

Research Article

Life-History Traits and Population Relative Fitness of Trichlorphon-Resistant and -Susceptible *Bactrocera dorsalis* (Diptera: Tephritidae)

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Life tables were established for trichlorphon-resistant and susceptible *Bactrocera dorsalis* strains based on the laboratory observations. Trichlorphon-resistant *B. dorsalis* strain had longer pupal and preoviposition periods, and mean generation time compared to the trichlorphon susceptible strain. Lower fecundity, emergence rate, and probability of standard fecundity P_F , and shorter female and male longevity also were apparent in the trichlorphon resistant strain. Based on the life tables, the life population trend index (I) of the resistant strain was 86.80, while that of the susceptible strain was 116.97. The net reproduction rate (R_0) and the intrinsic rate of increase (r_m) of the resistant strain were 1565.33 and 0.0164, while those of susceptible strain were 2184.00 and 0.0173, respectively. The results from this research revealed that the resistant strain was at a reproductive and developmental disadvantage relative to the susceptible strain.

1. Introduction

The oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), is distributed throughout Southeast Asia and the Pacific [1]. Now it has also infested many areas of China and thus causes serious financial loss to orchards globally [2]. The loss cost incurred by *B. dorsalis* was estimated to be as high as 44.6~176.5 million U.S. dollars in California, and also led to 230 million U.S. dollars potential economic loss of stone fruit industry in California [3], 1.26 billion U.S. dollars in 1997 in Taiwan, and about 1.47 billion U.S. dollars in 2004 in the Fujian [4–6].

Using insecticides is the major way to control this pest, however, frequent use of common insecticides had resulted in insecticide resistance in several insecticides, including organophosphates [7]. Resistance to insecticides has become a major problem of many pest species, including the oriental fruit fly. Keiser used 73 insecticides to determine their toxicity to *B. dorsalis* in 1973 [8], and found most of these insecticides had high toxicity. Purcell tested 3 insecticides (Malathion, Benzyl Cypermethrin and Carbaryl) and found

that Malathion was the most toxic in 1994 [9]. Resistance of *B. dorsalis* populations to insecticides in the field has become more and more serious since 2003 [2]. In 2004, it was reported that fly populations in Taiwan had resistance to ten insecticides (Naled, Fenthion, Trichlorphon, Fenitrothion, Formothion, Malathion, Methomyl, Cyfluthrin, Cypermethrin, and Fenvalerate), and that resistance to Malathion increased at the fastest rate, while Naled had the lowest rate [7, 10, 11].

In South China, the oriental fruit fly is distributed widely and its population density is very high, resulting in tremendous yield loss to many fruits. Chemical control strategies still play an important role in depressing oriental fruit fly density and reducing economic loss, therefore, it is very important to monitor the resistance of *B. dorsalis* to insecticides in the field [12, 13]. The development of resistance to organophosphate-based insecticides is a current and growing problem for the management of this pest species. A wide range of studies have focused on the elucidation of the molecular basis of this resistance [14, 15], and showed that flies exhibiting high levels of organophosphate resistance

carried three specific mutations in the *ace* gene of this species. Trichlorophon has been used to control *B. dorsalis* in commercial orchards in China, and now there is evidence of high resistance to this insecticide as well [2, 16–18], however the biology and ecology of the resistant populations of *B. dorsalis* has not been well studied.

The ecology of resistant insects is essential to the selection of control methods and the understanding of resistance dynamics. This study presents population life tables and life-history traits of susceptible and resistant strains to determine whether the relative fitness of resistant strains increases or decreases [19]. In some resistant insects, because the relative fitness of resistant insects is decreased, rotation of different insecticides and temporarily discontinuing the use of certain insecticides can decrease the frequency of resistance genes, and restore their susceptibility to certain insecticides [20, 21]. However, if the relative fitness of resistant insects is not affected by the resistance, these practices can only delay resistance development, and it is difficult to restore their susceptibility to those insecticides [22].

Compared to susceptible insects, resistant insects usually have a lower fecundity [23]. To provide a scientific basis for resistance risk management and achieve successful control of resistant *B. dorsalis*, it is important to study the biological and ecological variations between the trichlorophon-resistant and -susceptible *B. dorsalis* populations. This study examined the following areas: (1) the basic susceptibility of *B. dorsalis* to trichlorophon; (2) the development of resistance to trichlorophon through exposure over several generations; (3) the biological and ecological features of trichlorophon resistant strain.

2. Materials and Methods

2.1. *B. dorsalis* Strains. The trichlorophon resistant strain of *B. dorsalis* was collected in March 2003 from damaged carambola fruits, in Yangtao Park, Guangzhou City, Guangdong Province, China. Few insecticides had been used at this location because bags are used to protect carambola fruits from the flies. We collected about 2000 aging larvae from the damaged carambola, then placed the larvae into humid sand for pupation. After pupa emergence, flies were kept in the laboratory for 33 generations before using in the study. Bioassays were conducted every 3 generations, and new 24-h LC₅₀ values were obtained and guided the trichlorophon concentration which was used to treat the next 3 generations.

The susceptible strain was collected in August 2003 from the same place as the trichlorophon resistant strain, and maintained without any exposure to insecticides for 30 generations in the same laboratory as the resistant strain collected [2].

2.2. Method

2.2.1. Concentration-Response Bioassays. In order to make sure that the 24-h LC₅₀ value of the trichlorophon-resistant and -susceptible strains was stable, the populations of two strains from the field were both divided into 3 groups,

and the 24-h LC₅₀ value of each group was measured. Not only trichlorophon was used in the field, but also other organophosphorus pesticides which had systemic activity and the same mechanism as trichlorophon were used; so in the laboratory, we treated both larvae and adults with trichlorophon. The larvae of each generation were treated by topical application. In brief, aging larvae were treated with acetone diluted of trichlorophon whose concentration was the 24-h LC₅₀ value of the last time measurement. Treated larvae were then placed in humid sand for pupation. Adult flies, 3–5 days old, were treated by vial residues of acetone diluted trichlorophon, whose concentration was the 24-h LC₅₀ value of the last time measurement. Briefly, 5 mL of the acetone dilution was poured into a 250 mL triangular flask with constant shaking until the sides of the flask formed a uniform film. Excess diluent was discarded. When acetone evaporated, adults of *B. dorsalis* were then added to the flask, and supplied with a cotton ball saturated with 5% honey. The flask was sealed and placed at room temperature for $28 \pm 2^\circ\text{C}$ for 24 hours. Flies were considered dead when they could not crawl after continual prodding. The surviving adults were used for the next generation breeding [2, 24].

Two strains were both maintained at a temperature of $28 \pm 2^\circ\text{C}$ and in a photoperiod of 10:14 h [14]. The data from the regression equation, including 24-h LC₅₀ values of treatments, 95% confidence intervals and correlation coefficient (r), were analyzed by probit analysis. For each of 5 concentrations (treatments), there were 5 replicates, with each replicate using 30 flies. From the number of dead flies, we calculated the mortality and corrected mortality, translated corrected mortality into mortality probit. Then according to the logarithm of the concentrations and relevant mortality probits, we made the toxicity regression equation (LC-P line). Finally, according to the regression equation, we calculated the 24-h LC₅₀ value, the confidence interval, chi-square value, and correlation coefficient. If the 95% confidence intervals overlapped, we concluded that trichlorophon sensitivity was not statistically different between the strains [25]. The resistance ratios (RRs) are given as the values of the resistant LC₅₀ to trichlorophon/the susceptible LC₅₀ to trichlorophon in the same bioassay method [10, 11]. Microsoft Office Excel (2003) was used for data analysis, the test of significance (ANOVA: F test).

2.2.2. Duration of Life Stages. To determine the duration of the egg stage and hatching rate, we cut banana into small pieces and placed them in disposable plastic cups (150 mL), then we put the cups into the adult rearing cages (60 × 60 × 60 cm) of both strains to attract *B. dorsalis* female to lay eggs, respectively. The egg masses were removed after 2 hours, and 50 eggs from each strain were placed into a petri dish (Ø 9 cm) with filter paper containing banana juice. Hatched larvae were removed every two hours and the total number of larvae was counted.

Larval duration and pupation rate were determined from 50 susceptible and 50 resistant strain larvae that simultaneously eclosed. Banana was used to feed the larvae in a plastic box (15 × 15 × 15 cm). Dead and aging larvae were removed every 4 hours. The larval stage was from egg

hatch to aging, bouncing, larvae (larva of *B. dorsalis* have three instars, at the end of third-instar, they would bounce up 3–15 cm high and then fall to find a place to pupate). Total number of aging larvae was counted, and the duration of larvae and pupation rate were then calculated, respectively.

The duration of the pupal stage and the adult emergence rate was determined from 50 aging larvae from the susceptible and resistant strains. Bouncing larvae were placed into a box (15 × 15 × 15 cm) containing sand maintained at 70% RH. The emergence of pupae was observed every 8 hours until all pupa emerged. Newly emerged adults were removed every 8 hours. The duration of pupa was designated from the time aging, bouncing, larvae entered the sand to the time of adults emergence. The total number of adults was counted; the duration of pupa and emergence rate were then calculated.

2.2.3. Life-History Traits. Newly emerged adults (<8 h) were reared in a plastic cage (60 × 60 × 60 cm) with artificial feed and water. Before adults began to lay eggs (emerged about 10 d at 28 ± 2°C), 20 successful mating pairs were put into a new cage (60 × 60 × 60 cm) to observe egg laying every day until all female adults were dead. The total number of eggs laid by each female was recorded. Net reproduction rate (R_0 , the average fecundity of each adult by a generation), Intrinsic rate of increase (r_m , an important proliferation potential parameter of populations under certain environmental conditions, a composite indicator of the survival rate, fecundity, growth rate on the impact of population changes), and the index of population trend (I , the growth multiples of the next generation) were calculated using the following three formulas.

Formula of R_0 :

$$R_0 = \sum l_x m_x \quad (1)$$

(see [26]).

Formula of r_m :

$$\sum l_x m_x e^{-r_m x} = 1 \quad (2)$$

(see [27]), where x is age for insects; l_x is the population of x period m_x is the number of female at next generation of each female of x period.

Formula of I :

$$I = S_1 S_2 S_3 \cdots S_K F P_{\square} P_F \quad (3)$$

(see [28–30]), where $S_1 S_2 S_3 \cdots S_K$ is the survival rate at each acting stage, respectively; F is the standard egg number per female; P_F is probability of standard fecundity; P_{\square} is female rate.

2.2.4. Adults Survival Lines and Relative Fitness. We used age as an independent variable, the survival rate as the dependent variable to make a survival line, and fit a model based on the Weibull distribution. When shape parameter $c > 1$, then the age to which the vast majority of individuals in the population were able to achieve is its average life expectancy.

When shape parameter $c = 1$, then the population had the same mortality at different times. When shape parameter $c > 1$, then the population had very high mortality in the prophase, and most were dead before average life expectancy. The formula was as follows:

$$S_p(t) = e^{-(t/b)^c} \quad (4)$$

(see [31]), where S_p is survival rate of t age; b is scale parameter; c is shape parameter.

Fitness costs associated with resistance to insecticidal agents can have substantial negative effects on many life history traits and have been reported in Diptera [32, 33]. The formula of Relative fitness (R_f) was as follow: when $R_f > 1$, it suggested the fecundity of resistant strain was enhanced; when $R_f < 1$, it is suggested that the resistant strain possess a fitness defect

$$R_f = \frac{R_0 \text{ of resistant strain}}{R_0 \text{ of susceptible strain}} \quad (5)$$

(see [34, 35]).

3. Results

3.1. Establishment of Resistant Line. At the 8th generation, the resistant ratios (RRs) of the trichlorophon resistant strain exhibited up to a 41.42-fold increase (Table 1). After 14 generations of selection, the resistant ratios (RRs) rapidly went up to 84.55-fold. In order to understand the resistance stability, from the 14th generation to the 21st generation, no insecticide was used on the resistant strain, and the resistant ratios (RRs) rapidly declined to 19.49-fold; however, when trichlorophon was used again, after only 3 generations (i.e., the 24th generation in this experiment), the resistant ratios (RRs) went up to 54.60-fold. Then from 24th generation to 30th generation, the resistance of trichlorophon-resistant strain increased slowly, until the 33rd generation, the resistant ratios (RRs) reached 71.93-fold.

3.2. Growth and Development of Each Stage. Tables 2 and 3 showed that the duration of pupae, preoviposition period, longevity of female, longevity of male, fecundity per female, emergence rate, and probability of standard fecundity P_F of trichlorophon resistant strain all had a significant difference to that of the susceptible strain. Results also clearly showed that the duration of egg, duration of larvae, the pupation rate, mean generation time, hatching rate, pupation rate, and female rate P_{\square} had no significant differences between susceptible strain and trichlorophon-resistant strain.

3.3. Life-History Traits. Analyses of the population life tables, the influence of eggs, larvae, pupae, and adults of the susceptible and resistant strains, and the ratio of adult females indicated that the population tendency index of two strains had significant differences. The population tendency index of susceptible was 116.97, but that of the resistant strain was only 86.80, which suggested that the succeeding generation of the resistant strain was smaller than that of the susceptible strain, and had certain propagation disadvantages.

TABLE 1: Resistance ratios of the Trichlorphon-resistant line at selected generations.

Generation	No. of files	LC-P lines	Chi-square value (χ^2)	LC ₅₀ (mg · L ⁻¹) (95% FL)	RRs
Parental*	150	$y = 3.8072 + 5.8250x$	0.4924	1.6024 (1.3800–1.8600)	—
First	150	$y = 2.8577 + 3.7304x$	0.0883	3.7522 (2.8277–4.9788)	2.34
5th	150	$y = 2.0494 + 3.1722x$	1.8672	8.5142 (6.3843–11.3546)	5.31
8th	150	$y = -6.7862 + 6.9248x$	0.9521	50.3532 (21.9650–115.4311)	31.42
11th	150	$y = -1.0373 + 2.8953x$	0.9116	121.6741 (87.9158–168.3951)	75.93
14th	150	$y = 0.9795 + 1.8859x$	1.4533	135.4903 (85.4614–214.8062)	84.55
21th*	150	$y = 0.4228 + 3.0625x$	0.1085	31.2301 (23.2098–42.0217)	19.49
24th	150	$y = -1.7301 + 3.4657x$	4.0260	87.4861 (72.0158–106.2796)	54.60
27th	150	$y = -2.2498 + 3.5892x$	0.9287	104.6954 (89.0531–123.0853)	65.34
30th	150	$y = -4.4740 + 4.6329x$	7.0995	110.9027 (98.4476–124.9336)	69.21
33th	150	$y = -5.7631 + 5.2205x$	1.1999	115.2631 (103.6904–128.1274)	71.93

*Parental represented susceptible strain after 30 generations. the number of bioassays concentrations were 5.

Fecundity of the resistant and susceptible strains were both almost a parabolic shape; in the early oviposition period, the fecundity was small, and gradually increased, reaching a peak and then declining gradually. But there was a certain difference between the strains. The susceptible strain reached its peak oviposition time faster than that of the resistant strain. Fecundity at peak oviposition for the susceptible strain was more stable, while the resistant strain was more volatile. Based on the standard errors, the fluctuation range around the mean was larger in the resistant strain than that of susceptible strain (Figure 1).

3.4. Adults Survival Lines and Relative Fitness. The R_0 , r_m , and R_f of susceptible and resistant strains showed significant differences (Table 4), suggesting that the fecundity of the resistant strain declined significantly after the populations of *B. dorsalis* developed resistance to trichlorphon. The fitness study showed that the relative fitness of resistant strain obviously declined (only 0.7167 of the susceptible strain), which suggested that the survival and development of the resistant strain had been significantly poorer than the susceptible strain.

According to formula 2, the fitting of the adult survival curve equation of adults of susceptible and trichlorphon-resistant strains (Table 5) and survival curve (Figure 2) showed that the values of shape parameter (c) was 3.4637 and 2.6451. Both of them were greater than 1, in consistent with the type I of the basic model of survival curve, suggesting that the adults of both strains achieved their average life span and reached the inherent life to death. But the average survival rate of the susceptible strain was higher than that of resistant strain before 85 days.

4. Discussion

Insecticides can change the biology, ecology and other indicators of resistant insects. Many studies suggest that the resistant insects exhibit fitness costs or stimulate their proliferation [36, 37]. The variations of biology and ecology were closely related to different insecticides [38]. Studying the resistant population's relative fitness is the basis for

understanding and resolving the problem of resistance [39, 40]. Relative fitness refers to the relative capacity of biological survival and reproduction, compared to the susceptible strain. It is generally believed that the biological characteristics, such as declined fecundity and prolonged growth period, change relative fitness. However resistance increases the pest survival rate under selective pressure, which can often lead to a fitness decline. Resistant individuals have shown a survival competitive disadvantage in the absence of selective pressure agents [41, 42].

Our results in this study indicated that the resistant ratios (RRs) of trichlorphon-resistant strain of *B. dorsalis* quickly reached 84.55-fold after 14 generations under trichlorphon selected pressure. However, the resistance was not stable, with the resistant ratios (RRs) rapidly declining when insecticide applications ceased for 7 generations. After insecticide pressure was resumed, RRs went up rapidly only after 3 generations. A resistant strain of RRs 71.93-fold was obtained after 33 generations. These results showed that in *B. dorsalis*, the rising speed of RRs of trichlorphon-resistant strain was far smaller than that of spinosad-resistant strain; LD₅₀ of the selected line was 408 times greater compared with that of the untreated parental colony only after eight generations of selection [43]. And it was almost unanimous compared with rate of increase seen for other cases of insecticide resistance in *B. dorsalis*, including selection for resistance to six organophosphates, one carbamate, and three pyrethroids described previously in [7]. The results obtained here suggest that a rapid rise in trichlorphon-resistance may ultimately cause control failure after extended commercial use in the fields.

The life-history traits of *B. dorsalis* were significantly influenced by trichlorphon. The trichlorphon resistant strain had significant fitness costs when compared to the susceptible strain. The duration of pupa, preoviposition period, and mean generation time of resistant strain were all prolonged, while the longevity of female and longevity of male were shortened, and mean fecundity per female, the emergence rate, and probability of standard fecundity P_F were lower. The population tendency index of two strains had significant difference, the population tendency index of susceptible

TABLE 2: The development difference of each stage of two strains of *B. dorsalis*.

	Insect stages	Susceptible strain ($\pm se$)	Trichlorphon-resistant strain ($\pm se$)
	Duration of egg (<i>h</i>)	51.6220 \pm 0.3593	52.5060 \pm 0.1560
	Duration of larva (<i>h</i>)	163.3520 \pm 0.8037	163.6500 \pm 1.2250
	Duration of pupa (<i>h</i>)	267.7400 \pm 0.5931	272.1820 \pm 1.3398**
Adult	Preoviposition period (<i>d</i>)	16.0000 \pm 0.3162	20.6000 \pm 0.4000**
	Longevity of female (<i>d</i>)	66.9600 \pm 1.3908	62.8300 \pm 1.2955**
	Longevity of male (<i>d</i>)	72.1840 \pm 0.7263	60.8160 \pm 2.2512**
	Fecundity/female	324.2460 \pm 0.6094	254.5500 \pm 0.8158**
	Mean generation time (<i>h</i>)	481.9733 \pm 2.0076	488.1233 \pm 24636

Annotates: within the same row, * shows the significant differences between resistant strain and susceptible strain ($P < .05$) by ANOVA (F test), ** shows the significant differences between resistant strain and susceptible strain ($P < .01$) by ANOVA (F test). Tables 3–5 tables are the same.

TABLE 3: The life table of lab population of two strains of *B. dorsalis*.

stages	Effect factors	Survival rate (%)	
		Susceptible strain ($\pm se$)	Trichlorphon-resistant strain ($\pm se$)
Egg	Non-hatching	0.8360 \pm 0.0160	0.8200 \pm 0.0167
Larva	Recessive death	0.9240 \pm 0.0075	0.8960 \pm 0.0075
Pupa	Non-emergence	0.8960 \pm 0.0075	0.8520 \pm 0.0102*
	Female rate P_Q	0.5091 \pm 0.0169	0.5015 \pm 0.0109
Adult	Probability of standard fecundity P_F	0.1616 \pm 0.0010	0.1276 \pm 0.0011**
	Standard fecundity F	2000	2000
	Population tendency index I	116.97	86.8

Annotates: standard fecundity ($F = 2000$ eggs/per female) [13].

TABLE 4: The life-history traits and relative fitness of two strains of *B. dorsalis*.

Population Life Parameter	Susceptible strain ($\pm se$)	Trichlorphon resistant strain ($\pm se$)
R_0	2184.0000 \pm 50.3408	1565.3333 \pm 42.3365**
r_m	0.0173 \pm 0.0001	0.0164 \pm 0.0001**
R_f	1.0000	0.7167

TABLE 5: The adults survival lines of two strains of *B. dorsalis*.

Strains	Equation	Correlation coefficient (<i>r</i>)
Susceptible strain	$S_p(t) = e^{-(t/77.2504)^{3.4637}}$	0.9986
Trichlorphon-resistant strain	$S_p(t) = e^{-(t/68.0355)^{2.6451}}$	0.9972

was 116.97, but that of the resistant strain was only 86.80 (Table 2). The R_0 , r_m of resistant strains was smaller than that of susceptible strain, and R_f was only 0.7167 of the susceptible strain (Table 4). The average fecundity per female curves of two strains were both more or less a parabolic shape, but the susceptible strain reached its oviposition peak time in a shorter space of time than that of the resistant strain; the fecundity of oviposition peak time was more stable than that of resistant strains which was more volatile (Figure 1). Survival curves showed that the two strains were consistent with the I-type of the basic model of survival

curve, but the susceptible strain reached its oviposition peak time in a shorter space of time than that of the resistant strain; the fecundity of the oviposition peak time was more stable; than that of resistant strains which was more volatile (Figure 2). The values of shape parameter (*c*) was 3.4637 and 2.6451 (Table 5); they suggested that the adults of both strains achieved their average life span, and reached the inherent live to dead.

All the results could afford the important basics of resistance control of the resistant strain of *B. dorsalis*. In conclusion, the results obtained here show that in *B. dorsalis*, consistent with what has been seen in several species (*Culex pipiens*, *Helicoverpa armigera*, *Drosophila melanogaster*, *Cydia pomonella*) of insects in different orders, development of high levels of resistance to organophosphates will occur within a relatively short time after selection is applied, and had relative fitness costs [44–49]. The resistance gene had an adverse impact on the population reproduction and development. In general, arthropod resistance to insecticides often accompanies a fitness cost, which is the theoretical basis for using insecticide rotation, to govern pest resistance [50, 51]. For maintaining the effectiveness of this insecticide, any proposed management program must take into consideration the potential for resistance development seen here in the oriental fruit fly. If the major influencing factor of trichlorphon resistant strain was trichlorphon, when the resistance was found, it was proposed that trichlorphon and other organophosphate applications cease to allow the frequency of resistance genes to decrease. Because of the resistant strain’s fecundity disadvantages and fitness costs,

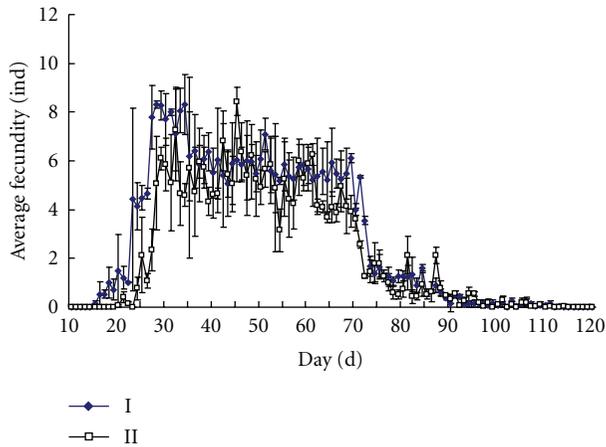


FIGURE 1: Oviposition lines of per female for two strains of *B. dorsalis*. I: Susceptible strain, II: Trichlorophon selected strain.

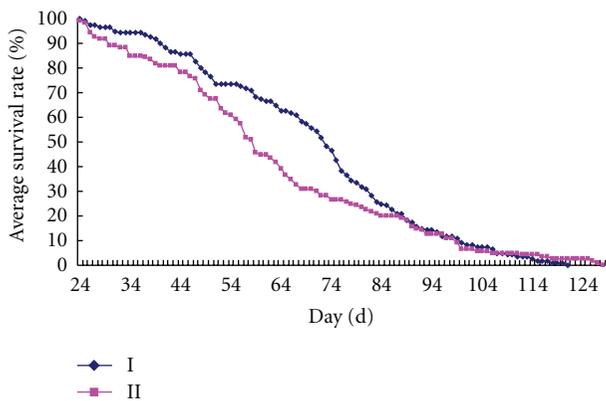


FIGURE 2: Survival curves of adults of two strains of *B. dorsalis*.

the population was relatively feeble, and without the presence of insecticides, the resistant population might slowly decline.

At the same time, in the nonresistant areas, rotation of trichlorophon and other different mechanism insecticides could thwart trichlorophon resistance development, increase the control effect, reduce environment pollution, and protect the environment, except for pyrethroids. The cross-resistance bioassays revealed, when the resistant ratios of trichlorophon resistant strain reached 69.21-fold, that some resistance to pyrethroids existed in trichlorophon resistant *B. dorsalis* strain. Pyrethroids showed about 30-fold cross-resistance to trichlorophon. So it is likely that oriental fruit flies already exhibiting higher resistance to trichlorophon also will develop middle-level resistance to pyrethroids. But abamectin showed low cross-resistance to trichlorophon, and we may use abamectin to rotate to trichlorophon (we will separately report this section study). Also we can use spinosad replace trichlorophon in the field where the population of *B. dorsalis* already had trichlorophon resistance, because according to the report by Hsu et al. [14], the results showed the spinosad did not exhibit cross-resistance to ten insecticides, including six organophosphates (naled, trichlorophon, fenitrothion, fenthion, formothion, and malathion), one

carbamate (methomyl), and three pyrethroids (cyfuthrin, cypermethrin, and fenvalerate) [43].

In this study, the biological and ecological indicators of two *B. dorsalis* strains were studied under laboratory conditions, although the dilution effect of gene flow to antagonistic alleles was avoided, the interference of other field factors outside was ignored, such as environment and natural enemies. So to be more accurate in our understanding of the dynamic resistance, and afford the most powerful evidence of resistance control, the biological and ecological indicators of trichlorophon resistant strain in the fields should be further studied.

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