Variation of vectorial capacity and life history traits of *Aedes aegypti*; main vector for dengue transmission with larval diet concentration

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Abstract

Vectorial capacity (VC) is the number of new infections disseminated per case per day by an insect vector. There are several attempts define the VC of disease vectors. Mathematical approximation using different biological parameters is one such approaches. Therefore, the present investigation was carried out to assess the effect of larval diet concentration on vector bionomic and vectorial capacity of *Aedes aegypti* in Sri Lanka. A batch of 400 first instar larvae of *Ae. aegypti* in 100 ml of water were exposed to three different concentrations (6%, 8% and 10%) of larval diet, made with tuna meal (12.5g), bovine liver powder (9.0g), brewer's yeast (3.5g). The effect of larval diet concentration on different biological parameters of larvae (mortality rate, survival rate), pupae (mortality rate, survival rate, pupation success), adult (mortality rate, longevity and fecundity of adults) and selected morphometric characters at each stage with respect to diet concentration were recorded. The whole experiment setup was repeated five times. Vectorial capacities for each diet treatment were calculated using $VC= ma^2p^n/-\log_e P$ mathematical approximation.

There was a significant effect of larval diet on most of larval growth parameters including head length ($F_{4,14}$ = 29.599; P<0.05), head width ($F_{4, 14}$ = 20.797; P<0.05), thoracic width ($F_{4, 14}$ = 55.924; P<0.05), abdominal length ($F_{4, 14}$ = 10.381; P<0.05), abdominal width ($F_{4, 14}$ = 7.239; P<0.05) and total length ($F_{4, 14}$ = 20.797; P<0.05). Most of larval growth parameters were varied significantly with different larval dietary concentrations including thoracic length ($F_{4, 14}$ = 4.662; P<0.05), abdominal length ($F_{4, 14}$ = 12.452; P<0.05), abdominal width ($F_{4, 14}$ = 5.890; P<0.05) and wing length ($F_{4,14}$ =7.001; P<0.05) of sexes, except thoracic width ($F_{4, 14}$ = 2.469; P>0.05). Further, biting frequency ($F_{4, 14}$ = 47.50; P<0.05), fecundity ($F_{4, 14}$ = 18.33; P<0.05) and survival rate ($F_{4, 14}$ = 3.61; P<0.05) of adult female, significantly varied with different larval diet concentrations. However, the longevity of adults ($F_{4, 14}$ = 0. 591; P>0.05) was not correlated significantly with larval food availability. The highest VC (196.37 ± 29.92) were observed from 10% larval treatment followed by 8% (27.30 ± 4.47). The VC of adult *Ae. aegypti* differed significantly ($F_{4, 14}$ = 24.048; P=0.014, at 95% level of confidence) among the different larval diet concentrations**.** Therefore, it is required to document the environmental variation at the larval stages in order to understand transmission dynamics and control of dengue in Sri Lanka.

Keywords: vectorial capacity, *Aedes*, larval, diet

Introduction

Ae. aegypti is an invasive species which transmit dengue, a seasonal vector borne disease (Kampen, 2014) and in case of dengue vector, vectorial capacity describes a vector's ability to spread disease among humans and takes into account host, virus, and vector interactions assuming that all three of these parameters are present (Garrett-Jones, 1964). *Ae. aegypti* larvae utilize a large variety of habitats and there are different food types in these habitats, which are consumed by larvae of *Ae. aegypti* in wild those are microorganisms, detritus (particulate organic matter), biofilm, and other organic matter such as dead invertebrates, plant materials that has been degraded by fungi or bacteria are the major source of nutrients for mosquito larvae (Clements, 1992). According to previous studies on larval feeding, the availability of larval food is important for larval development (Merritt *et al*, 1992), development and survival of adult, adult emergence (Okech *et al*, 2007), sexual maturation, fecundity and body size (Dominic and Das, 1996) and there is a relationship between vectorial capacity and larval food availability as it affects adult size and survival (Wallace, 1999). Vectorial capacity is the number of new infections disseminated per case per day by an insect vector. There are have been different criteria to define vectorial capacity of disease vectors and expression using mathematical based interpretation is one such approaches (Mitchell and Catteruccia, 2017). However, none of these attempt have made to define the vectorial capacity of disease vectors based on life cycle related biological information. Therefore, the objective of the present study is to define the vectorial capacity of *Ae. aegypti*; the main vector for dengue transmission in Sri Lanka by mathematical approximation.

Methodology

A batch of 400 first instar larvae of *Ae. aegypti* in 100 ml of water were exposed to three different concentrations (6%, 8% and 10%) of larval diet, made with tuna meal (12.5g), bovine liver powder (9.0g), brewer's yeast (3.5g). The effect of larval diet concentration on different biological parameters of larvae (mortality rate, survival rate), pupae (mortality rate, survival rate, pupation success), adult (mortality rate, longevity and fecundity of adults) and selected morphometric characters at each stage with respect to diet concentration were recorded. The whole experiment setup was repeated five times. The vectorial capacity of *Ae. aegypti* mosquito was evaluated using a mathematical based approach based on the data collected from the present study and previous usage of literature as described in below equation.

VC= $ma^2p^n / -\log_e P$

m=vector density, **a**= average biting frequency, **p**= survivorship, and **n**=extrinsic incubation period (Gary and Foster, 2001), the daily survival rate P were calculated using a mathematical formula; $\sqrt[d]{P}$, where d is the duration of study and P is proportion of female survive by the end of that period (Almeida *et al*., 2005).

Result and Discussion

There was a significant effect of larval diet on most of larval growth parameters including head length ($F_{4,14}$ = 29.599; P<0.05), head width ($F_{4, 14}$ = 20.797; P<0.05), thoracic width ($F_{4, 14}$ = 55.924; P<0.05), abdominal length ($F_{4, 14}$ = 10.381; P<0.05), abdominal width ($F_{4, 14}$ = 7.239; P<0.05) and total length ($F_{4, 14}$ = 20.797; P<0.05) of larvae. However, thoracic length ($F_{4, 14}$ = 2.136; P>0.05), survival rate ($F_{4, 14}$ = 0.230; P<0.05) and mortality rate ($F_{4, 14}$ = 0.214; P<0.05) of larvae did not show significant differences with larval diet concentration.

According to result that even though there is no significant difference in cephalothoracic length ($F_{4, 14}$ = 0.907; P>0.05) and cephalothoracic width ($F_{4, 14}$ = 2.777; P>0.05) of pupa, the highest pupal growth was noted at highest (10%) larval diet concentration. Further, the highest pupation success (97.8 ± 0.2 %) was showed by pupae emerged from larvae treated with 10% diet. However, no significant association was noted with the larval diet concentration ($F_{4, 14}$ =0.027; P>0.05). Both survival rate ($F_{4, 14}$ = 24.011; P<0.05) and mortality rate ($F_{4, 14}$ = 30.413; P<0.05) of pupae were significantly affected by larval diet concentration.

Most of larval growth parameters were varied significantly with different larval dietary concentrations including thoracic length ($F_{4, 14}$ = 4.662; P<0.05), abdominal length ($F_{4, 14}$ = 12.452; P<0.05), abdominal width ($F_{4, 14}$ = 5.890; P<0.05) and wing length ($F_{4,14}$ =7.001; P<0.05) of both adult male and female the except thoracic width ($F_{4, 14}$ = 2.469; P>0.05). In fact, the effect of sex ratio on the adult morphometry was also remained significant.

Furthermore, biting frequency ($F_{4, 14}$ = 47.50; P<0.05), fecundity ($F_{4, 14}$ = 18.33; P<0.05) and survival rate ($F_{4, 14}$ = 3.61; P<0.05) of adult female, significantly varied with different larval diet concentrations. However, the longevity of adults ($F_{4, 14}$ = 0. 591; P>0.05) was not correlated significantly with larval food availability.

Vectorial capacities for each diet treatment were calculated using $VC= ma^2p^n/-\log_e P$ mathematical approximation. According to result of the study there was a significant effect of larval diet on vectorial capacity of adult of *Ae. aegypti* ($F_{4, 14}$ = 24.048; P<0.05), and adult reared under the highest diet treatment (10%), were characterized with the highest vectorial capacity (196.37 ± 29.92) while 8% adult from larval diet treatment showed the lowest vectorial capacity (27.30 ± 4.47).

Table 1: Biting frequency, longevity, fecundity and survival rate of adult *Aedes aegypti* fed with different concentration of larval diet

Diet concentration (%)	Biting frequency	Longevity	Fecundity	Survival rate
6	76.56 ±1.52^a (75.04-78.08)	33.5±2.5^a (31.0-36.0)	60.4± 10.8^a (49.6-71.2)	94.95± 0.35%^{a} (94.60-95.30)
8	82.91 ±3.07^a (82.84-82.98)	34.50 ±2.5^a (32.0-37.0)	65.24±6.32^a (58.92- 71.56)	95.3± 1.30%^{b} (94.0-96.6)
10	99.6 ±0.4^b (99.2-100.0)	37.0 ±2.0^a (35.0-39.0)	116.40±0.78 ^{b} (115.62-117.18)	97.95±0.65%^{b} (97.30-98.60)

Overall, the present study concludes that multiple biological parameters of the dengue vector, *Ae. aegypti* significantly affects by the dietary supplement to its larvae and the larvae fed with the high food amount produced adults with larger wing sizes and longer longevity, greatly increasing the vectorial capacity. Hence, this investigation highlights the requirement in accounting the environmental variation at the larval stages in order to understand transmission dynamics and control of dengue in Sri Lanka.

Table 2: Measurements of adult *Aedes aegypti* fed with different concentration of larval diet.

Larval diet concentration (%)	Thoracic Length (mm)		Thoracic Width (mm)		Abdominal Length (mm)		Abdominal Width (mm)		Wing Length (mm)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
6	1.00±0.04[a] (0.06-1.04)	1.34±0.03[a] (1.31-1.37)	0.75±0.02[a] (0.73-0.77)	0.97±0.02[a] (0.95-0.99)	2.20±0.03[a] (2.17-2.23)	2.60±0.03[a] (2.57-2.63)	0.44±0.02[a] (0.42-0.46)	0.64±0.01[a] (0.63-0.65)	2.36±0.04[a] (2.32-2.40)	3.12±0.03[a] (3.09-3.15)
8	0.99±0.04[a] (0.95-1.03)	1.33±0.03[a] (1.30-1.36)	0.74±0.02[a] (0.72-0.76)	0.96±0.02[a] (0.94-0.98)	2.21±0.03[a] (2.18-2.24)	2.60±0.03[a] (2.58-2.63)	0.47±0.02[a,b] (0.45-0.49)	0.68±0.01[a,b] (0.67-0.69)	2.37±0.04[a] (2.33-2.41)	3.13±0.03[a] (3.10-3.16)
10	1.14±0.04[b] (1.10-1.18)	1.52±0.03[b] (1.49-1.55)	0.80±0.02[a] (0.78-0.82)	1.03±0.02[a] (1.01-1.05)	2.40±0.03[b] (2.37-2.43)	2.83±0.03[b] (2.80-2.86)	0.51±0.02[b] (0.49-0.53)	0.75±0.01[b] (0.74-0.76)	2.54±0.04[b] (2.50-2.58)	3.36±0.03[b] (3.33-3.39)

Note: Values are mean ± SE, range in parenthesis. Different superscript letters in a column show significant differences ($P<0.05$) as suggested by General Linear Modelling followed by Tukey's HSD (Honest Significant Difference) at 95% level of significance.

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