ACCELERATED QUARANTINE TREATMENT DEVELOPMENT FOR INSECTS ON POOR HOSTS

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Quarantine treatments are being developed in Hawaii so that fresh fruits and vegetables that potentially harbor quarantine pests can be exported to overseas markets. The probit 9 standard for quarantine treatment efficacy (maximum 32 survivors in a million treated individuals) was initially recommended with fruit flies and heavily infested fruit in mind (Baker 1939) and has been the guiding principle in quarantine research. The probit 9 approach centers on high mortality of the treated population and for heavily infested commodities usually provides adequate quarantine security. However, this standard may be too stringent for commodities that are rarely infested or are poor hosts. The *alternative treatment efficacy* approach measures risk as the probability of a mating pair, gravid female, or parthenogenic individual surviving in a shipment (Landolt et al. 1984). This will be a function of many factors but the main quantitative argument for deviating from probit 9 is low infestation rate of the commodity. Rambutan is a poor host for its high-risk regulatory pests *Bactrocera dorsalis* (Hendel) (oriental fruit fly, Diptera: Tephritidae) and *Cryptophlebia* spp. (Lepidoptera: Tortricidae) in Hawaii. The alternative treatment efficacy approach can be applied to pest risk management for these pests in this export crop.

Calculating Pest Risk. The main criterion for defining risk is the probability of a potential mating pair surviving in a shipment of fruit. To calculate risk, estimates are needed for infestation rate, shipment size, and the efficacy of the disinfestation treatment. In 1995-1996 (two seasons), over 47,000 mature fruits of ten varieties of rambutan were harvested from orchards in Hawaii to assess natural levels of infestation by any internal feeding pests such as fruit flies and *Cryptophlebia* (McQuate et al. submitted). Over all varieties, infestation rates (number of adults emerging per fruit) for the quarantine pests were 0.07% for *B. dorsalis* (33 adults emerged from 47,188 fruits) and 0.11% (50 adults emerged from 47,188 fruits) for *Cryptophlebia.* Using the approach of Couey and Chew (1986, Table 1) the upper bound of the 95% confidence limit was calculated as 0.09% for *B. dorsalis* and 0.13% for *Cryptophlebia* and these values were used infestation rate in pest risk calculations.

Realistic estimates for shipment size in terms of number of fruits were determined from fruit weight data. It was estimated that shipment sizes of 2000 and 10,000 kg would have approximately 50,000 and 250,000 fruits, respectively.

The probability of finding one or more mating pairs as a function of infestation rate in the field, shipment size, and expected survival of the pest after a disinfestation treatment is given by:

$$P = [1 - e^{-NFT/2}]^{2} \qquad \text{(Liquido et al. 1996, 1997)}$$

where N is the number of fruit in a shipment, F is the field infestation rate (per fruit), and T is pest survival after a postharvest treatment. NFT is the average number of live pests in a shipment after a postharvest treatment. If we assume the postharvest treatment (*T*) provides probit 9 efficacy (99.9968% mortality of the pest), we can calculate the frequency of live pest occurrence in a series of rambutan shipments, and the probability of having a mating pair in a single shipment for *B. dorsalis* and *Cryptophlebia* (Table 1). For example, at the larger shipment size, 250,000 fruits, the predicted frequency of occurrence (*NFT*) of live *B. dorsalis* is 0.003 (1 individual in 333 shipments), and the probability of a having a mating pair in a shipment is 1.3×10^{-5}! Therefore, probit 9 efficacy of the treatment provides a high level of overkill, and the probability of a having a mating pair of either of these two pests in a shipment of rambutan is extremely small.

If probit 9 efficacy of a disinfestation treatment results in significant overkill, the efficacy of the treatment can be reduced to some extent while still maintaining quarantine security. Assuming we are trying to prevent a mating pair from arriving in a shipment, the equations to calculate the required treatment mortality (*m*) are as follows:

$$m = 1 - (NR/(i*n*s))$$

$$NR = -2*(\log_e (1 - sqrt\ (P))$$ (Vail et al. 1993)

where *i* is the infestation rate (proportion of infested fruit, used upper bound of 95% confidence interval for infestation rate determined in the field), *n* is the number of fruit in a shipment, and *s* is the natural survival rate of insects in fruit after harvest. *NR* is the number of fruit (*N*) multiplied by the infestation rate (*R*) and is a constant function of *P*. We arbitrarily set *P*, the probability of having one or more mating pairs, at 0.01 (99% chance of having <1 mating pair). If we assume that the survival rate (*s*) is 1.0, *m* becomes solely a function of infestation rate and shipment size.

From these estimates, the required quarantine treatment efficacy can be calculated to ensure with 95% confidence that <1 mating pairs survives in a shipment (Table 1). For example, in a shipment size of 250,000 rambutan fruits the required treatment efficacy to prevent the shipment of a mating pair for *B. dorsalis* is 99.906% mortality, which translates to probit 8.11. For the same shipment size, the required treatment efficacy to prevent the shipment of a mating pair for *Cryptophlebia* is 99.935% mortality, which translates to probit 8.21.

Estimates for the required treatment efficacy can be used to determine the number of insects that must be tested such that if no survivors are found, we will have 95% confidence that the probability of survivors meets the treatment efficacy or probit level established. Basically, the probit 9 standard requires that 100,000 insects be tested with ≤ 3 survivors--with the alternative treatment efficacy approach, low infestability of the host is included in a probability equation and the number of required test insects can be reduced. The equation to calculate the number of test insects (*n*) is:

$$n = [\log(1 - C)]/\log(\ m)$$ (Couey and Chew 1986)

where *C* = confidence level (between 0 and 1), and *m* is the level of required mortality (between 0 and 1).

For *B. dorsalis* and *Cryptophlebia* in rambutan under two shipment size conditions, the required number of test insects (*n*) ranged from 639 to 4607 (Table 1). For example, to ensure quarantine security for *B. dorsalis* in a shipment of 250,000 rambutan fruits or less, 3,185 insects must be treated with the proposed treatment with no survivors.

Key Points

- The *alternative treatment efficacy approach* estimates risk of pest survival and reproduction based on biological, ecological, quarantine treatment, and marketing or distribution data.
- Acceptance of the concept of pest risk management (i.e., probability of a mating pair in a shipment) for qualifying pests/commodities will often decrease the number of required test insects (relative to probit 9) when developing quarantine treatments, thereby saving time and resources.
- Decreasing the time involved in developing a quarantine treatment will help farmers export their crop sooner.
- Naturally low infestation rates determined for the primary internal-feeding regulatory pests of rambutan in Hawaii, *B. dorsalis* and *Cryptophlebia* spp., suggest that this crop/quarantine pest system is amenable to the alternative treatment efficacy approach.

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Table 1. Required treatment efficacy and number of test insects for *Bactrocera dorsalis* and *Cryptophlebia* spp. infesting rambutan using the alternative treatment efficacy approach (95% confidence that <1 mating pair survives in a shipment)

Pest	Infestation rate (%)	95% CL (upper bound)	Shipment size (kg)	Shipment size (# fruits)	Probability of $\geq$1 mating pairs with probit 9	Treatment efficacy required	Probit	# Test insects required (0 survivors)
B. dorsalis	0.07	0.09	10,000	250,000	1.3×10^{-5}	99.906	8.11	3,185
			4000	50,000	5.1×10^{-7}	99.532	7.59	639
Cryptophlebia	0.11	0.13	10,000	250,000	2.7×10^{-5}	99.935	8.21	4,607
			4000	50,000	1.1×10^{-6}	99.676	7.51	923