PROBABILITY OF DETECTING CARIBBEAN FRUIT FLY (DIPTERA: TEPHRITIDAE) INFESTATIONS BY FRUIT DISSECTION

WALTER P. GOULD
USDA-ARS, Subtropical Horticulture Research Station,
Miami, FL

ABSTRACT

Quarantine inspectors search for fruit fly infestations in incoming shipments by visual inspection and by dissecting or cutting a sample of fruit in each shipment. The reliability of the latter procedure for detecting fruit fly larvae is questionable and, therefore, a test was conducted to determine its effectiveness. Infested grapefruit, mangoes, guavas, and carambolas were cut open to determine the efficacy of cutting fruit in detecting larval infestations of Caribbean fruit flies, *Anastrepha suspensa* (Loew). From 1 to 36% of the larvae were detected by dissection, but 17.9 to 83.5% of the infested fruit were detected. The percentage of Caribbean fruit fly larvae present in an infested fruit that can be detected by cutting varies with the type of fruit infested. The overall percentage of infested fruit detected also varies in the same manner. Carambolas were the easiest fruit in which to find larvae and green guavas the most difficult. Overall, only 9.5% of the larvae in field-infested guavas and 16.9% of those in cage-infested fruits were detected. Between 17.9% (green guavas) and 83.5% (carambolas) of the infested fruit was detected. There was considerable variation in the number of larvae found by different inspectors.

Key Words: Caribbean fruit fly, *Anastrepha suspensa*, larval detection.

RESUMEN

Los inspectores cuarentenarios detectan infestaciones de moscas de las frutas buscando frutas dañadas y cortando una muestra de ellas en un determinado cargamento. Se disectaron toronjas, mangos, guayabas, y carambolas infestadas para determinar la eficiencia del corte de frutas en la deteccción de la infestación larval de *Anastrepha suspensa* (Loew). Del 1 al 36% de las larvas fueron detectados mediante la disección; sin embargo, este método permitió encontrar del 17.9 al 83.5% de las frutas infestadas. El porcentaje de larvas de moscas de las frutas del Caribe detectado cortando frutas infestadas varió con los diferentes tipos de frutas. El porcentaje de frutas infestadas varió de la misma manera. La fruta en la cual fue más fácil encontrar larvas fue la carambola y la más difícil la guayaba verde. En resumen, solamente fue detectado el 9.5% de las larvas en las guayabas, y el 16.9% en las frutas que fueron infestadas en jaulas. Fue detectado entre el 17.9% (guayabas verdes) y el 83.5% (carambolas) de las frutas infestadas. Hay considerable variación en el número de larvas encontradas por diferentes inspectores.

Prevention of the spread of undesirable pests is a worldwide problem and quarantines have been established for many pest organisms. The family Tephritidae includes many species of fruit flies whose larvae attack valuable cultivated fruits and vegetables. Two dozen important species and hundreds of species of minor importance exist around the world (Robinson & Hooper 1989). Most fruit flies lay their eggs under the skins of fruits and vegetables. The larvae burrow and feed inside the fruit or vegetable making it unpalatable and accelerating decay. Many countries have plant protection agencies whose mission is to exclude these unwelcome pests (Shannon 1994). The main line of defense is the vigilance of inspectors who check incoming fruit and vegetable shipments. The main method of detecting fruit flies in a shipment of a commodity is to sample a number of fruits or vegetables and examine them for possible signs of infestation, a procedure that often includes cutting open some of the fruits and examining them for eggs and/or larvae (Anon. 1993).

Cutting fruits and vegetables to detect insect infestation is time consuming and only a fraction of a shipment can be inspected in this way, but there are no feasible alternatives. Holding the commodity until any larvae emerge is not practical because it would hold up the shipment for too long and destroy its value. Other methods, such as detecting sound of feeding larvae, have not yet proven practical (Calkins & Webb 1988, Hansen et al. 1988, Hansen et al. 1992, Harrison et al. 1993).

Many factors can affect the probability of finding a larva, such as the ability of the inspector, the stage of the insect present, and the type of fruit. In this study, I determined the probability of detecting Caribbean fruit fly, *Anastrepha suspensa* (Loew), larvae given three variables. I looked at four types of fruit, different stages of ripeness, and variations in the efficiency of the inspectors.

MATERIALS AND METHODS

Four different types of fruit were used. Guavas were obtained from J. R. Brooks and Son, a local packing house, and ripe guavas were harvested from trees on the USDA station in Miami. Mangoes and carambolas were also obtained from J. R. Brooks and Son. Grapefruits were obtained from Bernard Egan & Co., a packing house in central Florida. Guavas received from the packing house were separated into ripe (yellow) and immature (green). The guavas had a significant field infestation. Grapefruits, mangoes, and carambolas did not have a detectable infestation in the field so they were exposed to approximately 100,000 Caribbean fruit flies in an outdoor cage for 1 to 3 days (carambolas and mangoes), or 7 days (grapefruit). Field-infested guavas were cut open 1 day after being received from the packing house or being picked and could contain all stages of eggs and larvae. Mangoes were held 5 to 13 days after infestation before being cut open, and grapefruit and carambolas were held for 7 days after infestation before cutting. These holding periods allowed development of larvae to the third instar and precluded presence of eggs and early instars.

The fruits were randomly divided into a control and a treatment group. The number of fruits used per replicate depended on the number available, between 15 and 150 per replicate, and the experiment was replicated three to five times for each type of fruit.

To compare effect of fruit type and ripeness, cutting was done by one inspector using the following guidelines: Each fruit was cut with a 15-cm utility knife into 1-cm thick slices (from 5 to 10 depending upon fruit size). Mangoes were sliced from each side until the seed was reached, then turned 90° and sliced again until the seed was reached. Each slice was examined for the presence of Caribbean fruit fly larvae, and the total number observed was recorded. Sliced fruits with larvae and unsliced control fruits were placed in 1-liter plastic buckets containing vermiculite and held for several weeks. The vermiculite was then sifted for larvae and pupae.

Another experiment was conducted to examine the effect of the inspector on the probability of detection. Five additional inspectors were recruited for the test. All were either active employees of the Florida Department of Agriculture & Consumer Services, Division of Plant Industry (DPI) or ex-DPI members who had routinely cut fruits looking for larvae. The five DPI or ex-DPI inspectors and the original inspector each cut 10 or 20 infested grapefruit (fly cage infested). The five DPI inspectors were allowed to cut fruit any way they chose. The original inspector followed the previous guidelines.

Percentage of larvae detected by cutting and percentage of infested fruits detected by cutting were transformed using the angular transformation (arcsin) and both transformed and untransformed data analyzed using unbalanced ANOVA by GLM (SAS Institute 1988). Untransformed percentages are presented in the tables for comparison. If the ANOVA F-test was significant at the 0.05 level, the Waller-Duncan K-ratio t-test (SAS Institute 1988) was used to separate means. T-test and Proc Reg were also used (SAS Institute 1988).

RESULTS AND DISCUSSION

There was no significant difference between the number of larvae emerging from control and the cut fruits (paired t-test, P=.998, α=0.05). Therefore, very few larvae were physically damaged by the cutting, and tearing the fruit open did not affect the larvae's ability to mature and leave the fruit.

The infestation levels in the fruits varied (Table 1). Green guavas from Brooks had the lowest infestation level, ripe guavas from Brooks slightly higher, and ripe guavas from the USDA station, much higher levels. The infestations from the cage varied as well. In most of the replications, the infestations were low (one or fewer larvae per fruit); however, there were several with moderate infestations and several with extremely high infestations.

There was considerable variation between replications in the percentage of larvae detected by cutting for all fruit types (Table 2). Green guavas overall had the lowest percentage of larvae detected (1.1%). Carambolas had the highest (about 36%). Only 9.5% of the larvae in field-infested guavas were detected by cutting. Only 16.9% of the larvae in all of the cage-infested fruits (carambolas, grapefruits, mangoes) together were detected by cutting.

From 64 to 98% of larvae escaped detection. However, since many larvae were often found in one fruit, there was a higher probability of an infested fruit being de-

TABLE 1. FRUIT INFESTATION LEVELS OF *A. SUSPENSA* (LARVAE PER FRUIT).

Field-Infested Guavas	Replication					Mean
	1	2	3	4	5	
Green-Brooks	6.000	0.167	0	0.200	0	1.273
Ripe-Brooks	8.662	0.967	0.240	0.200	—	2.517
Ripe-USDA station	39.120	38.920	13.320	—	—	30.453
Cage-Infested Fruits	**Replication**					**Mean**
	1	2	3	4		
Grapefruits	0.633	3.840	0.680	58.580		15.933
Mangoes	225.750	0.100	0.750	1.600		57.050
Carambolas	20.220	11.000	0.320	—		10.513

TABLE 2. PERCENTAGE OF *A. SUSPENSA* LARVAE DETECTED BY CUTTING.

Fruit type	Replication				Mean[1]
	1	2	3	4	
Carambolas	9.0	35.8	62.5	—	35.8a
Ripe Guavas-Brooks	29.6	13.5	25.6	—	22.9ab
Grapefruits	15.8	7.8	11.8	2.8	9.5bc
Mangoes	1.9	0.0	20.0	0.0	5.5bc
Ripe Guavas-USDA station	4.7	0.0	9.0	—	4.6bc
Green Guavas-Brooks	1.1	2.2	0.0	—	1.1c

[1]Means within a column followed by the same letter are not significantly different by ANOVA followed by Waller-Duncan K-ratio t-test.

tected than Table 2 would indicate (Table 3). As many as 83.5% of carambolas with larvae were detected. This is probably because carambolas are a fairly translucent fruit and larvae are more easily observed. Green guavas were the most difficult in which to detect larvae; only 17.9% of the infested fruit were detected. This may be because they were inspected one day after we received them, thus the fruit flies could be in the egg stage or very early instar and very difficult to see. This fruit is also tough and difficult for the inspector to cut up. Analysis of variance found that in the percentage of infested fruit detected, there was a significant difference only between the carambolas and all of the other fruit, except ripe guavas from Brooks. None of the other pairwise comparisons was significant.

The effect of size of infestation and the percentage of larvae found did not show a high correlation, but generally the more larvae that were present, the lower the percentage found by the inspector. This may be due to a fatigue factor in those extreme infestations where thousands of larvae were present. Taking log ten of the number of larvae present makes the distribution of the percentage of larvae detected look like the normal distribution. The best regression had an r^2 of 0.11; with an outlier deleted, it improved only to 0.29.

TABLE 3. PERCENTAGE OF *A. SUSPENSA* INFESTED FRUITS DETECTED BY CUTTING.

Fruit Type	Replication					Mean[1]
	1	2	3	4	5	
Carambolas	60.5	90.0	1	—	—	83.5a
Ripe Guavas-Brooks	77.8	66.7	60.0	0.0	—	51.1ab
Ripe Guavas-USDA station	66.7	36.0	48.0	36.0	—	46.7b
Grapefruits	23.3	22.2	58.0	—	—	34.5b
Mangoes	85.0	0.0	28.6	0.0	—	28.4b
Green Guavas-Brooks	7.2	22.3	0.0	60.0	0.0	17.9b

[1]Means within a column followed by the same letter are not significantly different by ANOVA followed by Waller-Duncan K-ratio t-test on arcsin transformed data. Untransformed means are presented.

TABLE 4. PERCENTAGE OF *A. SUSPENSA* LARVAE DETECTED BY CUTTING BY DIFFERENT INSPECTORS.

Inspector 1	08.4
Inspector 2	49.1
Inspector 3	29.5
Inspector 4	17.8
Inspector 5	17.7
Inspector 6	16.3
Mean	23.1
St. Dev.	14.4

In the inspector comparison, the percentage of larvae found varied from 8% to 49% (Table 4). Most of the difference could be attributed to the methods each inspector used. Inspector 1 was obviously hurrying and found the fewest larvae. Inspector 2 shredded the fruit into tiny pieces, took much longer than the others, and found more larvae. The other three inspectors' results were very similar. Because the inspectors knew their results were being compared and studied, they probably found more larvae than they would have otherwise. The main reason for performing this test was to determine the relationship between the method and the inspector so we could assess the results of the first part of this study compared to 'real world' inspectors. We concluded that the data obtained with the inspector in the first part of this study (using a consistent cutting method) were reasonably comparable to those of the DPI inspectors.

In summary, the percentage of Caribbean fruit fly larvae present in an infested fruit that can be detected by cutting varied with the type of fruit infested. The overall percentage of infested fruit detected also varied in the same manner. Carambolas were the easiest fruit in which to find larvae and green guavas the most difficult. Overall, only 9.5% of the larvae in guavas and 16.9% of those in cage-infested fruits were detected. Between 17.9 and 83.5% of the infested fruit was detected. There was considerable variation among inspectors based on the method used to inspect the fruit.

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REFERENCES CITED

ANONYMOUS. 1993. Animal Plant Health Inspection Service. Plant Import Manual: Nonpropagative. U.S. Govt. Printing Office. Washington, D.C.

CALKINS, C. O., AND J. C. WEBB. 1988. Temporal and seasonal differences in movement of the Caribbean fruit fly larvae in grapefruit and the relationship to detection by acoustics. Florida Entomol. 71: 409-416.

HANSEN, J. D., C. L. EMERSON, AND D. A. SIGNOROTTI. 1992. Visual detection of sweetpotato weevil by non-invasive methods. Florida Entomol. 75: 369-375.

HANSEN, J. D., J. C. WEBB, J. W. ARMSTRONG, AND S. A. BROWN. 1988. Acoustical detection of oriental fruit fly (Diptera: Tephritidae) larvae in papaya. J. Econ. Entomol. 81: 963-965.

HARRISON, R. D., W. A. GARDNER, W. E. TOLLNER, AND D. J. KINARD. 1993. X-ray computed tomography studies of the burrowing behavior of fourth-instar pecan weevil (Coleoptera: Curculionidae). J. Econ. Entomol. 86: 1714-1719.

ROBINSON, A. S., AND G. HOOPER, (eds.) 1989. Fruit Flies, Vol. 3A World Crop Pests. Elsevier, Amsterdam. 372 pp.

SAS INSTITUTE. 1988. SAS/STAT User's Guide. Release 6.03 Ed. SAS Institute, Cary, NC.

SHANNON, M. J. 1994. APHIS, pp. 1-10 *in* J. L. Sharp and G. J. Hallman [eds.] Quarantine treatments for pests of food plants. Westview Press, Boulder, Colorado. 290 pp.