fly damage to cherry crops in this region can exceed 60% (Guo 2007).

From 2014 to 2016, we monitored fruit fly populations in the cherry growing region of Qingdao in Shandong Province to determine the species present, the effect cherry variety had on *Drosophila* abundance, and also the effect trap height had on trapping.

Materials and Methods

STUDY SITE

This study took place at the Beizhai Experimental Orchard of Qingdao Academy of Agricultural Science in Laoshan District, Qingdao, Shandong Province, in a 2 ha orchard of cherry trees. When the survey started in 2014, the mean height of the trees was 2.1 m, reaching 2.4 m at the end of 2016. The cherry trees were surrounded by peach and apple trees. Due to the diversity of cherry varieties, the harvest period lasts from mid-May to mid- to late Jun, and there was a small amount of fruit falling onto the soil. Chemical treatments were restricted to 3 fungicide sprays per yr and no insecticides were used.

TRAPPING METHOD

Traps consisted of 600 mL plastic bottles. To allow flies to enter the bottle traps, we cut 8 holes (0.6 cm diam) in the upper half of the bottle in various places.

The attractant and killing solution consisted of 50 g of brown sugar, 80 mL of anhydrous ethanol, 50 mL of rice vinegar, 370 mL of water, and 2 g of 90% dichlorvos. One hundred fifty mL of the solution was added to each bottle, along with 10 g of ripe banana.

EFFECT OF CHERRY CULTIVAR ON *DROSOPHILA* SPECIES, CATCH RATE, AND FLY PHENOLOGY

Three cultivars of cherry were sampled: the early ripening cv. 'Hongdeng,' mid-season ripening cv. 'Van,' and the late ripening cv. 'Summit.' For each cultivar 5 trees were selected and a trap was suspended 1.2 m above the ground from each tree. Traps were replaced every 3 d and brought back to the laboratory to identify and count the fruit flies.

EFFECT OF TRAP HEIGHT ON CATCH

This experiment was conducted in the same orchard as the cultivar study. We used a 5 point sampling method (Pelz-Stelinski et al. 2006) in the study orchard, and at each point, the nearest same-cultivar cherry tree was selected to hang 1 trap at each of the 4 different test heights (at ground level, 1 m, 1.5 m, or 2 m above the soil). Traps were replaced every 3 d with new bottles containing fresh liquid bait. Old traps were brought back to the laboratory where fruit flies were removed, identified to species, and counted.

DATA ANALYSIS

Fly abundance was expressed as number of individuals per trap per 3 d. Data normality was checked using the 1-sample Kolmogorov-Smirnov test. In case of non-normality, we used a log transformation. In cases where normalization was unsuccessful, we used a non-parametric ANOVA to test for differences. Means were separated using LSD. Data were processed with Excel 2007, and ANOVA using the SPSS 20.0 statistics program (SPSS Inc., Chicago, Illinois, USA).

Results

FRUIT FLY ABUNDANCE

Four fruit fly species were collected in cherry orchards each yr from 2014 to 2016: *Drosophila melanogaster* Meigen, *D. suzukii* Matsumura, *Drosophila hydei* Sturtevant (Diptera: Drosophilidae), and *Drosophila immigrans* Sturtevant (Diptera: Drosophilidae). These 4 species accounted for 66.7, 29.7, 3.0, and 0.6% of the total, respectively (Fig. 1). Whereas *D. melanogaster* and *D. suzukii* peaked on 9 Jul and 12 Jul, respectively, the other 2 species were found only at low levels and did not have a distinct seasonal peak.

Considering the overall seasonal activity, the number of fruit flies in 2014 peaked around 24 Jun, significantly earlier than in 2015 (12 Jul) and 2016 (15 Jul), which is closely related to the phenology of fruit maturation (Fig. 2).

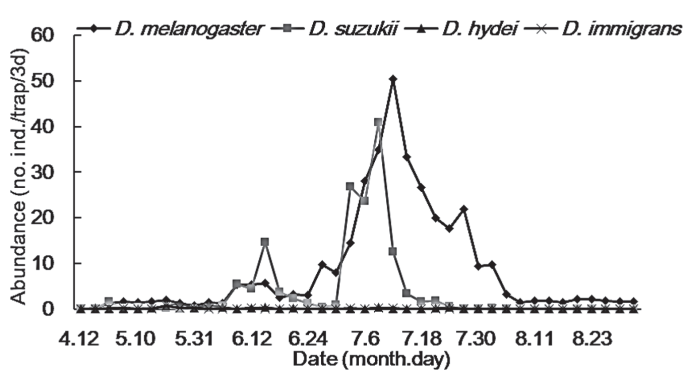

Fig. 1. Mean (± SD) abundance of 4 fruit fly species in a cherry orchard in China.

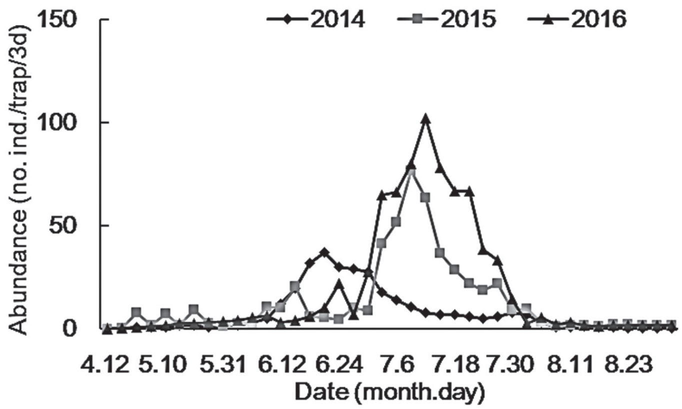

Fig. 2. Comparison of total fruit fly abundance from 2014 to 2016 in a cherry orchard in Qingdao, China.

EFFECT OF CHERRY CULTIVARS ON FRUIT FLY CAPTURES

Peak trap captures of *D. melanogaster* differed significantly among cultivars (Hongdeng, Van, and Summit) on 12 Jul ($F = 35.67$; df = 2; $P < 0.001$) (Fig. 3). Peak trap captures of *D. suzukii* (on 3 Jul, 9 Jul, 9 Jul for cv. Hongdeng, Van, and Summit, respectively) differed significantly among cultivars ($F = 49.35$; df = 2; $P < 0.001$) (Fig. 4).

In the cv. Hongdeng, all 4 *Drosophila* spp. were captured, but *D. melanogaster* was the dominant species, with peaks in mid-Jul and with an average peak among years of 30.4 ± 3.7 (± SD) individuals per trap per 3 d. The second most common species, *D. suzukii*, showed seasonal peaks of abundance in mid-Jun and early Jul, with an average peak abundance among yr of 25.6 ± 1.4 individuals per trap per 3 d.

In cv. Van, all 4 *Drosophila* flies were trapped, and *D. melanogaster* was the dominant species. Peak catches of *D. melanogaster* occurred in mid-Jul, with an average peak among yr of 78.6 ± 8.2 individuals per trap per 3 d. *Drosophila suzukii* showed peaks in mid-Jun and early Jul, with an average peak abundance among yr of 56.2 ± 7.3 individuals per trap per 3 d. The peak of *D. suzukii* on cv. Van was earlier than on cv. Hongdeng.

In cv. Summit, all 4 *Drosophila* flies were trapped, with *D. melanogaster*, the dominant species, peaking in mid-July at 62.6 ± 5.8 individuals per trap per 3 d; *D. suzukii* had peaks in trap capture in mid-Jun and early Jul (48.3 ± 2.9 individuals per trap per 3 d). The peak of fruit fly activity coincided with the flies in cv. Van. (Fig. 5).

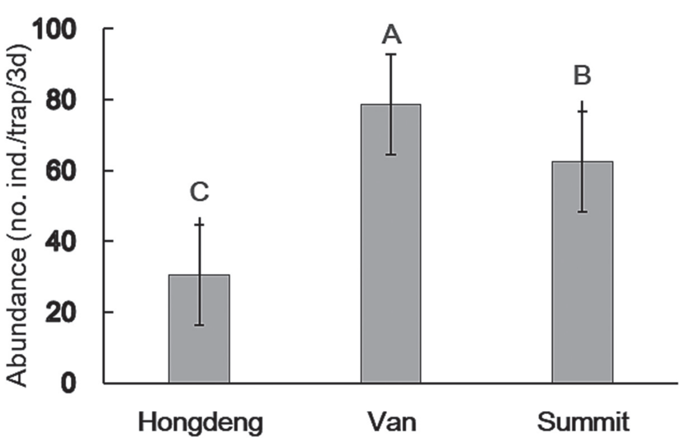

Fig. 3. Analysis of the peak number of *D. melanogaster* in different cherry cultivars.

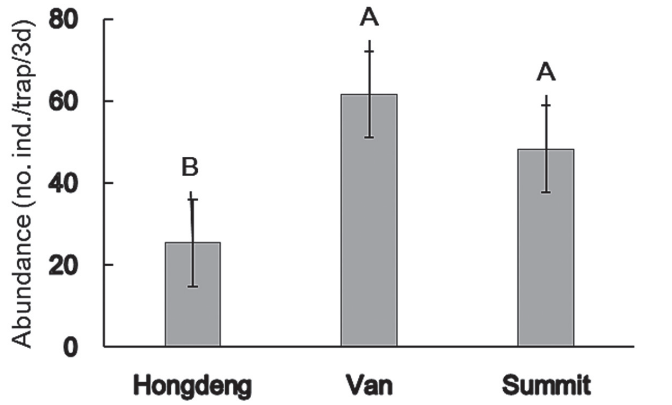

Fig. 4. Analysis of the peak number of *D. suzukii* in different cherry cultivars.

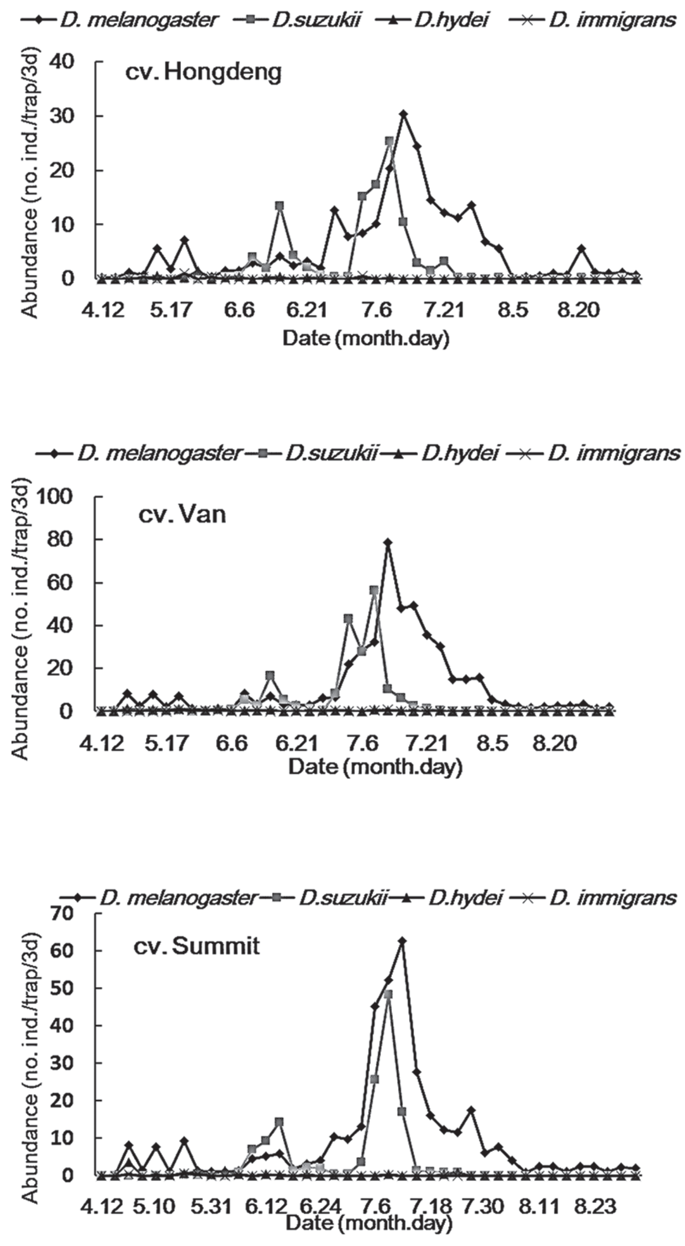

Fig. 5. Phenology of 4 fruit fly species in 3 cherry cultivars in Qingdao, China, 2014 to 2016.

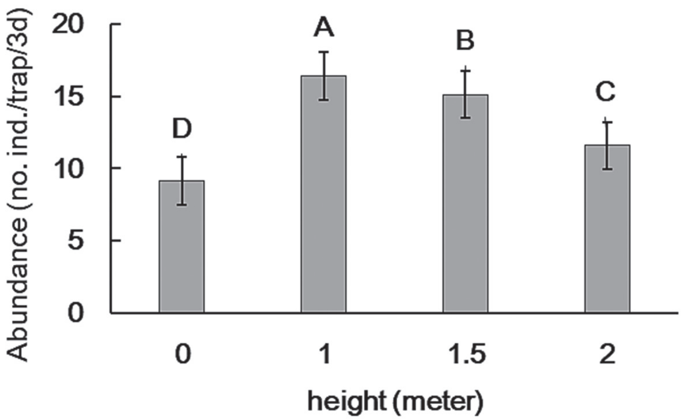

Fig. 6. Relationship of trap captures to height of the traps.

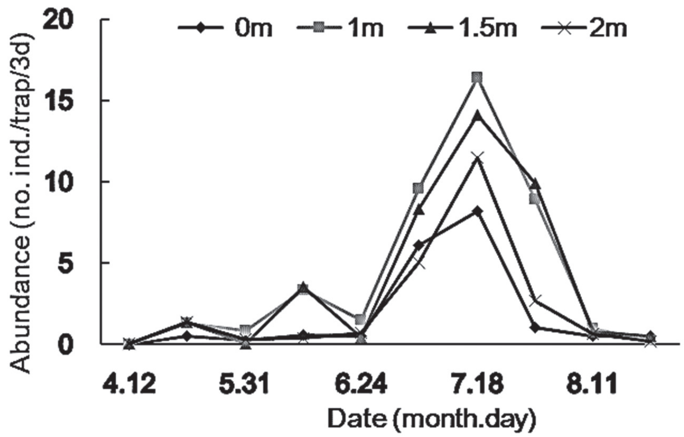

Fig. 7. Mean (± SD) fruit fly abundance over the course of the seasons.

EFFECT OF TRAP HEIGHT ON *DROSOPHILA* FRUIT FLY CAPTURES

Most fruit flies were captured by traps placed at 1 m above the soil (16.4 ± 0.9 individuals per trap per 3 d), significantly more (F = 139.56; df = 3; P < 0.001) than at other heights (Fig. 6). There was little fruit fly activity at ground level. During the entire investigation period, the mean relative proportions of fruit flies trapped at different heights were 17.5, 31.7, 28.9, and 22.2% at ground level, 1 m, 1.5 m, and 2 m, respectively.

The numbers captured at different heights followed the overall seasonal dynamics of fruit flies. The number of fruit flies peaked around 18 Jul (Fig. 7) with an average over the 3 yr of investigation of 8.2, 16.4, 14.1, 11.5 individuals per trap per 3 d at ground level, 1 m, 1.5 m, and 2 m above the soil.

At all 4 heights, the numbers of *D. melanogaster* flies captured were significantly greater than those of the other 3 flies. The maximum number (66.6 ± 21.5 individuals per trap per 3 d) of *D. melanogaster* were captured 1 m above the soil, but the maximum number (14.6 ± 1.6 individuals per trap per 3 d) of *D. suzukii* were captured 1.5 m above the soil. The trap numbers of *D. hydei* and *D. immigrans* were low at all 4 height levels (Table 1).

Discussion

A great deal of research has been done on the damage caused by *Drosophila* fruit flies. In Baqiao District, Shanxi Province, *D. melanogaster* and *D. suzukii* were found to be the dominant species, comprising 50.2 and 45.9% of the total number of *Drosophila*, respectively (Guo et al. 2014). Another study found *D. melanogaster* and *Drosophila simulans* Sturtevant (Diptera: Drosophilidae) to be the dominant species on *Myrica rubra* (Ming et al. 2008). In South Korea, *D. suzukii* is the principal fruit fly pest on cherry and other berries (Guerrieri 2016), whereas in Europe and Turkey, *Rhagoletis cerasi* (L.) (Diptera: Tephritidae) is the principal fruit fly pest in cherries (Kepenekci et al. 2015). In northeastern Chile, *D. suzukii* is the most important pest in cherries and strawberry (Arnó & Gabarra 2016). In northern China, we detected an increase in fruit fly abundance from 2014 to 2016, and the principal species were *D. melanogaster*, *D. suzukii*, *D. hydei*, and *D. immigrans*. *Drosophila melanogaster* was the dominant species. *Drosophila melanogaster* is also the dominant species in Sichuan Province, but *D. immigrans* is present (Guo et al. 2007). In Gansu Province, *D. melanogaster* is dominant, with *D. suzukii and D. hydei* also present (Guo 2007). The above reports are basically consistent with our survey. Regional and between-yr differences in fruit fly species presence and importance may be closely related to differences in climate, local environmental factors, and different cultivars.

The synchronization of fruit fly seasonal activity to their host fruits has been reported for various crops in several parts of the world (Lee et al. 2015; Joshi et al. 2017), as well as in China (Zhang et al. 2013; Guo et al. 2014). In the northeastern region of Spain, cherry and strawberry-feeding fruit flies reach their peaks from Mar to Apr (Arnó & Gabarra 2016). However, we found that cherry-feeding *Drosophila* fruit flies in cherry can be trapped in cherry fruit production. They peak in late Jun to mid-Jul before beginning to decrease. High temperatures usually reduce the number of fruit flies (Harris et al. 2014; Kinjo et al. 2015). We also found that the period of *Drosophila* fruit fly population decline coincided with high temperatures in Qingdao.

We found significant differences in the number of fruit flies attracted to different cherry cultivars. In our study, the cultivar maturing in the middle of the season (cv. Van) attracted the greatest numbers of fruit flies, followed by the late maturing cultivar (cv. Summit). The early maturing cultivar (cv. Hongdeng) attracted the fewest flies. Late-maturing cultivars usually attract more fruit flies (Guo et al. 2014). The greater occurrence of fruit flies on the mid-season ripening cherry is likely due to the warmer temperatures during this period. Early maturing cv. Hongdeng matured at the end of May, and fruit flies occurred in Jun and Jul. This suggests that the use of an early maturing cherry cultivar like cv. Hongdeng could be recommended to farmers as a way to reduce fruit fly infestation by achieving a harvest before the pest reaches peak abundance.

We also found significant differences in the effectiveness of traps suspended at different heights, with the greatest number of flies caught 1 to 1.5 m above the soil, a finding consistent with the most effective trapping height of 1 to 2 m reported by Darwish et al. (2015). The high fruit fly capture rate also may be related to the flight height of *Drosophila* fruit flies, though we have no data on this. Our data suggest that traps should be positioned at the 1 to 1.5 m height when monitoring fruit fly populations.

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Table 1. Mean trap captures (± SD) of fly catches by height and species.

		Species			
Trap height (m)	Sampling date	*D. melanogaster*	*D. suzukii*	*D. hydei*	*D. immigrans*
Ground level	12-Apr	0.0 a	0.0 a	0.0 a	0.0 a
	10-May	1.6 ± 0.6 a	0.0 b	0.6 ± 0.6 ab	0.0 b
	31-May	0.6 ± 0.2 a	0.2 ± 0.2 a	0.0 a	0.2 ± 0.2 a
	12-Jun	2.2 ± 0.7 a	0.4 ± 0.4 b	0.0 b	0.0 b
	24-Jun	2.0 ± 0.4 a	0.2 ± 0.2 b	0.0 b	0.0 b
	18-Jul	21.0 ± 0.7 a	11.2 ± 0.5 b	0.0 c	0.0 c
	30-Jul	4.2 ± 0.7 a	0.0 b	0.0 b	0.0 b
	11-Aug	2.0 ± 0.4 a	0.0 b	0.0 b	0.0 b
	23-Aug	2.0 ± 0.4 a	0.0 b	0.0 b	0.0 b
1 m	12-Apr	0.0 a	0.0 a	0.0 a	0.0 a
	10-May	5.0 ± 2.6 a	0.0 b	0.0 b	0.2 ± 0.2 b
	31-May	3.0 ± 0.5 a	0.0 b	0.0 b	0.2 ± 0.2 b
	12-Jun	4.0 ± 0.6 a	9.0 ± 1.0 b	0.2 ± 0.2 c	0.2 ± 0.2 c
	24-Jun	5.2 ± 0.7 a	0.8 ± 0.2 b	0.0 b	0.0 b
	18-Jul	66.6 ± 21.5 a	0.8 ± 0.6 b	0.0 b	0.2 ± 0.2 b
	30-Jul	34.0 ± 6.5 a	1.6 ± 0.6 b	0.2 ± 0.2 b	0.0 b
	11-Aug	3.8 ± 0.5 a	0.2 ± 0.2 b	0.0 b	0.0 b
	23-Aug	0.4 ± 0.2 ab	0.6 ± 0.2 b	0.0 a	0.0 a
1.5 m	12-Apr	0.0 a	0.0 a	0.2 ± 0.2 a	0.0 a
	10-May	5.2 ± 2.3 a	0.0 b	0.2 ± 0.2 b	0.0 b
	31-May	0.0 a	0.0 a	0.2 ± 0.2 a	0.0 a
	12-Jun	6.4 ± 0.7 a	7.2 ± 1.2 a	0.6 ± 0.2 b	0.0 b
	24-Jun	1.4 ± 0.6 a	0.4 ± 0.2 b	0.0 b	0.0 b
	18-Jul	54.6 ± 12.2 a	4.2 ± 1.7 b	0.0 b	0.0 b
	30-Jul	12.8 ± 1.0 a	14.6 ± 1.6 a	0.0 b	0.0 b
	11-Aug	3.0 ± 0.3 a	0.2 ± 0.2 b	0.0 b	0.0 b
	23-Aug	2.0 ± 0.6 a	0.0 b	0.2 ± 0.2 b	0.0 b
2 m	12-Apr	0.0 a	0.0 a	0.2 ± 0.2 a	0.0 a
	10-May	5.2 ± 1.0 a	0.0 b	0.4 ± 0.2 b	0.0 b
	31-May	1.0 ± 0.4 a	0.0 b	0.2 ± 0.2 b	0.0 b
	12-Jun	1.4 ± 0.2 a	0.2 ± 0.2 b	0.0 b	0.0 b
	24-Jun	2.0 ± 0.4 a	0.4 ± 0.2 b	0.4 ± 0.2 b	0.0 b
	18-Jul	45.6 ± 2.3 a	1.4 ± 0.6 b	0.4 ± 0.4 b	0.0 b
	30-Jul	10.8 ± 1.1 a	0.0 b	0.0 b	0.0 b
	11-Aug	2.4 ± 0.5 a	0.2 ± 0.2 b	0.0 b	0.0 b
	23-Aug	0.6 ± 0.2 a	0.2 ± 0.2 ab	0.0 b	0.0 b

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