

**Effect of food types on competitive interaction between *Aedes aegypti* (LINNAEUS, 1762) and *Ae. albopictus* (SKUSE, 1894) (Diptera, Culicidae): a proximate level appraisal**

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**ABSTRACT.** Competitive interactions between coexisting *Aedes aegypti* and *Ae. albopictus* have been implied as a crucial factor shaping life history traits and population characteristics. The overlap in resource requirements and similarities in the life history strategies of the two *Aedes* mosquitoes form a basis for competitive interactions. In the present study, the role of the food quality of the larval habitats in influencing the outcome of competition between *Ae. aegypti* and *Ae. albopictus* is evaluated to highlight food quality as a basis for asymmetric competitive outcomes. Instar I larvae of the two mosquitoes were reared using conspecifics or heterospecifics of constant size and equal ratio with four different food types: boiled rice, boiled pulses, a mixture of boiled rice and pulses, and fish food. Competitive interactions were evaluated using age at pupation (AP), pupal weight (PW), dry adult weight (AW) and wing length (WL) with respect to intra- and inter-specific competition for the two sexes of each mosquito species. The results show that *Ae. albopictus* developed faster but achieved a smaller size compared to *Ae. aegypti* under interspecific competition conditions, the extent of the difference varying significantly with the food type. Given the variety of food resources available in the small container larval habitats, the results of the study imply that food quality may act differentially with respect to larval development and adult body size, depending on the conspecifics or heterospecifics and on the sex of the species concerned. The dominance of one species over the other may also be a consequence of the resource utilization pattern that varies in the larval habitats.

**KEY WORDS:** *Aedes*, resource based competition, life history traits, food type.

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## INTRODUCTION

The coexistence of the dengue vectors *Aedes aegypti* (LINNAEUS, 1762) and *Ae. albopictus* (SKUSE, 1894) (Diptera: Culicidae) in different larval habitats has been reported from various geographical locations (O'MEARA et al. 1995, BRAKS et al. 2004, JULIANO et al. 2004, REY et al. 2006, KAMGANG et al. 2010). The similarities in life history strategies and the resources required for larval development result in an overlap of spatial occupancy in available larval habitats by both mosquito species (MERRITT et al. 1992, O'MEARA et al. 1995, WALKER et al. 1996, JULIANO et al. 2002, 2004). Consequently, developing larvae of *Ae. aegypti* and *Ae. albopictus* may compete for resources, the outcome of which may vary with the relative abundance of the two species in the larval habitats (AGNEW et al. 2002, ARRIVILLAGA & BARRERA 2004, BÉDHOMME et al. 2005, LEGROS et al. 2009, REISKIND & LOUNIBOS 2009, ALTO et al. 2015). In addition to numerical abundance, environmental factors like temperature (LOUNIBOS et al. 2002, KIRBY & LINDSAY 2009, WESTBROOK et al. 2010, COURET et al. 2014, EWING et al. 2016) and food resources (RENSHAW et al. 1994, ARRIVILLAGA & BARRERA 2004) influence the outcome of larval development. The outcome of both interspecific and intraspecific competition influences the population dynamics of both these mosquito species, as is evident from different laboratory and field studies (AGNEW et al. 2002, GAVOTTE et al. 2009, GILLES et al. 2011). Competitive effects can be evaluated through variations in life history traits like pupal weight, adult weight and wing length (AGNEW et al. 2002, JULIANO 2009, 2010). The life history traits in mosquitoes are determined by the larval feeding characteristics, which in turn depend on the resources available in their habitats. Resource-based competitive interactions have been studied in different forms, which has led to the concept of context-dependent competition between mosquitoes, especially between *Ae. aegypti* and *Ae. albopictus* (JULIANO 2009). Assessment of variations in life history traits is a feasible way of accounting for competitive interactions within and between mosquito species.

Competitive interactions vary with the strains and origin of the mosquitoes and the local conditions that define the population. For instance, both mosquito species are observed in household waste containers that may carry organic residues of diverse origin, particularly as regards food and beverages (VEZZANI & SCHWEIGMANN 2002). In conditions where resources are abundant, differences in their quality may have consequences for the tempo of larval development, inclusive of the preference for a resource by one or other of the mosquito species. Whereas earlier studies mostly described the effects of resource quantity on competitive interactions, few dealt with the quality of the resources available. Plant-based detritus provides *Ae. albopictus* with a competitive advantage over *Ae. aegypti* (JULIANO 1998, BRAKS et al. 2004), which is reduced by the presence of animal carcasses (DAUGHERTY et al. 2000). There is evidence suggesting that animal-based resources favour

*Ae. aegypti* (MOORE & FISHER 1969), whereas plant-based resources favour *Ae. albopictus* (BARRERA 1996, MURRELL & JULIANO 2008): consequently, the competitive interaction between the two mosquito species can be described as context-dependent (JULIANO 2009). The diversity of larval habitats and resources present therein supports the hypothesis of context-dependent competitive interactions between the two congeneric mosquito species. In Kolkata, India, the diversity of larval habitats of *Aedes* MEIGEN, 1818 mosquitoes suggests the presence of a varied type of resources in them, which can influence the outcome of competition in developing larva (BANERJEE et al. 2013b, 2015a). Pupal productivity from the larval habitats of Kolkata indicates that both species occupy them, although the relative density varies considerably (MOHAN et al. 2014). A study was therefore conducted using larval food types as an explanatory factor for the outcome of inter- and intraspecific competition between *Ae. aegypti* and *Ae. albopictus* in Kolkata, India. The experimental design employed in the present study would enable an assessment of the resource quality dependent variations in the competitive interactions in the two *Aedes* mosquitoes. While reduction in larval habitats has been highlighted in the past, the consequences of varying resource quality on larval development and population fitness level have remained unexplored. Body size and various other life history traits are crucial measures for predicting the disease transmission potential of mosquitoes. Thus, an evaluation of life history trait related variations arising out of the competition linked to resource quality variations would help to understand population level variations in *Aedes* mosquitoes with greater clarity.

## MATERIAL AND METHODS

### Laboratory rearing and experimental design

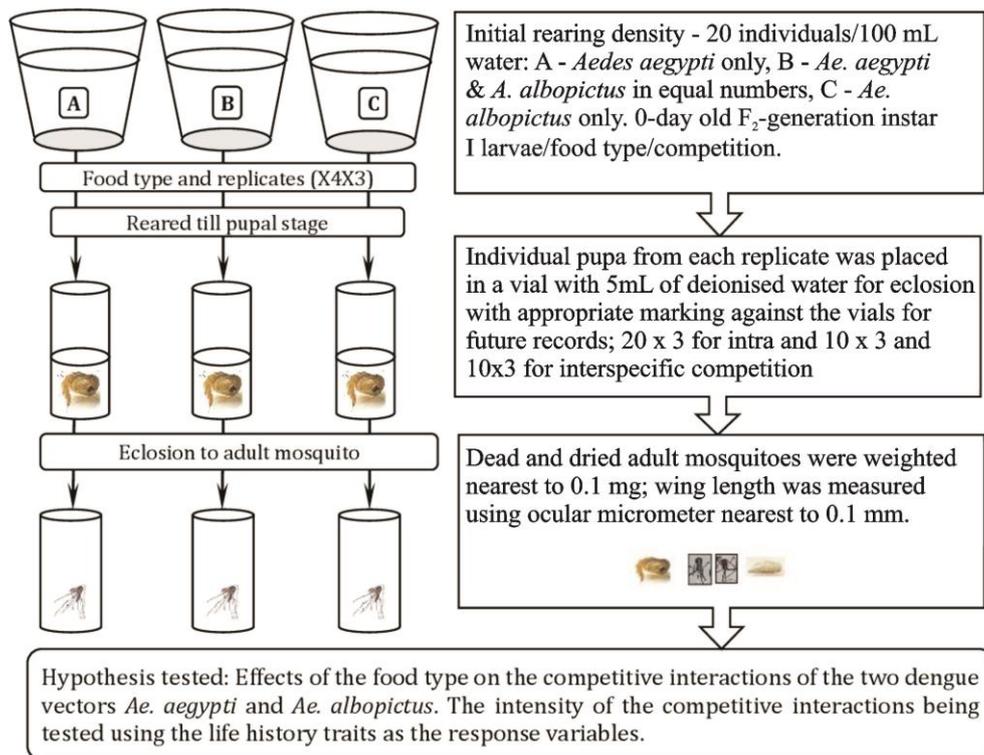
Laboratory culture was initiated following the collection of the immature stages of the two mosquito species (*Ae. aegypti* and *Ae. albopictus*) from different larval habitats in selected sites of urban and suburban Kolkata (BANERJEE et al. 2013a, 2013b, 2015b). Field collected immatures were treated as the P-generation, which were reared to obtain the F<sub>2</sub> generation 0 day old (<6 hr) instar I larvae (AMBRUSTER & HUTCHINSON 2002) to initiate the experiment. From the general collection of P-generation immatures, individual pupae were placed in vials and, upon emergence as adult mosquitoes (P-generation), the species were identified and then segregated. The adults (P-generation) of *Ae. aegypti* and *Ae. albopictus* were reared separately in wooden cages with the provision of 20% sucrose solution on the first and third days and blood fed on the second and fourth days post emergence. The rearing procedure for the two mosquitoes complied strictly with the synchronized hatching of eggs, and the emerging instar I larvae (F<sub>1</sub> generation) were

transferred immediately after hatching to plastic containers (100 ml, Tarson<sup>®</sup> specimen container, India) containing 75 ml of deionised water and tap water (1:1 ratio) and placed inside a wooden mosquito cage. In each container, fish food (Tokyu<sup>®</sup>, Japan) was provided *ad libitum* and the water was changed daily. The relative humidity was maintained above 80% by placing a water-filled tub below the wooden mosquito cage. The temperature remained between 25 and 27°C under laboratory conditions during the monsoon period (July to September 2013). Following emergence of the F<sub>1</sub>-generation adults, the mosquitoes were fed with 20% sucrose solution, and then blood at the end of the third and fifth days post emergence. The mosquito cages were provided with oviposition substrates with either moist tissue paper in a Petri dish or a small specimen container filled with aged tap water. The culture was maintained for the two species *Ae. aegypti* and *Ae. albopictus* separately following their initial separation from the F<sub>1</sub>-generation adults. Monitoring of the containers with eggs was continued to obtain the desired larval stages of both species.

In order to assess the competitive interactions, the F<sub>2</sub> generation 0 day old (<6 hr) instar I larva were reared under three different species ratios with four different food types being supplied. Maintaining a constant rearing density (20 individuals/100 ml water), the number of individual larvae of *Ae. aegypti* and *Ae. albopictus* was A) 20:0 (Intraspecific competition between *Ae. aegypti*), B) 10:10 (Interspecific competition between *Ae. aegypti* and *Ae. albopictus*) and C) 0:20 (Intraspecific competition between *Ae. albopictus*) per container. Four different types of food were provided: fish food (used as a balanced diet), Boiled Rice (rich in carbohydrate), boiled pulses (rich in protein) and both boiled rice and pulses (mixture of carbohydrate and protein) *ad libitum*. These 12 treatments (4 food types x 3 initial densities) were replicated 3 times, and appropriate monitoring was carried out for the rearing of the larvae under these experimental conditions. The temperature and relative humidity of the laboratory were also maintained at 25 ± 1°C and 50 ± 2% respectively.

The containers were monitored daily for pupation. Upon pupation the date of pupation was recorded (AP – Age at Pupation) and individual pupae were weighed (PW – Pupal Weight) to the nearest 0.1 mg using a pan balance (ADAM<sup>®</sup>, ADA 71/L, Adam Equipment, UK). Then, the individual pupae were placed in small glass vials containing 5 ml of doubly distilled water, after which these were covered with fine cloth for eclosion. The vials were numbered serially with regard to the date of pupation and the respective initial density and food treatment. Following eclosion, the water was removed from the vials using a sterile syringe, and the sex (for both intraspecific and interspecific competition) and species (for interspecific competition) of the emerging adults were noted and recorded. After the natural death of the mosquitoes, the adult dry weight (AW – Adult Weight) was recorded to the nearest 0.1 mg (ADAM<sup>®</sup>, ADA 71/L, Adam Equipment, UK). The wings of the individual mosquitoes were removed and their lengths measured to the nearest 0.1 mm using

a dissecting stereomicroscope (Olympus® SZX, Olympus Corporation, Tokyo, Japan) fitted with an ocular micrometer (Erma®, Japan). The experimental design is outlined in Fig. 1.



**Fig. 1.** Outline of the experimental design followed in the study. In all instances F<sub>2</sub> generation 0-day old (<6h) instar I larvae were considered for the experiments.

### Statistical analysis

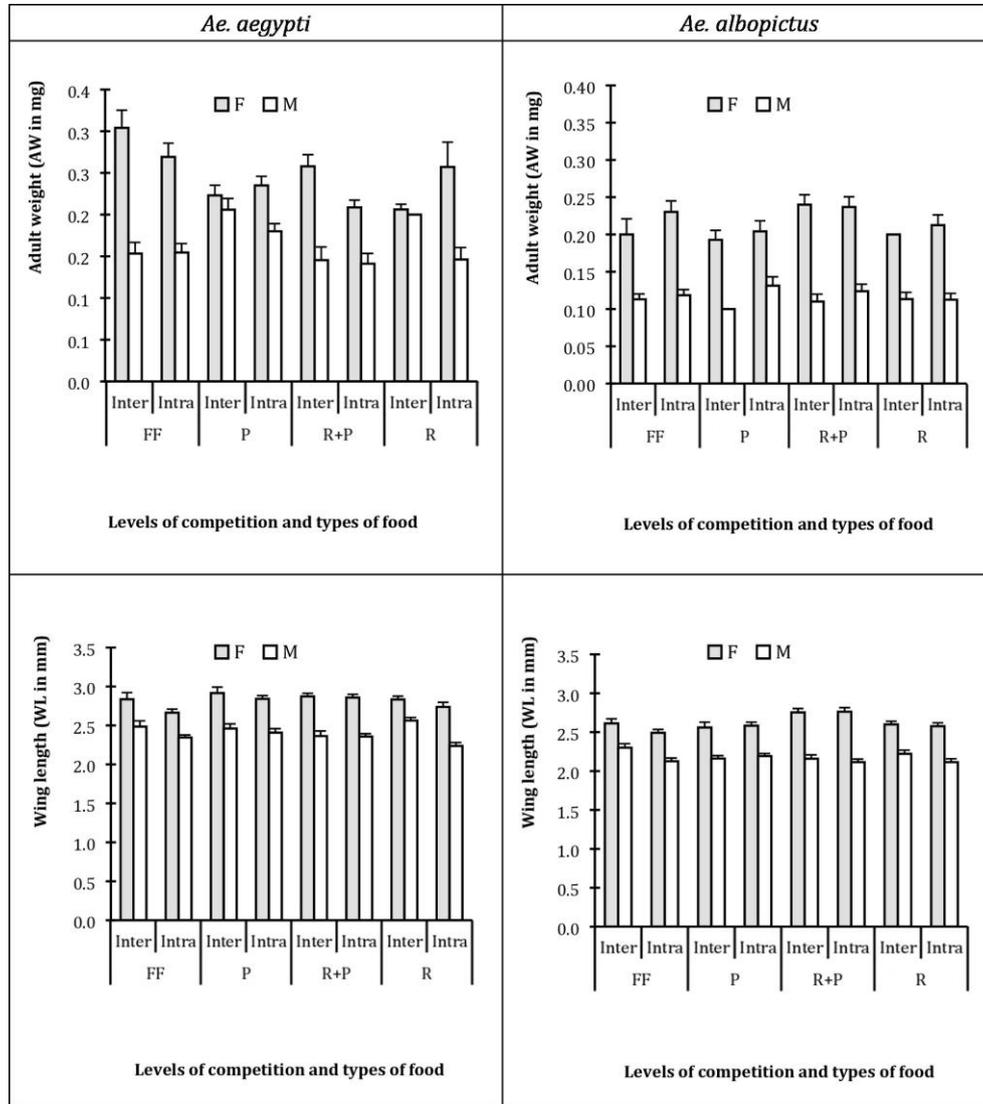
In order to assess the effects of competition on life history traits (age at pupation – AP, in days; pupal weight – PW, in mg; adult body weight – AW, in mg; wing length – WL, in mm), the food types, sexes, and types of competition regarded as explanatory variables and a logistic regression complying with the binomial generalized linear model with logit link was employed to comment on the variations in the life history traits of the two *Aedes* mosquitoes. In the logistic regression, a particular life history trait (response variable) was assumed to follow a binomial (n, p) distribution with n replicates (sampling efforts) for each treatment level (the levels of the explanatory variables; Food type – 4, sex – 2 and competition – 2). The linear combination of the explanatory variables was represented by

the probability parameter  $p$ . A weighted binary function with logit link was employed and the parameters were estimated by maximum likelihood using XLSTAT software (ADDINSOFT 2010). The equation is represented as life history trait ( $y$ ) =  $1/(1 + \exp(- (a + b_1x_1 - b_2x_2 - b_3x_3)))$ , where  $x_1$  is food type,  $x_2$  is competition,  $x_3$  is sex. The Chi square value (Wald's Chi-square) was used to deduce the significance of the estimated parameters of the model.

The analysis was extended with univariate ANOVA using food types, sex and competition type as the explanatory variables against each of the life history traits for each species. Thus, four separate ANOVAs were conducted to deduce the individual and interactive effects of the sources of variations (explanatory variables). The partial  $\eta^2$  values against each of the sources indicate the extent of the variations explained by a particular factor, either independently or as an interaction (ZAR 1999). The differences in life history traits between the two *Aedes* species reared using four different food types were assessed following DAUGHERTY et al. (2000) and the data compared using the Kruskal-Wallis test with multiple comparisons. The analysis was further extended using GLM Mixed model ANOVA, taking different food types and sex as explanatory variables and the differences in life history traits between *Ae. aegypti* and *Ae. albopictus* as response variables. The statistical analyses were performed following ZAR (1999) using XLSTAT (ADDINSOFT 2010).

## RESULTS

The competitive interactions between *Ae. albopictus* and *Ae. aegypti* were evident as a result of rearing density and variation in food type. Life history traits like age at pupation (AP), pupal weight (PW), adult weight (AW) and wing length (WL) varied significantly between the two competitive interactions encountered during the larval stages (Fig. 2). In conspecific conditions, the differences in the life history traits were evident and comparable to the heterospecific conditions. The extent of competitive interactions varied with the food type, although the effects were similar in both species (Fig. 2). Although males emerged as adults faster than females, the females of both species performed better under both conspecific and heterospecific conditions with respect to the remaining traits (PW, AW and WL) (Fig. 2). The results of GLM depicted significant differences in AP, PW, AW and WL for both species as explained by the treatment factors, i.e. food type, density and sex. Wald's chi square values explained the significant contribution of explanatory variables to the response variables (Table 1).



**Fig. 2.** Life history traits (AP – age at pupation in days; PW – pupal weight in mg; AW – adult weight in mg and WL – wing length in mm) of *Aedes aegypti* and *Ae. albopictus* reared with conspecifics (INTRA) or heterospecifics (INTER) using four different food types (FF – fish food; P – pulses; R+ P – rice + pulse and R – only rice) at a constant density of 20 individuals / 100 mL. The data was taken on the basis of early (E) and late (L) emerging adults (based on the first and last 10 individuals).

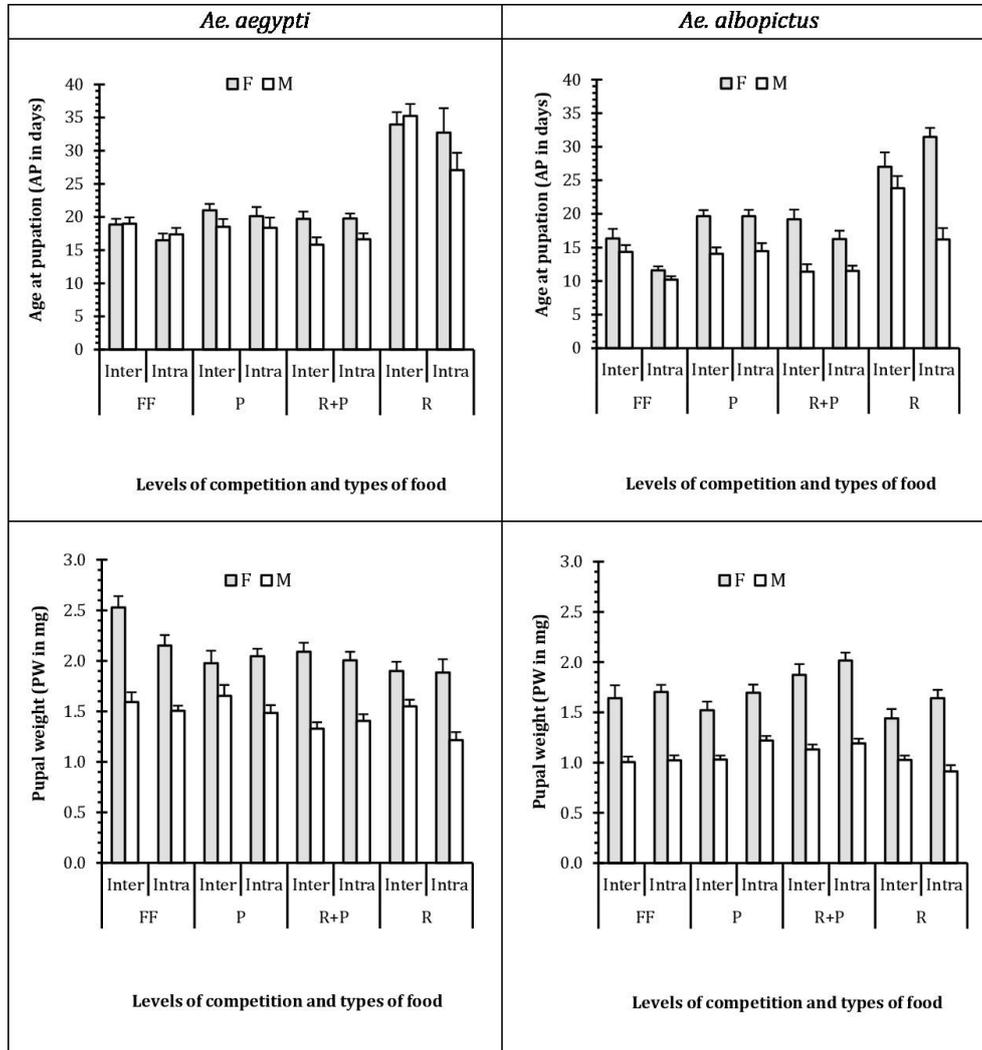


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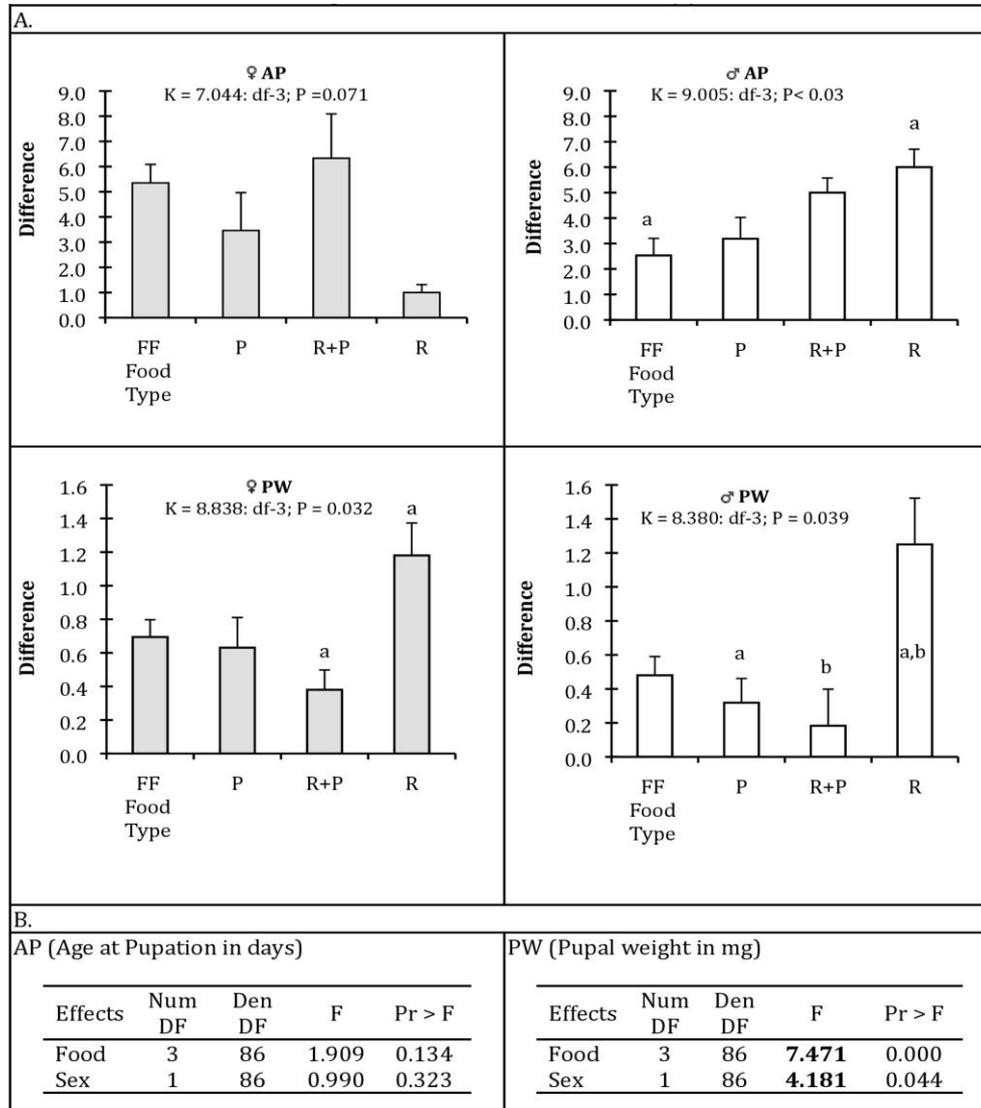
The results of univariate ANOVA show that for *Ae. aegypti* AP and PW varied significantly for all three explanatory variables, i.e. food type, competition level and sex, whereas the competition level had no significant effect on adult weight and food type had no significant effect on wing length in *Ae. aegypti*. Also, the interaction of the three explanatory variables had a significant effect on the response variables (Table 2). For *Ae. albopictus* AP varied significantly for all three explanatory variables as well as for all of their interactions. PW, AW and WL had a significant effect because of food variation and

**Table 1.** The results of logistic regression (binomial generalized linear model with logit link) to deduce the effects of the treatment factors, i.e. the explanatory variables, on the life history traits of the two species of *Aedes* mosquitoes. The regression equations are shown below along with the test of significance for the explanatory variables.

<i>Aedes aegyptis</i>				<i>Aedes albopictus</i>					
Source	Intercept	Food	Density	Sex	Source	Intercept	Food	Density	Sex
<i>Age at pupation (AP in days)</i>									
Value	-3.921	0.155	0.288	0.172	Value	-3.864	0.109	0.344	0.116
SE	0.075	0.011	0.028	0.029	SE	0.067	0.013	0.030	0.030
Wald $\chi^2$	2736.423	182.545	103.338	34.996	Wald $\chi^2$	3373.340	70.249	131.449	14.638
Pr > $\chi^2$	< 0.0001	< 0.0001	< 0.0001	< 0.0001	Pr > $\chi^2$	< 0.0001	< 0.0001	< 0.0001	0.000
<i>Pupal weight (PW in mg)</i>									
Value	-3.832	0.134	0.268	0.138	Value	-3.907	0.111	0.345	0.132
SE	0.237	0.037	0.094	0.097	SE	0.219	0.041	0.104	0.105
Wald $\chi^2$	262.472	13.297	8.208	2.023	Wald $\chi^2$	318.099	7.316	11.037	1.596
Pr > $\chi^2$	< 0.0001	0.000	0.004	0.155	Pr > $\chi^2$	< 0.0001	0.007	0.001	0.207
<i>Adult weight (AW in mg)</i>									
Value	-3.759	0.137	0.214	0.144	Value	-3.830	0.094	0.338	0.097
SE	0.668	0.108	0.271	0.282	SE	0.610	0.116	0.297	0.305
Wald $\chi^2$	31.698	1.619	0.623	0.263	Wald $\chi^2$	39.418	0.655	1.294	0.101
Pr > $\chi^2$	< 0.0001	0.203	0.430	0.608	Pr > $\chi^2$	< 0.0001	0.418	0.255	0.751
<i>Wing length (WL in mm)</i>									
Value	-3.883	0.136	0.290	0.155	Value	-3.900	0.117	0.336	0.128
SE	0.199	0.031	0.078	0.080	SE	0.171	0.032	0.079	0.078
Wald $\chi^2$	378.849	19.558	13.688	3.771	Wald $\chi^2$	521.959	13.574	18.240	2.683
Pr > $\chi^2$	< 0.0001	< 0.0001	0.000	0.052	Pr > $\chi^2$	< 0.0001	0.000	< 0.0001	0.101
AP = 1 / (1 + exp(-3.92+0.15*Food+0.29*Density+0.17*sex))									
PW = 1 / (1 + exp(-3.83+0.13*Food+0.27*Density+0.14*Sex))									
AW = 1 / (1 + exp(-3.76+0.14*Food+0.21*Density+0.14*Sex))									
WL = 1 / (1 + exp(-3.88+0.14*Food+0.29*Density+0.15*Sex))									
AP = 1 / (1 + exp(-3.86+0.11*Food+0.34*Density+0.12*Sex))									
PW = 1 / (1 + exp(-3.91+0.11*Food+0.35*Density+0.13*Sex))									
AW = 1 / (1 + exp(-3.83+0.09*Food+0.34*Density+0.10*Sex))									
WL = 1 / (1 + exp(-3.90+0.12*Food+0.34*Density+0.13*Sex))									

**Table 2.** The results of the univariate ANOVA using the food types, competition level and sex of the adults of both the species *Aedes aegypti* and *Ae. albopictus* as explanatory variables against the four life history traits AP, PW, AW, and WL as response variables. The values in bold indicate significant differences at  $P < 0.05$  level. MS – Mean Square.

Variable	<i>Aedes aegypti</i>			<i>Aedes albopictus</i>		
	df	MS	F	df	MS	F
<i>Age of pupation</i>						
Food	3	1723.416	<b>56.770</b>	3	1336.646	<b>54.947</b>
Comp	1	155.226	<b>5.113</b>	1	302.833	<b>12.449</b>
Sex	1	178.881	<b>5.892</b>	1	1844.569	<b>75.826</b>
Food * Comp	3	52.215	1.720	3	74.417	<b>3.0591</b>
Food * Sex	3	56.071	1.847	3	149.591	<b>6.1494</b>
Comp * Sex	1	18.355	0.605	1	99.546	<b>4.0921</b>
Food * Comp * Sex	3	32.830	1.081	3	123.293	<b>5.0683</b>
Error	263	30.360		284	24.326	
<i>Pupal Weight (PW)</i>						
Food	3	1.085	<b>6.977</b>	3	1.342	<b>12.198</b>
Comp	1	0.713	<b>4.582</b>	1	0.290	2.639
Sex	1	19.726	<b>126.9</b>	1	24.892	<b>226.281</b>
Food * Comp	3	0.205	1.321	3	0.101	0.921
Food * Sex	3	0.442	<b>2.841</b>	3	0.295	<b>2.684</b>
Comp * Sex	1	0.009	0.056	1	0.162	1.476
Food * Comp * Sex	3	0.329	2.116	3	0.065	0.593
Error	263	0.156		284	0.110	
<i>Adult weight (AW)</i>						
Food	3	0.013	<b>3.528</b>	3	0.009	<b>2.868</b>
Comp	1	0.009	2.375	1	0.006	1.824
Sex	1	0.339	<b>88.57</b>	1	0.608	<b>187.601</b>
Food * Comp	3	0.002	0.416	3	0.003	0.857
Food * Sex	3	0.033	<b>8.517</b>	3	0.003	1.025
Comp * Sex	1	0.003	0.835	1	0.000	0.039
Food * Comp * Sex	3	0.014	<b>3.678</b>	3	0.002	0.588
Error	263	0.004		284	0.003	
<i>Wing length (WL)</i>						
Food	3	0.081	1.436	3	1.342	<b>12.198</b>
Comp	1	0.674	<b>11.97</b>	1	0.29	2.639
Sex	1	9.351	<b>166.2</b>	1	24.892	<b>226.281</b>
Food * Comp	3	0.116	2.068	3	0.101	0.921
Food * Sex	3	0.117	2.084	3	0.295	<b>2.684</b>
Comp * Sex	1	0.008	0.144	1	0.162	1.476
Food * Comp * Sex	3	0.031	0.543	3	0.065	0.593
Error	263	0.056		284	0.11	



**Fig. 3.** Differences in life history traits between *Aedes aegypti* and *Ae. albopictus* reared together in equal abundance with four different food types (FF – fish food, R – boiled rice, P – boiled pulses, R+P – boiled rice and pulse) provided *ad libitum*. The data were compared using the Kruskal-Wallis test with multiple comparisons following the Steel-Dwass-Critchlow method with Bonferroni correction (A). The results of GLM Mixed model ANOVA using food types and sex of the adults of both *Ae. aegypti* and *Ae. albopictus* as explanatory variables and the differences in the life history traits (AP, PW, AW, WL) of the two species as response variables. The values in bold indicate significant differences at the P < 0.05 level. The values in bold indicate significant differences at the P < 0.05 level (B).

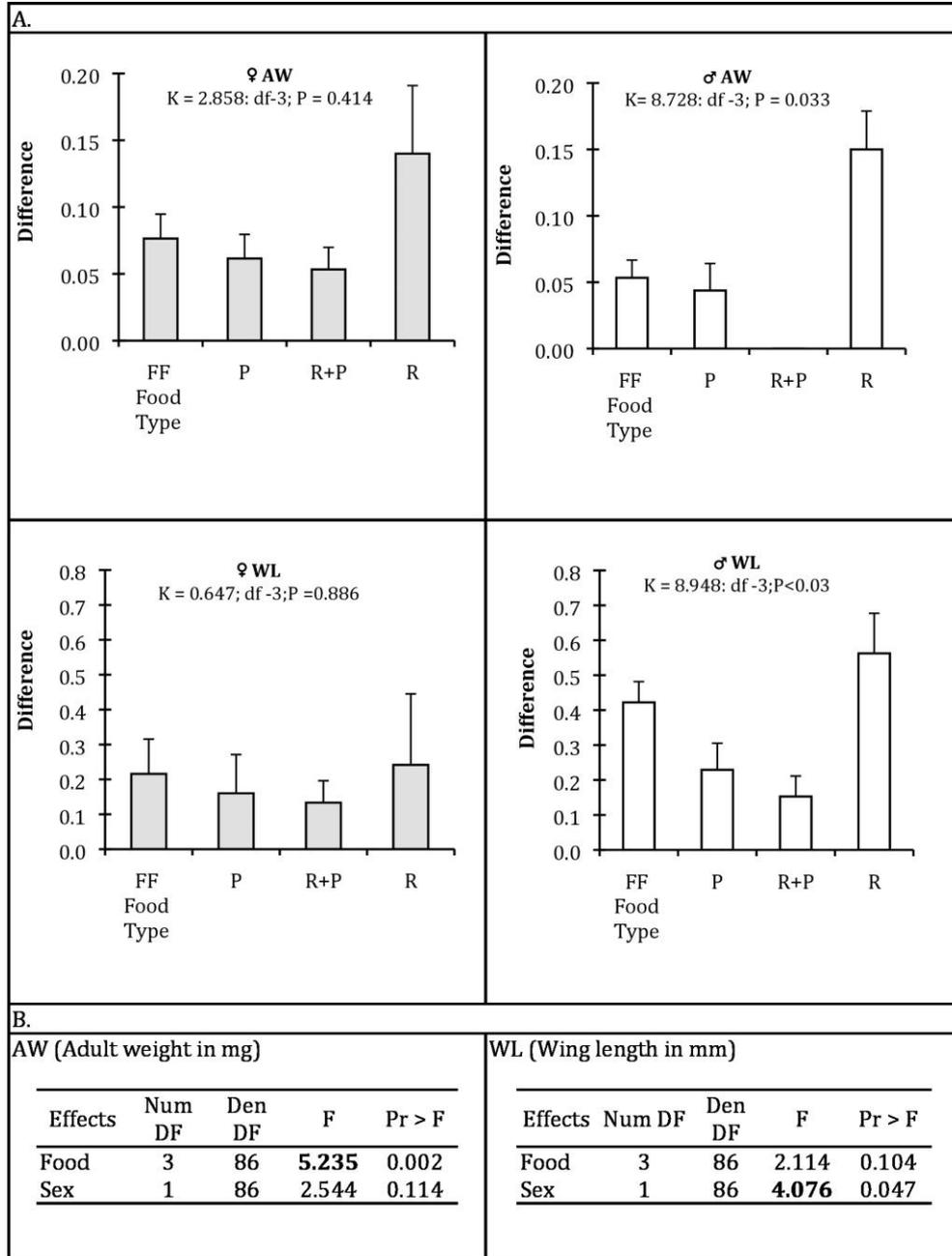


Fig. 3. Continued.

sex (Table 2). The life history traits of *Ae. aegypti* and *Ae. albopictus* are compared in Fig. 3. In almost all instances, the values are in favour of *Ae. aegypti*, illustrating the fact that *Ae. albopictus* reached the pupal stage early, with lower pupal weight, adult weight and wing length in both sexes. For the males, the differences in all the life history traits were significant, but for females only the pupal weight was significantly different when the food types were considered as a source of the variations. The result thus indicates that food quality induced differential effects on the two competing mosquitoes *Ae. aegypti* and *Ae. albopictus*, resulting in early emergence but smaller mosquitoes in the latter.

## DISCUSSION

Competitive interactions in the larval stages of *Aedes* mosquitoes influence the morphological and physiological characteristics of the adults (BRIEGEL 1990, GRIMSTAD & WALKER 1991, SUMANOCHITRAPON et al. 1998, BRIEGEL & TIMMERMANN 2001). Since body size and wing length are linked with the longevity and reproductive success of *Aedes*, competitive interactions are significant in shaping the population. Both interspecific and intraspecific competition influence the life history traits of *Ae. aegypti* and *Ae. albopictus* to a considerable extent (AGNEW et al. 2002, JULIANO 2009, 2010) and can thus be considered a vital factor for disease transmission potential (ALTO et al. 2008a, 2008b). The disease transmission potential of dengue vectors is linked with the fitness of the mosquitoes (JULIANO et al. 2014), reflected through body size and various life history traits that are influenced by larval development and the resources acquired during the larval stages. Resource-based competition in *Ae. aegypti* and *Ae. albopictus* arises out of the similarities in their biology and ecology. Both species of *Aedes* mosquitoes breed in artificial containers of different materials and origins (MEDRONHO et al. 2009, BURKE et al. 2010), which are, in many instances linked with household disposables (BANERJEE et al. 2013b, 2015). The development of the larval stages is greatly dependent on the resource content in these containers and can act as a limiting factor during overcrowded conditions. Similar conditions are observed in *Aedes* mosquitoes in other natural larval habitats (BRADSHAW & HOLZAPFEL 1992, CLEMENTS 1992, RENSHAW et al. 1994), which affects larval development and population growth (BROADIE & BRADSHAW 1991, RENSHAW et al. 1994, MUNSTERMANN & CONN 1997, LORD 1998). Such competitive interactions and resultant effects on the prospective viral role have been established by different studies (ALTO et al. 2008a, 2008b, PADMANABHA et al. 2011, MUTURI et al. 2012). Exploration of resource-based competition and its effect on the life history traits of *Ae. aegypti* and *Ae. albopictus* is thus imperative for a better understanding of their biology.

In the present study, an assessment was done to correlate resource-dependent competitive interactions and life history traits of *Ae. aegypti* and *Ae. albopictus*. In view of the results obtained it appears that both species are affected by interspecific rather than intraspecific competition with respect to all food levels and both sexes. The pattern of competitive interactions appears to resemble the conditions where the food supplied to the competing larvae was supplemented with additional resources, such as insect carcasses (DAUGHERTY et al. 2000). Inter- and intraspecific competition between *Ochlerolatus caspius* and *Culiseta longiareolata* also showed a similar kind of response when the initial density was varied (TSURIM et al. 2013). In separate studies, the effects of food on this competition resulted in differential responses by the two *Aedes* mosquitoes (AGNEW et al. 2002, YEE et al. 2004). Several studies have been conducted on competitive interactions between *Ae. albopictus* and *Ae. aegypti* with variations in the food substrates (DAUGHERTY et al. 2000, YEE et al. 2007, MURRELL & JULIANO 2008, BARA et al. 2014, COURET et al. 2014). The outcome of the competitive interactions was in favour of *Ae. aegypti* (MOORE & FISHER 1969), or of *Ae. albopictus*, and in a few instances, both species were equal as competitors (BLACK et al. 1989, HO et al. 1989, DAUGHERTY et al. 2000, LOUNIBOS et al. 2002, ALTO et al. 2005, 2008a, MURRELL & JULIANO 2008). On a comparative scale, the outcome of competitive interactions is context-dependent, with the presence of one food type favouring one of the two species (DAUGHERTY et al. 2000, MURRELL & JULIANO 2008). However, variation of the amount of food was used as a factor influencing the outcome of the competition in majority of instances (JULIANO 2009). In the present study, food quality was a factor that influenced the outcome of competition as measured by the life history traits. Although the assessments were conducted using a fixed rearing density of the developing larvae, the results suggest that food type differentially affects the life history traits under conditions of intra- and interspecific competition. For both the *Aedes* species, the outcome of the competitive impact may have consequences in the population build-up and elimination of one species at the cost of the other. However, adult survival and reproductive success is required to substantiate such a proposition, which will have to be assessed in further studies. Nonetheless, the present study has shown that food quality can be a source eliciting differential responses by the mosquitoes under conspecific and heterospecific conditions.

In the context of resource-based interspecific competition, it is apparent from the results that *Ae. albopictus* outcompeted *Ae. aegypti* in terms of larval development time (AP), but pupal weight (PW), adult weight (AW) and wing length (WL) were higher in the latter. As a consequence of the heterospecific interactions between the two species, it seems that *Ae. albopictus* employs a superior strategy in the competition with *Ae. aegypti*. In situations where the two species coexist, *Ae. albopictus* may emerge as the dominant species with a higher relative abundance but smaller body size, whereas in *Ae. aegypti* body size may be

larger but the developmental time longer. Body size has an immense effect on vector competence, as demonstrated by studies of *Ae. aegypti* (JULIANO et al. 2014) and *Aedes triseriatus* (PAULSON & HAWLEY 1991). Energy reserves in adult *Aedes* depend on resource acquisition in the larval stages, which may be affected by nutritional deprivation during larval development. Females with larger body sizes are said to have greater energy reserves than smaller ones. After eclosion to the adult stage, females with greater energy reserves can utilize them for survival and flight performance; moreover, a substantial proportion can be used to initiate oogenesis if the energy reserves have a threshold lipid content (BRIEGEL & HÖRLER 1993). But smaller females, having lower energy reserves, require blood meals for their survival at a very early part of the adult stage; as a result, multiple feeding in the early days of the adult stage enhance their potential for disease transmission (TAKKEN et al. 1998). The consequence of interspecific competition between the two species may therefore have different effects in the adults and thus roles in disease transmission. It appears that the strategies of the two species are different under conditions of interspecific competition. For *Ae. albopictus*, the early development but smaller size may facilitate the faster completion of the life cycle and thus chances to dominate, whereas *Ae. aegypti* may develop late but attain a comparatively larger size, thereby posing a greater risk of disease transmission owing to the ability to host a higher number of pathogens. Although transmission is inevitable in both cases, the role of the species may vary depending on the competitive interactions they are involved in.

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