Pakistan J. Zool., pp 1-11, 2024. **DOI**: https://dx.doi.org/10.17582/journal.pjz/20230628030638

Two-sex Life Table Parameters of Oriental Fruit Fly *Bactrocera dorsalis* (Diptera: Tephritidae) on Methyl Eugenol-Based Diet

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Article Information
Received 28 June 2023
Revised 20 October 2023
Accepted 04 November 2023
Available online 31 January 2024 (early access)

Authors' Contribution
SJ conceived the study and design of the research. MY and MM did acquisition of data. SJ, MY, MM and SH analysed and interpreted the data. SJ, AH, MY, MS, AH, AAK and SH, obtained financing. SJ wrote the manuscript. All authors critically revised the manuscript for intellectual content, read and agreed to the published version of the manuscript.

Key words
***B. dorsalis*, Methyl eugenol, Fitness, Population traits, Two sex life parameters, Tephritidae**

ABSTRACT

Bactrocera dorsalis (Hendel) is an economically significant pest of fruits and vegetables worldwide. The *B. dorsalis* has invaded over seventy countries, including China, and has caused massive losses to a part of the agricultural ecosystem. Fundamental data about *B. dorsalis* is a prime necessity for implication of integrated management. Two-sex life table traits are better procedure as compared to traditional life table because two sex life table tools describe both male and female sexes. Demographic traits of the oriental fruit fly have been studied on natural and artificial diets via both traditional and two-sex life tables. However, this study describes the age-stage two-sex life table parameters of this frugivores fly on methyl eugenol (ME) based diet and laboratory made diet. Results showed that the larval duration of *B. dorsalis* was shorter on a methyl eugenol mixed diet, and the total fecundity of *B. dorsalis* was slightly higher on methyl eugenol diet as compared to control diet. Reproductive parameters including R_0, *GRR*, *r*, and *λ* of *B. dorsalis* flies were highest on the methyl eugenol mixed diet in compared to the control diet. Mating pair success percentage was increased in *B. dorsalis* when reared on the ME-mixed diet in comparison to those deprived of the methyl eugenol diet. This study concluded that methyl eugenol is an accelerates for mating success and fitness of *B. dorsalis* reared in a laboratory condition. Our findings will be helpful for future work regarding methyl eugenol implication against the *B. dorsalis* and related sibling species.

INTRODUCTION

The oriental fruit fly, *Bactrocera dorsalis* (Hendel), is a member of the family Tephritidae and the order Diptera. It is considered a prominent polyphagous pest of fruits and vegetables worldwide, particularly in the Asia-Pacific region (Hassan *et al*., 2020; Jaffar and Lu, 2022). Due to its high reproductive potential (400–1800 eggs per female), short life cycle (more than five generations per year), rapid dispersal ability (50–100 km per year), and wide range of hosts, the expansion and invasion of *B. dorsalis* can cause significant damage (20-30%) to fruits (Liu *et al*., 2019; Piñero *et al*., 2013). This notorious pest has caused major agricultural destruction in mango fruits, resulting in a yield loss of up to 80% (Jiang *et al*., 2017), an average yield loss of 5.65 t/ha in orchards, and a financial loss of US$ 3428.97 per hectare (Cugala *et al*., 2020). In integrated pest management (IPM) programs, several strategies exist to control pest populations. One of the most successful and quick approaches involves luring males using pheromone or their precursor components (environment friendly), facilitating the sexual communication of *Bactrocera* species (Liu *et al*., 2018).

The attraction of fruit flies using methyl eugenol (ME) via a bait trap termed male annihilation technique (MAT) is convenient for reducing male fruit flies in agricultural

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0030-9923/2024/0001-0001 $ 9.00/0

orchards (Liu *et al*., 2013, 2018). However, adult male *B. dorsalis* flies shows a strong preference for ME, while mature female flies are particularly attracted to 4-allyl-1,2-dimethoxybenzene-carboxylate (allylveratrol) ingested by the male flies. The presence of sequestered 2-propenyl-4,5-dimethoxyphenol (DMP), and E-coniferyl alcohol (E-CF) (Liu *et al*., 2019; Ren *et al*., 2021). Male flies, which have been sterilized through pupal stage X-rays and gamma-ray (γ) techniques, can be protected and subsequently fed an ME diet. This approach can be employed for the large-scale management of *B. dorsalis* in agricultural fields or orchards (Chang *et al*., 2015; Shelly, 2021; Zhao *et al*., 2017). Organic ME has been identified in over 450 plant species. This specific kairomone is particularly appealing to male flies from *Bactrocera* species, with a notable attraction towards oriental fruit flies like *B. umbrosa* and *B. carambola* (Liu *et al*., 2018; Sim *et al*., 2022). Consequently, for the effective management of *B. dorsalis* in agricultural fields or orchards, it is essential to conduct fundamental laboratory studies in order to design farm-level management programs. A comprehensive understanding of the life history of this pest is crucial for the development of more efficient control measures. In laboratory settings, artificial food proves to be a more practical tool for rearing flies compared to natural food (Ras *et al*., 2017). Employing the life table technique is a valuable approach for acquiring critical life history traits of the oriental fruit fly, including survival rates and demographic characteristics, as well as the population's growth potential. These insights are indispensable for integrated pest management (IPM) programs aimed at monitoring this organism (Jha *et al*., 2012; Vargas *et al*., 2000).

IPM programs focused on fruit fly control widely targeted on *Bactrocera* species (Bai *et al*., 2019; Gao *et al*., 2023; Liu *et al*., 2019). Successfully addressing involves precise pest identification, comprehensive scouting, the construction of specific infrastructure, raising awareness, and providing training to promote the widespread adoption of control measures, particularly in the framework of managing invasive species (Shikano *et al*., 2022; Zeng *et al*., 2022). For comprehensive IPMs, foundational studies concerning the life characteristics of fruit flies play an essential role in their monitoring (Jaffar *et al*., 2023). The two-sex life table study is considered a comprehensive method for identifying susceptible and resistant stages in the life histories of insects (Abbas and Hafez, 2021). Numerous studies have presented the life parameters of both sexes, males and females, on both natural and artificial diets (Liu *et al*., 2020; Vargas *et al*., 2015). Nevertheless, several studies have also indicated that an ME diet significantly impacts the life characteristics, aggregation, and sexual behaviors of adult male *B. dorsalis* (Liu *et al*., 2013, 2017, 2018). Males fed on an ME diet tend to exhibit greater attractiveness to virgin females than ME-deprived males. The proportion of attractive males begins to increase at seven days after emergence (DAE) and continues to rise with the age of the flies, up to 27 DAE, corresponding with sexual maturity.

Studies have demonstrated the positive impact of ME on male mating performance across various *Bactrocera* fruit fly species (Pereira *et al*., 2013; Shelly *et al*., 1996), This effect could potentially enhance the cost-effectiveness of the sterile insect technique (SIT). However, the practical implementation of ME in fly emergence and release facilities has been limited by the absence of a viable method to administer ME to large populations of sterile males before their release (Dowell *et al*., 2005; Steck *et al*., 2019). Conventional methods for the emergence and containment of sterile fruit flies do not accommodate ME feeding, and because of its lethality, ME exposure must be brief (Salvato *et al*., 2004). To address this issue, a study conceptualized a machine for feeding ME to sterile males, wherein the males are gently brushed off and gathered subsequent to their interaction with the ME-impregnated conveyor belt (Tan and Tan, 2013). While this system has displayed promising results in experimental settings, its application to millions of sterile males on an industrial scale presents significant challenges. Therefore, there is an imperative need to devise simpler techniques for exposing sterile males to ME in a manner that seamlessly integrates with prevailing protocols for emergence and containment procedures.

Considering the broader distribution and substantial economic and quarantine implications associated with *B. dorsalis* when compared with *B. carambolae*, the development of an efficient mechanism for delivering ME and enhancing male mating success within sterile male release facilities would markedly enhance the cost-effectiveness of the SIT within comprehensive area-wide IPM initiatives targeting *B. dorsalis* (Isasawin *et al*., 2014).

Understanding of the consumption of ME throughout the male fruit fly's life cycle remains unknow (Wee *et al*., 2018). In comparison, fewer studies address the sequestered effects on the female adults' sexual behavior (Liu *et al*., 2022). Hence, this research aims to assess the tolerance and impact of an ME-fed diet on the fitness and demographic parameters of the oriental fruit fly, *B. dorsalis*.

MATERIALS AND METHODS

Organism of study

Mature oriental fruit flies and larvae were collected from various orchards around Guangzhou using both manual collection and employing ME and E-CF as attractants, following by (Liu *et al*., 2022). These adult flies and larvae were then reared on an artificial diet within the laboratory of the Entomology Department at South China Agricultural University in Guangzhou, Guangdong, China. The components of the adult liquid diet (cotton wool soaked in water) were prepared in a Petri dish measuring 9 x 1.5 cm². Solid diet components, fulfilling the insects' protein requirements, were created by combining yeast with mixed sucrose in a ratio of 1:1. These components were then placed in a Petri dish within a rearing cage measuring 30 x 30 x 30 cm³. After pupation occurred, the pupae were transferred to the rearing cage, and a similar cage was used to provide food for the emerging adults. Every two days, the adult food and water were replaced to prevent bacterial and fungal contamination. Mature male flies were released into cages containing female flies for breeding. Post-mating, when female flies became gravid, approximately 3-4 days were required for egg collection, A 1 mm layer of artificial diet was applied inside the receiving plastic vial, combined with orange juice to facilitate egg collection. The vial's surface served as the substrate for oviposition. Flies' eggs were gently collected using a soft camel hair brush and then transferred to a plastic box measuring 6 x 6 x 6 cm³, containing an artificial diet. Muslin linen was employed to cover the plastic box. Environmental conditions, such as temperature, humidity, and photoperiod, were maintained at 26 ± 1°C, 65.00% RH, and a light-dark cycle of 12:12 h, respectively, as per the protocols established in our previous studies (Jaffar and Lu, 2022). Fly populations fed on ME-mixed diets and control diets (without ME) were acclimated for at least two generations under controlled conditions before initiating the main experiments.

Diet preparation and ME delivery

Laboratory experiments were conducted using a semi-artificial diet, both with and without ME treatment. The larvae were provided with an artificial diet composed of 150 g of corn flour, 150 g of banana, 30 g of sucrose, 30 g of yeast powder, 30 g of paper towel, 0.6 g of sodium benzoate, 1.2 mL of hydrochloric acid (HCl), 2.0 mg of folic acid, 0.010 mg of vitamin B12, 0.007 mg of vitamin E, and 300 mL of clean tap water. To expose the larvae of the mass-reared strain *B. dorsalis* to ME, we incorporated pure ME (98%) into the diets for the 1st, 2nd, and 3rd instar larvae at doses of 5 µL/100 g, 50 uL/100 g, and 100 µL/100 g (wet weight) during two intervals for each instar. ME was introduced into the diets using a micropipette (Eppendorf), and the compound was thoroughly mixed into the wet-weighed diet within 800 g containers. Subsequently, approximately 400–800 eggs were placed on the diet's surface. These containers were then positioned over vermiculite for pupation. As the fruit fly larvae matured, mature adults were exposed to 100 uL of ME every four days, within a one-hour window from 09:00 to 10:00 am. The adult diet consisted of hydrolysate yeast and sugar in a 1:1 ratio, and water *ad libitum*.

Life traits

After 12 h, the hatched eggs were selected from the reared population of flies; an individual fly egg was observed until adult formation; at the same time, hundreds of eggs were observed daily on each diet. Subsequent to the adult flies emergence, ten adult pairs of male and female flies were mated to observe reproductive traits. Each pair of flies was maintained in a small plastic jar (9 x 3 x 3 cm³). Similarly, after eight days, small disposable plastic vials, as described above were used to collect the eggs. The data on reproductive parameters on both diets were calculated until the flies' deaths according to the methodology (Campoy *et al*., 2022; Mobarak *et al*., 2022; Mohamed *et al*., 2021).

Two sex life table analysis

Daily measurements of biological fitness and demographic parameters on both diets (containing ME and without ME) were analyzed using the software "Two-Sex" (Chi *et al*., 2020, 2022; Chi, 2015). The t-test of each parameter of biological fitness of *B. dorsalis* was used to differentiate the mean difference between two diets using statistics 8.1 (Kou *et al*., 2022). Demographic age-specific traits of *B. dorsalis* flies, e.g., unique rate of survival according to age stage (l_x), expectation of life (e_{xj}), female exact fecundity (f_x), age exact eggs laying/fecundity (m_x), and age exact motherhood/maternity (l_x*m_x), as well as population traits were analyzed with the following equations.

The l_x and m_x were estimated by Equation 1 and 2:

$$l_x = \sum_{j=1}^{k} s_{xj} \quad ...(1)$$

$$m_x = \frac{\sum_{j=1}^{k} s_{xj} f_{xj}}{\sum_{j=1}^{k} s_{xj}} \quad ...(2)$$

Where; s_{xj} denotes the probability of a newly hatch larvae surviving to age *x* and stage *j*. *k* shows stages number and f_{xj} is the age stage exact fecundity of the individual at age *x* and stage *j*.

The 'O_d' represents the number of days that female laid eggs and was estimated by Equation 3:

$$O_d = \frac{\sum_{x=1}^{N_f} D_x}{N_f} \quad ...(3)$$

Where; N_f shows the number of ♀ adults and 'D_x' represent the number of days that a ♀ produced offspring.

The parameter r signifies the asymptotic population growth rate as time tends towards infinity, and the population attains its stable age-stage distribution. The population would exhibit an increase at a rate of per unit of time. The r was computed employing the interactive bisection technique and subsequently followed by the Euler–Lotka equation, with age being indexed 0 according to the study by (Goodman, 1982):

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1 \quad ...(4)$$

The symbol λ denotes the population growth rate in the time tending towards infinity, as the population achieves a stable age-stage distribution. The population size will increase at a rate of λ per unit of time. The value of λ was evaluated using Equation 5.

$$\lambda = e^r \quad ...(5)$$

The parameter R_0 signifies the cumulative count of eggs deposited by an individual female over the course of her lifespan. The R_0 value was derived through employing of Equation 6.

$$R_0 = \sum_{x=0}^{\infty} l_x m_x \quad ...(6)$$

The variable T symbolizes the duration required for a population to amplify to R_0 times its current size, once the state of stable increase is attained. The determination of T was derived through the application of Equation 7.

$$T = \frac{\ln R_0}{r} \quad ...(7)$$

The life expectancy (e_{xj}) indicates the predictable period that an individual of age 'x' and stage 'j' will survive. The 'e_{xj}' value was derived following the methodology outlined by (Chi and Su, 2006) using Equation 8:

$$e_{xj} = \sum_{i=x}^{\infty} \sum_{y=j}^{k} s'_{iy} \quad ...(8)$$

Where; s'_{iy} represents the probability that an individual of age x and stage j will survive to age i and stage y by assuming $s' = 1$.

The v_{xj} indicates the assurance to forthcoming offspring at age x and stage j. The v_{xj} value was estimated using by Equation 9 (Tuan *et al*., 2014):

$$v_{xj} = \frac{e^{r(x+1)}}{s_{xj}} \sum_{i=x}^{\infty} e^{-r(i+1)} \sum_{y=j}^{\beta} s'_{iy} f_{iy} \quad ...(9)$$

RESULTS

Biological parameters of B. dorsalis

The development period (days) of *B. dorsalis* from egg to pre-adult stages was different in the two different diets (artificial diet containing ME and without ME; As we previously stated that we maintained each egg of *B. dorsalis* in separate dishes, hence we collected data of both sexes individually from every stage. The minimum egg development period was observed on an ME diet (1.00 ± 0.00 d) for females and (1.17 ± 0.06 d) for males as compared to the control diet (diet without ME) with (1.78 ± 0.07 d) slight long duration for female eggs and (1.75 ± 0.07 d) for male eggs in Table I.

The development time of female 1st instars (2.35 ± 0.08 d) and male 1st instars (2.27 ± 0.06 d) was shorter in duration on the ME diet than the control diet e.g., female 1st instars (2.67 ± 0.08 d) and male 1st instars (2.52 ± 0.08 d). The 2nd instar larvae of both sexes showed a longer development period on the ME diet as compared to the control diet, while the 3rd instar larvae period on the control diet was long as compared to the ME diet. Meanwhile, the total larval period of both sexes was longer on the control diet as compared to the ME diet. Similarly, the pupal development period both of sexes was longer on the control diet in comparison to the ME diet and the development time of adult females (124.56 ± 1.06 d) and males (102.05 ± 0.58 d) were longer on the control diet in comparison to the ME diet Table I.

The adult males longevity (egg-adult) was higher (119.77 ± 0.58 d) on the control diet as compared to the ME mixed diet. Similarly, the total longevity of female adults was highest on the control diet (142.78 ± 1.09 d) as compared to ME mixed diet. Mating success percentage (those pairs of adults that mate successfully and females that produce viable eggs) of *B. dorsalis* was higher for flies on the ME diet in comparison to the control diet in Table I.

Total pre-oviposition period (TPOP) of female adults (40.17 ± 0.43 d) was longer on the control diet in comparison to the ME diet (31.82 ± 0.43 d). Similarly, the adult preoviposition period (APOP) in female flies was longer on the control diet (21.94 ± 0.33 d) as compared to the ME mixed diet (15.75 ± 0.29 d). The oviposition period of female adults was higher (20.48 ± 0.30 d) on the ME mixed diet as compared to the control diet (17.06 ± 0.20 d). The maximum eggs layed was observed on ME diet (232.8 ± 6.81 eggs female^{-1}) as compared to the control diet (200.22 ± 2.98 eggs female^{-1}) (Table II).

Table I. Effect of methyl eugenol (ME) mixed diet and without ME diet on the biological parameters of *B. dorsalis*.

Traits	Gender	ME diet	Control	F	t	Df
Egg (d)	Female	1.00±0.00 (n:40)	1.78±0.07(n:36)	1.03	-6.00	42,45
	Male	1.17±0.06 (n:48)	1.75±0.07 (n:44)	1.04	-7.00	43,47
1st instar (d)	Female	2.35±0.08 (n:40)	2.67±0.08 (n:36)	1.25	-3.14	39,35
	Male	2.27±0.06 (n:48)	2.52±0.08 (n:44)	1.27	-3.03	43,47
2nd instar (d)	Female	2.62±0.08 (n:40)	2.22±0.09 (n:36)	1.21	2.98	35,39
	Male	2.52±0.08 (n:48)	2.23±0.09 (n:44)	1.08	1.97	43,47
3rd instar (d)	Female	2.85±0.17 (n:40)	3.33±0.15 (n:36)	1.45	-2.34	39,35
	Male	2.67±0.09 (n:48)	3.23±0.06 (n:44)	2.21	-5.40	47,43
Total larval period (d)	Female	7.83±0.20 (n:40)	8.22±0.20 (n:36)	1.11	-3.40	39,35
	Male	7.46±0.15 (n:48)	7.98±0.13 (n:44)	1.21	-4.03	47,43
Pupae (d)	Female	7.25±0.18 (n:40)	8.22±0.13 (n:36)	2.08	-4.46	39,35
	Male	7.62±0.20 (n:48)	8.00±0.10 (n:44)	3.99	-1.87	47,43
Egg-adult period (d)	Female	133.97±1.69(n:40)	142.78±1.09(n:36)	6.64	-6.32	39,35
	Male	109.79±1.68(n:48)	119.77±0.58(n:44)	8.51	-5.69	47,43
Male adult period (d)		93.54±1.68(n:48)	102.05±0.58(n:44)	9.06	-4.65	47,43
Female adult period (d)		117.90±1.30(n:40)	124.56±1.06(n:36)	1.68	-3.49	39,35
MPS (%)		85.34±2.34(n:40)	65.12±1.53(n:36)	1.06	-3.23	34,29
TPOP (d)		31.82±0.43(n:40)	40.17±0.43(n:36)	1.09	-14.7	39,35
APOP (d)		15.75±0.29(n:40)	21.94±0.33(n:36)	1.17	-14.3	35,39
Oviposition days (d)		20.48±0.30(n:40)	17.06±0.20(n:36)	2.59	9.06	39,35
Fecundity eggs/female		232.8±6.81(n:40)	200.22±2.98(n:36)	5.80	4.22	39,35

d, days; Df, treatment and error; n, represents the no. of individual; MPS, mating pair success; APOP, Adult pre-oviposition period of a female adult; TPOP, total pre-oviposition period of a female counted from emergence. The SE of the mean values of each biological parameter were estimated by using two-sex life table software. Significant differences in high value of means between methyl eugenol and control diet using independent t-tests are marked in bold within row.

Table II. Effect of methyl eugenol (ME) mixed diet and without ME diet on the reproductive parameters of *B. dorsalis.*

Traits	ME diet	Control
Intrinsic rate of increase *r* (per day)	0.111	0.09
Finite rate of increase λ (per day)	1.121	1.09
*GR*R (eggs/individual)	105.82	90.10
R_0 (eggs/individual)	93.12	72.08
Mean generation time (T) (day)	39.75	48.05
Doubling time (D) (day)	6.07	7.79
Survival rate (S) at SASD (proportion)	0.99	0.991
Birth rate (B) at SASD (per day)	0.12	0.10
Death rate (D) at SASD (per day)	0.006	0.009

r, The intrinsic rate of increase (per day); λ, The finite rate of increase (per day); *GRR,* Gross reproductive rate (offspring/individual); R_0, The net reproductive rate (offspring); T, The mean generation time (days); SASD, stable age-stage distribution.

Reproductive traits

Reproductive traits are shown in Table II. Results have shown that *B. dorsalis* fed on the ME diets show higher values of λ (1.12 d^{-1}) and *r* (0.11 d^{-1}) in comparison to the flies the control diet e.g., λ (1.09 d^{-1}) and *r* (0.09 d^{-1}). The R_0 of flies on the ME diet (93.12 offspring) was higher in comparison to the control diet (72.08 offspring). While, generation time (*T*) was longer on the control diet (48.05 days) in comparison to ME diet (39.75 days). Similarly, *GRR* was higher on the ME diet (105.82 offspring individual^{-1}) than on the control diet (90.10 offspring individual^{-1}). There was no statistical difference in the survival rate of *B. dorsalis* at SASD between the two different diets. The birth rate of *B. dorsalis* at SASD (stable age-stage distribution) was higher (0.12 d) when fed on the ME in comparison to the control diet (0.10 d). Similarly, the death rate of *B. dorsalis* was significantly lower (0.006 d) on the ME diet in comparison to the control diet (0.009) (Table II).

Survival rate

Our findings showed the age *x* and stage *j* of *B. dorsalis* when fed on artificial diet containing ME and without ME. Growth values between stages varied among *B. dorsalis* populations on the two different diets. The probable lines are showing the age-stage specific survival rate of *B. dorsalis* on the different (with and without ME). The progressive period of *B. dorsalis* male and female flies was longer and the survival was higher with the ME diet (Fig. 1A) and the inverse pattern was observed in the control diet (Fig. 1B). The survival for male (0.48, 20-89 d) and female (0.40, 20-113 d) flies was higher on the artificial diet containing ME in comparison to the control diet e.g., male (0.44, 20-109 d) and female (0.36, 22-124 d). Survival rate of pupae (0.87, 11-12 d) was higher on the ME diet in comparison to the control diet (0.80, 13-14 d).

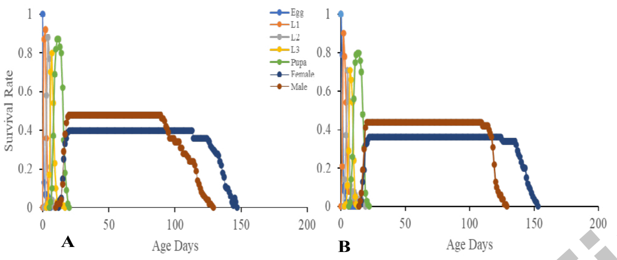

Fig. 1. Age-stage-specific survival rate (s_{xj}) of the *B. dorsalis* fed on artificial diets containing methyl eugenol (A) and without methyl eugenol diet (B). L1: 1st instar larvae, L2: 2nd instar larvae, L3: 3rd instar larvae.

Age-specific survival and fecundity

Figure 2 is a graph of the lines for *lx*, *fxj*, *mx*, and *lx***mx* for oriental fruit flies on the two different diets. The *lx* value was initially higher (1.00, 0-4 d) on the ME diet in comparison to the control diet. The *lx* value for both diets then decreases with the ME diet flies decreasing earlier. Meanwhile, the *lx***mx* for the ME diet increases earlier and reaches a higher level (93.12, 58-145 d) than the control diet (72.08, 63-153 d). The values of *fxj* were higher (18.60, 40 d) on the ME diet than the control diet (17.77, 49 d).

Life expectancy in B. dorsalis

The life expectancy of each individual of *B. dorsalis* on the two different diets is shown in (Fig. 3). Life expectancy of eggs was higher (107.37, 0 d) on the ME diet in comparison to control diet e.g., 106.14, 0d. A higher life expectancy of female flies was observed (127.77, 18 d) on the control diet in comparison to the ME diet. Similarly, male adult longevity was higher (104.77, 15 d) on the artificial diets containing ME (98.89, 11 d).

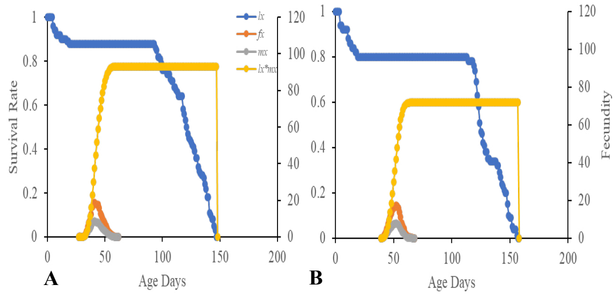

Fig. 2. Age-specific survival rate (l_x), female age-specific fecundity (f_x), age-specific fecundity (m_x), and age-specific maternity (l_x*m_x) of *B. dorsalis* when fed on artificial diet containing ME (A) and without ME diet (B).

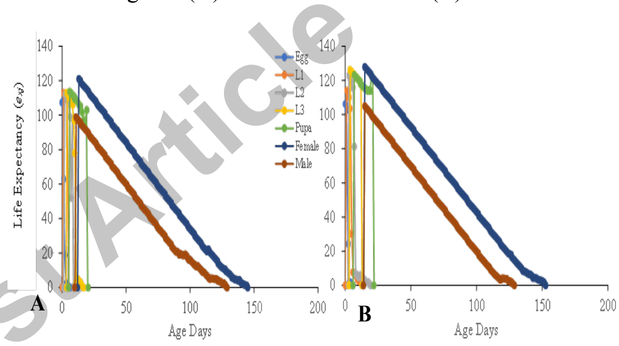

Fig. 3. Impact of artificial diet on the age-stage-specific life expectancy (e_{xj}) of *B. dorsalis*, A, diet containing ME, B, diet without ME. L1: 1st instar larvae, L2: 2nd instar larvae, L3: 3rd instar larvae.

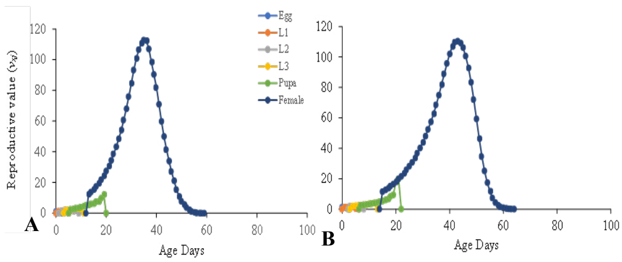

Fig. 4. Impact of artificial diet on the age-stage reproductive value (v_{xj}) of *B. dorsalis*, A: diet containing ME, B: diet without ME. L1: 1st instar larvae, L2: 2nd instar larvae, L3: 3rd instar larvae.

Reproductive value

Figure 4 shows the value of v_{xj} at different ages *x* and stages *j* of *B. dorsalis* on two different diets. This value represents the contribution of each age or stage towards the forthcoming population. These results showed that the v_{xj} curve of female *B. dorsalis* on the diet containing ME displayed a higher peak (112.36, 36 d) in comparison to the control diet (109.19, 44 d). The difference in the values of v_{xj} are exactly the same as the finite rate values in Table II, thus the result shows that the v_{xj} was higher on the ME diet as compared to the control diet.

Expected fecundity

Resources and the existence of possible mates can have an impact on the fecundity rate. Expected fecundity of *B. dorsalis* females remains high (232.8, 0-28 d) on the ME diet, while fecundity of *B. dorsalis* on the control diet remains lower (200.22, 0-40 d) but with a longer adult duration in comparison to the ME diet (Fig. 5). Fecundity of females decreases on both diets with the passage of time. These results showed that expected fecundity was higher on the artificial diet containing ME with a shorter adult life duration than on a control diet.

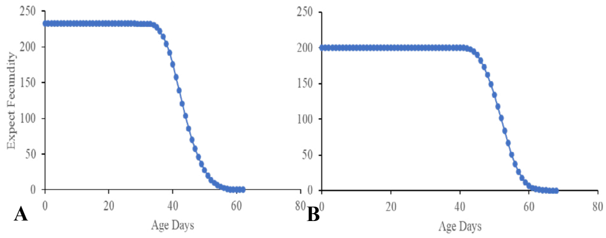

Fig. 5. Impact of artificial diet on expected fecundity by female adults of *B. dorsalis*, A: diet containing ME, B: diet without ME.

DISCUSSION

B. dorsalis, commonly known as the oriental fruit fly, is an economically significant invasive pest with a wide geographic distribution (Li *et al*., 2023). This invasive species was first reported in Taiwan Islan in 1912 and has since spread to various regions across the country. It is particularly widespread in southern China, where the subtropical climate is conducive to its establishment. The fly's rapid spread is attributed to factors like favorable climatic conditions, suitable host plants, and human-assisted dispersal through the movement of infested fruits and vegetables.

Many countries employ a range of pest management strategies to combat *B. dorsalis* and other invasive insects. These include the application of chemical pesticides IPM practices, phytochemicals and biological control methods (Jaffar *et al*., 2022). IPM approaches aim to reduce pesticide use and include measures such as field sanitation, the release of natural enemies' predators, parasitoids, SIT, MAT (trapping and luring), respectively.

The relationship between insect longevity and diet is frequently explored in the literature, and modifications in dietary composition have proven crucial in aging related to an organism. Recent investigations have highlighted that insects' lifespan can be extended through the addition of yeast, proteins, vitamins, minerals, and sterols in their diets. Conversely, lifespan experiences a sharp reduction when protein yeast is eliminated entirely, replaced by amino acids, only to rebound with a combined dietary approach (Fanson and Taylor, 2012). However, several studies have investigated the biology and ecology of various natural host plants for *Bactrocera* species as well as artificial diets (Ekesi *et al*., 2016; Mir *et al*., 2014); yeast, sucrose, honey and other supplementary organic ingredients promote insect growth and fitness and can serve as essential nutrient components in diets used for mass-rearing of fruit flies. By controlling the abiotic and biotic factors, food resources are substantial tool for investigating the development of insect pests given their high levels of fecundity and shorter biological life cycle (Awmack and Leather, 2002). Our study described the effects of ME-mixed in an artificial diet on the fitness of each stage of *B. dorsalis* under laboratory conditions.

The shorter period and faster period of development in insects were due to their higher fitness (Zhu *et al*., 2022). In this study, the fitness of *B. dorsalis* was moderately higher on the ME diet in comparison to control diet. The duration of egg, larvae, pupae, and adult stages of *B. dorsalis,* as well as oviposition and fecundity were higher on the ME diet which means that the ME diet has important effect on biological development. Previous literature has reported that male longevity tends to be higher than female longevity (Mir *et al*., 2014; Wei *et al*., 2015). We found higher longevity of female than male flies on the control diet. While overall results showed that the ME diet had no effects on male and female longevity. Mortality rate was slightly higher on the diet without ME than the ME mixed diet (Table I). Although previous research on the fitness of *B. dorsalis* has shown that fitness was when fed on apples than peaches and oranges that indicating the same conclusion i.e., nutritious food plays the most important role in the growth and developmental rate of the *B. dorsalis* (Goundoudaki *et al*., 2003; Zhu *et al*., 2022).

Compared to typical or traditional life tables, the two-sex life table tool is efficient in describing the basic ecological data and the effect of food on the fitness of insect pests (Chi *et al*., 2020; Chi, 2015). However, *B. dorsalis* females strongly prefer mating with males that previously consumed the ME mixed diet (Shelly, 2021). Although the effect of the ME diet on the life traits of *B. dorsalis* using two sex tools is lacking. In the present study, the life cycle of both sexes of *B. dorsalis* was shorter on the ME diet as compared to control diet, while fecundity was moderate on ME diet. These results indicate that nutritious diet is a large factor in the rearing of insects in the laboratory control conditions (Kaur *et al*., 2021; Mohamed *et al*., 2021).

The effect of the ME diet has been observed in female reproduction, adult mating frequency, and male longevity in *B. dorsalis* (Shelly and Edu, 2008). The findings showed that *B. dorsalis* males could mate frequently, and some individuals could mate up to fifteen times throughout their adult lives (Ting-ting *et al*., 2010). The mating success and competitiveness that has been reported in various studies (Tan and Nishida, 2020) as well as in our results have revealed that mating is enhanced in *B. dorsalis* ME-fed pairs as compared to control diet. Fecundity plays an important role in producing the dynamics of insect populations (Gilioli *et al*., 2016). Egg production increases with the passage of time after the first mating until oviposition (Shelly and Edu 2008). Moreover, the results show high fecundity and a long oviposition period of *B. dorsalis* when fed on the artificial diet containing ME (Table II).

The values of reproductive traits r, λ, R_0 and *GRR* are important in describing the role of food on the fitness of insect pests. Studies of these parameters reveals that *B. dorsalis* shows that the species can have rapid population development in a short time (Mohamed *et al*., 2021). According to life table theory, if r is greater than 0 it indicates that the population will be able to grow on its host (Chen *et al*., 2017). In the current research, high reproduction, high natal rate, and low mortality rate of *B. dorsalis* were observed on ME based diet.

CONCLUSION

In conclusion, from this study ME diets and their consequences that both sexes of *B. dorsalis* are potential fruit eating pest worldwide while consumed ME as precursor sex pheromone. For the both diets experiment, beside there were no apparent changes in *B. dorsalis* life span. The ME mixed diet fed flies had enhanced the mating success, tolerance, and ME-fed female flies had higher fecundity while the plane diet has no significant impact on the immature life span of *B. dorsalis.* Although the 1st and 2nd instar larvae high mortality on the ME diet, our findings will be more beneficial for future work related to mass rearing of sterile populations of *B. dorsalis*.

ACKNOWLEDGMENT

The authors thanks to editor, all anonymous referees, for their immense effort, constructive comments, suggestions on this manuscript.

Funding

This research has no funding

IRB approval

Not applicable.

Data availability

The data used in this study would be made available by the corresponding author on request.

Statement of conflicts of interest

The authors have declared no conflict of interest.

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