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ORIGINAL ARTICLE

Preference of *Zeugodacus cucurbitae* (Coquillett) for three commercial fruit vegetable hosts in natural and semi natural conditions

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Abstract – Introduction. Host preference of *Zeugodacus cucurbitae* in three vegetables was determined under choice and no-choice experiments. **Materials and methods.** The experiments were conducted in both semi-natural (under cage) and natural (no cage) field conditions. The trials were run for three seasons between March 2013 and July 2014 in Morogoro Region, Tanzania. In each season, two sets of plots of watermelon *Citrullus lanatus*, cucumber *Cucumis sativus* and pumpkin *Cucurbita* sp., were established in mono and mixed cropping systems. A set of plots was placed under individual cages and another set of plots was left open. Colonies of *Z. cucurbitae* were regularly established from wild cucurbits and the emerging adults were maintained on artificial diets. The adults were released into cages once in a cropping season, at a sex ratio ratio of 1:1. A total of 60 and 180 adults were released into *choice* (4×4 m) and *no choice* (4×12 m) plots respectively. Open fields were infested naturally. Released adults were between 21 and 30 days old post emergence. Flies were released between six and eight weeks after sowing the vegetables. Fruits were harvested a week after release of flies into cages. Trials were also conducted to determine the dominant cucurbit infester in cucumber. Infestation rates and incidences were determined and used to indicate preference of *Z. cucurbitae* among the three vegetables. **Results and discussion.** Highest infestation rate of *Z. cucurbitae* was recorded in watermelon while lowest in pumpkin. Infestation rates were significantly high in fruits grown under *no choice* compared to *choice* plots. More flies emerged from fruits grown in *no choice* plots. However, infestation rates were not significantly different among fruits from natural and semi-natural conditions. Other cucurbit infesters, *Dacus bivittatus*, *D. frontalis*, *D. vertebratus* and *D. ciliatus* emerged from fruits grown in open (no cage) field plots. Further results show that *Z. cucurbitae* dominated *Dacus bivittatus* and *D. frontalis* in cucumber. **Conclusion.** Watermelon is the most preferred host of the dominant cucurbit infester *Z. cucurbitae*.

Keywords: Tanzania / watermelon / *Citrullus lanatus* / cucumber / *Cucumis sativus* / pumpkin / *Cucurbita* spp. / fruit fly / melon fly / *Zeugodacus cucurbitae* / host preference

Résumé – Préférence de *Zeugodacus cucurbitae* (Coquillett) pour trois légumes-fruits commerciaux en conditions naturelles et semi-naturelles. Introduction. L'hôte de préférence de la mouche du melon (*Zeugodacus cucurbitae*) a été déterminé par des expériences de choix et de non-choix parmi trois légumes. **Matériel et méthodes.** Les expériences ont été réalisées dans deux conditions de champ semi-naturelle (sous cage) ou naturelle (sans cage). Les essais ont été effectués durant trois saisons de culture entre mars 2013 et juillet 2014 dans la région de Morogoro, en Tanzanie. À chaque saison, deux lots de parcelles de melon d'eau *Citrullus lanatus*, de concombre *Cucumis sativus* et de citrouille *Cucurbita* sp., ont été établis suivant des systèmes de mono-culture ou de culture mixte. Un lot de parcelles a été placé sous cages individuelles et un autre lot de parcelles a été laissé ouvert. Les colonies de *Z. cucurbitae* ont été régulièrement approvisionnées à partir de cucurbitacées sauvages et les adultes émergents ont été entetenus avec des régimes alimentaires artificiels. Les adultes ont été introduits dans les cages une fois par saison de culture, selon un sex-ratio de 1:1. Un total de 60 et 180 adultes ont été respectivement relâchés dans les parcelles de choix (4×4 m) et de non-choix (4×12 m). Les parcelles ouvertes ont été infestées naturellement. L'âge moyen des adultes libérés variait entre 21 et 30 jours. Les mouches ont été libérées entre 6 et 8 semaines après le semis des légumes. Les fruits ont été récoltés une semaine après la libération des mouches dans les cages. Les essais ont également été effectués afin de déterminer

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la mouche des cucurbitacées dominante chez le concombre. Le taux et l'incidence des infestations ont été déterminés et utilisés pour indiquer la préférence de *Z. cucurbitae* parmi les trois légumes. **Résultats et discussion.** Le taux d'infestation de *Z. cucurbitae* le plus élevé a été enregistré chez le melon d'eau, le plus bas chez la citrouille. Le taux d'infestation était significativement élevé pour les fruits cultivés sans aucun choix par rapport aux parcelles proposant le choix. Davantage de mouches ont émergé des fruits cultivés sur les parcelles sans choix. En revanche, les taux d'infestation n'étaient pas significativement différents entre les fruits cultivés à l'air et ceux sous cage. D'autres mouches des cucurbitacées, *Dacus bivittatus*, *D. frontalis*, *D. ciliatus* et *D. vertebratus* émergé des fruits cultivés dans les parcelles ouverte. D'autres résultats montrent que *Z. cucurbitae* dominait *Dacus bivittatus* et *D. frontalis* chez le concombre. **Conclusion.** La pastèque est l'hôte préféré de la mouche du melon *Z. cucurbitae* dominante chez les cucurbitacées.

Mots clés : Tanzanie / pastèque / *Citrullus lanatus* / concombre / *Cucumis sativus* / citrouille / *Cucurbita* spp. / mouche des fruits / mouche du melon / *Zeugodacus cucurbitae* / hôte de préférence

1 Introduction

Melon fly *Zeugodacus cucurbitae* (Coquillett) is a serious pest of fruit vegetables. It is native to the Indian subcontinent, but it has spread to Southeast Asia, Pacific and Indian Ocean islands, and continental Africa [1]. Additional studies suggest that *Z. cucurbitae* originated from Central Asia and expanded its range to East Asia and Hawaii on one hand and to Africa and the Indian Ocean islands on the other [2]. The exact date of introduction into Africa is unknown, although records date back to the previous century, with the earliest report from Tanzania. However, the distribution range of *Z. cucurbitae* was restricted to East Africa for many decades, until the turn of the century when the species was reported from West Africa [3]. Despite its long presence on mainland Africa, *Z. cucurbitae* has received little attention in terms of research and management compared to the recently introduced *Bactrocera dorsalis* Hendel. Presently, *Z. cucurbitae* seems to dominate the other cucurbit infesters in terms of abundance in the field as well as incidence and infestation rate in fruits [4].

Zeugodacus cucurbitae damages up to 125 plant species [5]. Cucurbitaceous hosts are the most preferred, notably bitter gourd *Momordica charantia* L., muskmelon *Cucumis melo* L., snake gourd (*Trichosanthes anguina* L. and *T. cucumerina* L.), cucumber *Cucumis sativus* L., pumpkin *Cucurbita* sp., and watermelon *Citrullus lanatus* (Thunb.) Matsum. & Nakai [6, 7].

Studies on behavior of *Z. cucurbitae* indicate that adult flies spend considerable time on low, succulent, leafy vegetation surrounding cultivated areas [8] like *Manihot esculenta* Crantz and *Ricinus communis* L. [9]. Unlike the larvae, adult fruit flies do not feed on the flesh of a healthy fruit, but on juices from decaying or damaged fruit, as well as on nectars, plant saps and bird faeces [8]. Females visit host plants mainly to oviposit. Thus the selection of host species and the fruit type for larvae is pre-determined by the egg-laying females. As larvae do not leave the fruits during their development, they have no further choice among fruits or hosts. Therefore, a female chooses the best possible host plant on which to oviposit and for her offspring to develop *i.e.* "mother knows best" [10].

Preference is the set of likelihoods of accepting a particular specified set of resources that are perceived [11]. Host preference first of all takes into consideration the sum of plants that are hosts to an insect species (host range) as well as how acceptable and/or suitable those hosts are relative to each other (host specificity). Furthermore, host preference takes into consideration incidence and infestation rate of a pest in a host. Thus when two hosts are available in equal abundance, the one that is attacked with a high infestation rate is the preferred host.

When phytophagous insects lay their eggs on many host species (polyphagy), adult females do not select all hosts equally. Instead, preferences in both pre-alighting (host finding) and post-alighting (host acceptance) foraging behavior are often shown towards particular host species. In the presence of several potential host plants, a female will lay most eggs on her most preferred plant species (or habitat or plant part), fewer eggs on her next preferred plant, and so on [12]. In absence of competition a species occupies a fundamental niche and uses a full range of resources needed for its growth and reproduction. However, this may not be the case in natural field environment with several insect species sharing the same fundamental host niche. One likely outcome is host niche partitioning, and competing species are confined to limited hosts in their realized niche.

Specific oviposition preference has a genetic basis, and/or could be based on larval conditioning [13] although it can also be affected by prevailing conditions. This is determined by nutritional quality of the plant, predation, diseases, survival, risk spreading, competition and proximity to other resources. Suitability of a host, a key factor guiding insect choice, can depend upon a number of factors such as nutritional quality, host plant defense chemicals, prevalence of natural enemies or microenvironment [12]. According to preference-performance hypothesis (optimal oviposition theory) females are assumed to maximize their fitness by ovipositing on high quality hosts. Therefore, oviposition preference should correlate with host suitability for the offspring and later adult fecundity [14]. On the basis of optimal preference theory, host preference may be evaluated in terms of juvenile performance; whose correlates include survival rates, development to a particular stage or in some instances morphological size, but is frequently evaluated as developmental time.

A number of studies have reported the preference of *Z. cucurbitae* based on developmental rates in selected fruit vegetables in the laboratory [7, 15]. Currently host range and preference studies in the controlled laboratory conditions are being discouraged in favor of tests conducted in the field, because of radical variations in parameters like larval development, survival and mortality between unpicked and picked fruits [16]. Appropriately designed studies to test preference of *Z. cucurbitae* in natural and semi natural conditions, under choice and

Figure 1. Cage and no cage treatments before (top) and after (bottom) sowing the vegetables.

no-choice field settings are therefore desirable. In the present study we tested the hypothesis that preference of *Z. cucurbitae* among cucurbitaceous hosts is dependent on the number of available hosts. We also tested the hypothesis that preference of *Z. cucurbitae* is independent of presence of other competing cucurbit infesters.

2 Materials and methods

2.1 Host preference experiment

Preference of *Z. cucurbitae* among three commercial host plants, i.e *Cucurbita* sp., *C. lanatus* and *C. sativus* was assessed at the Horticulture Unit, Sokoine University of Agriculture (SUA), Morogoro, Tanzania. The area is located at latitude S06° 50'-S06° 45' Longitude E37° 35' – E37° 40' and altitude of 520 m asl.

The experimental setup included a *no host choice* treatment, consisting of 6 mono-cropped plots of 4×4 m, each with 32 replicate plants of a single host and a *host choice* treatment with 2 poly-cropped plots of 4 × 12 m, with 32 replicate plants of each host (large plots). The latter, plants of the three species were haphazardly mixed both within and between lines. Three of the *no host choice* plots and one of the *host choice* plots were isolated under net cages (cage treatment, *figure 1*) and the abundance of infesting fruit flies manipulated by adding 60 adult *Z. cucurbitae* in 4 × 4 m plots and 180 adult *Z. cucurbitae* in 4 × 12 m plots (sex ratio 1:1). In the remaining plots, vegetables were grown in an open space with no control on fruit fly infestation (no cage treatment). Treatments and

plots were haphazardly interspersed on a surface of approximately 11.5 ha in the SUA Horticulture Unit. Seeds were directly sown, and planting dates were adjusted based on days to flowering of each vegetable, in order to synchronize fruit setting. Standard agronomic procedures were followed. This setup was repeated three times; March–June 2013, October–December 2013 and April–July 2014.

Colonies of *Z. cucurbitae* were established from infested cucurbitaceous plants, collected from the Horticulture Unit as per previously used procedures [17]. Cohorts of *Z. cucurbitae* were established by placing cucurbitaceous fruits into the population cages for 24 h. The fruits were placed in rearing cages until adult emergence. Individuals emerging within 3 days were placed in the same cohort. Adults were separated by sexes and maintained on an artificial diet containing enzymatic yeast hydrolysate (ICN Biomedical, Irvine, CA) and sucrose (ratio 1:3) as well as water. We released 3 weeks old adults into cages, about 6 to 8 weeks after sowing the vegetables. All fruits were harvested a week after release of adults.

At each sampling date, twenty fruits were haphazardly harvested from each host species in each plot and taken to the rearing facility located within the Horticulture unit. The fruits were counted, weighed and placed in rearing containers containing sterilized sand as pupation media. After ten days, the containers were examined for puparia. Pupae were removed, counted and placed on petri dishes with a moist filter paper and placed in emergence containers. Emerged adults were removed by an aspirator and were killed by freezing for 4 h. The adults were later placed in 70% alcohol and sorted to species levels using keys [18, 19]. Incidence of fruit flies was established as percentage of infested samples. Infestation rate was established as the number of adult flies per kg of fruit.

2.2 Dominance experiment

Cucumber variety Ashley was grown at the Crop Museum of SUA between June and August 2012 for fruit sampling. Harvestable cucumber fruit were determined by using cucumber harvesting indices, *i.e.* presence of smooth and dark green epidermis. Three cucurbit fruit fly species were included, based on frequency and number of emerged adults; *Z. cucurbitae, Dacus bivittatus* (Bigot) and *D. frontalis* Becker. We harvested eighteen samples, each of 20 fruits of each harvestable stage. First, incidences of fruit fly in a sample of 20 fruits were averaged. Then incidence of each fruit fly species in each cucumber fruit stage was determined by dividing number of positive samples to the total number of samples in the stage. Split plot experiment was used to compare incidences and infestation rates of cucurbit fruit fly species in two cucumber fruit stages. The sources of variation were cucumber fruit stages (immature and mature fruits) and cucurbit fruit fly species. The main factor was cucumber fruit stage and the sub factor was fruit fly species.

2.3 Data analysis

Abundances of flies emerging per kg of fruit were quantified from 2012 to 2014 and tested through Analysis of Variance (ANOVA) with fruit (3 levels: watermelon, cucumber,

Table I. Incidences and infestation rates of *Z. cucurbitae*.

Condition	Cropping	Fruit	Total weight of fruits (kg)	Total number of flies kg^{-1}	Min	Max	Min	Max	Incidence (%)
					weight of fruit (kg)		number of emerged flies		
Cage	Choice	Cucumber	7.886	57.06	0.028	0.286	0	22	78.3
Cage	Choice	Pumpkin	4.486	82.48	0.009	0.221	0	22	68.3
Cage	Choice	Watermelon	2.301	304.22	0.004	0.209	0	72	83.3
Cage	No choice	Cucumber	7.623	72.94	0.018	0.271	0	26	81.7
Cage	No choice	Pumpkin	3.568	84.92	0.003	0.128	0	41	66.7
Cage	No choice	Watermelon	4.071	109.80	0.002	0.433	0	36	86.7
No cage	Choice	Cucumber	7.997	55.40	0.046	0.311	0	33	70.0
No cage	Choice	Pumpkin	2.317	89.77	0.001	0.109	0	14	48.3
No cage	Choice	Watermelon	0.989	209.30	0.002	0.197	0	12	80.0
No cage	No choice	Cucumber	6.980	48.85	0.033	0.297	0	22	56.7
No cage	No choice	Pumpkin	2.952	49.79	0.001	0.226	0	12	41.7
No cage	No choice	Watermelon	1.110	226.13	0.003	0.196	0	21	73.3

pumpkin), caging (2 levels: cage present, cage absent) and host Choice (choice, no choice) as fixed, orthogonal factors and season (3 levels: 2012, 2013, 2014) as random orthogonal factor. Cochran's C tests were used to verify the homogeneity of variances (in all cases reached after fourth root or logarithmic transformation) and Student-Newman-Keuls (SNK) tests for *a posteriori* comparisons of means [20]. The package GAD was used to analyze the data.

Data on incidences and infestation rates were transformed after failing to satisfy the ANOVA assumptions of normality, homogeneity of variance and independence of means and variances. Logarithmic transformation was used for infestation rate (whole numbers, highly variable) while arcsine transformation was use for incidence (proportions). A two-way analysis of variance (ANOVA) was performed using GenStat (VSN International, UK).

3 Results and discussion

3.1 Host preference

We harvested 720 fruits throughout the trials; an average of 240 fruits for each of the three species. The harvested fruit weighed 52.28 kg in total (*table I*). The highest infestation rate of *Z. cucurbitae* was 302.4 adult flies kg^{-1} recorded from watermelon, harvested from *caged*, *no-choice* plots, while the lowest was 49.79 recorded in pumpkin from *no cage*, *choice* plots. Incidence of *Z. cucurbitae* was highest in watermelon grown in caged, poly-cropped plots while the least incidence in pumpkin from *no cage*, *choice* plots (*table I*).

A total of 4,175 adult *Z. cucurbitae* were collected throughout the trials, the highest numbers emerged from watermelon grown in *cage*, *choice* plots, while the lowest numbers emerged from pumpkin grown in *no cage*, *choice* plots. More adult *Z. cucurbitae* flies were collected from fruits harvest from *cage* than *no cage* treatments. Likewise, more flies

Table II. Number of emerged *Z. cucurbitae* adults.

Fruit species	No cage		Cage		Total
	No choice	Choice	No choice	Choice	
Watermelon	251	207	447	452	1,357
Cucumber	341	443	556	450	1,790
Pumpkin	147	208	303	370	1,028
Total	739	858	1,306	1,272	4,175

emerged from fruits grown in *choice* than *no choice* plots (*table II*).

Infestation rates of *Z. cucurbitae* differed significantly ($P < 0.01$) among three fruit species, being highest in watermelon and lowest in pumpkin (*table III*). The infestation rates of *Z. cucurbitae* were significantly ($P < 0.05$) higher in fruits harvested from *no choice* plots but did not differ significantly among fruits harvested from *no cage* and *caged* plots. Significant temporal differences were also observed among years (*figure 2*). All the interactions among fruits, growing condition and cropping were not significant (*table III*).

Previous studies reported preferred hosts of *Z. cucurbitae*, including ash gourd [21], bitter gourd [7, 22, 23] and cucumber [22]. However, these previous studies did not include watermelon and pumpkin. Results of the present study contrasts what was reported earlier from the same region, whereby highest incidence and infestation rate of *Z. cucurbitae* were recorded in cucumber, followed by pumpkin and watermelon [4, 24]. In the latter case, fruits were sampled randomly, based on availability, hence there was a large discrepancy on number of samples among hosts.

We examined preference based on willingness of an insect to use a host plant as opposed to performance traits that encompass the ability of the pest to grow, survive, and develop on a host plant [25]. Adult *Z. cucurbitae* selected the host for as a source of food and for subsequent development of
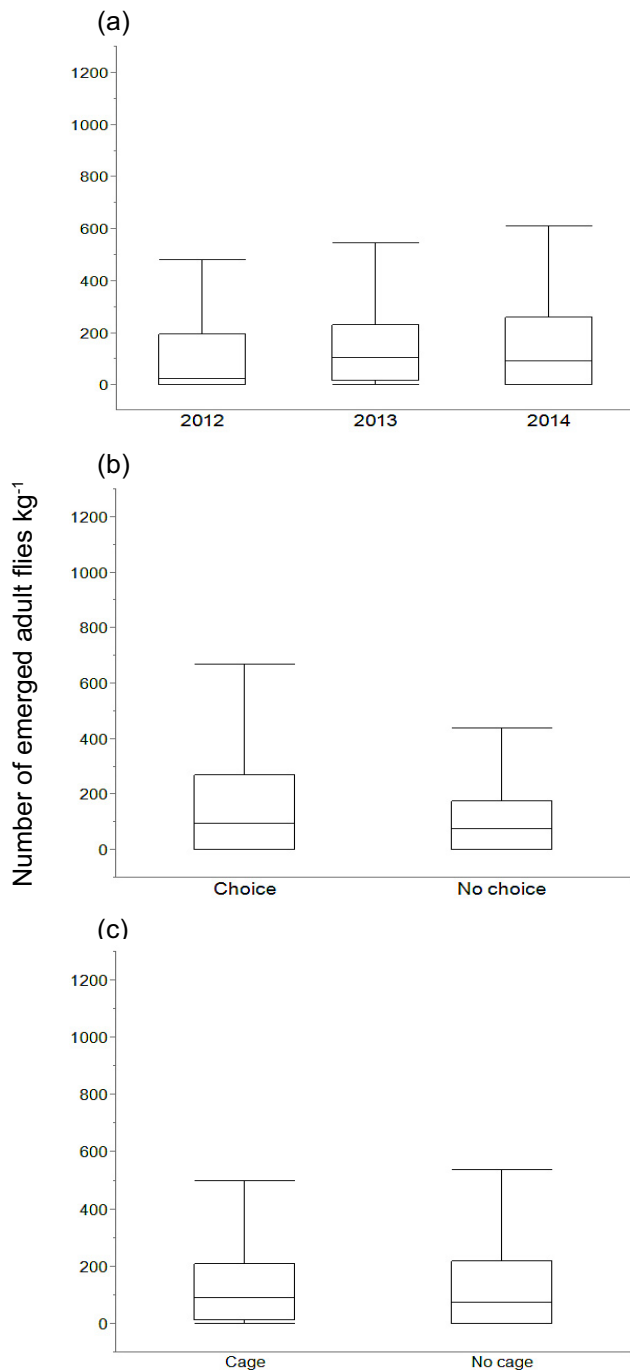
(a)

(b)

Number of emerged adult flies kg^{-1}

(c)

Figure 2. Number of emerged adult flies kg^{-1}: (a) in different seasons; (b) between *choice* and *no choice*; (c) between cage and no cage treatments.

maggots. The larvae were forced to use the chosen host since they could not discriminate hosts [26]. In this regard, natural selection would favor strategies that maximize lifetime reproductive success [27].

Several factors were reported to influence willingness of an insect to use a host [28], including abundance of a host, physical and chemical properties of the host, learning and in

Table III. Analyses of variance (ANOVA) and *a posteriori* comparisons (SNK tests) testing differences in infestation rates of *Z. cucurbitae* (emerging flies for kg of fruit) in response to Fruit (watermelon, cucumber, pumpkin), Year (2011, 2012, 2103), Caging (cage present, absent) and Host Choice (choice, no choice).

	d.f.	MS	F-values	
Fruit (F)	2	164.711	185.15	**
Host Choice (H)	1	5.611	23.26	*
Cage (C)	1	24.279	12.86	n.s.
Year (Y)	2	16.559	5.41	**
F × Y	4	0.890	0.29	n.s.
F × C	2	8.364	2.52	n.s.
F × H	2	2.717	0.69	n.s.
Y × C	2	1.888	0.62	n.s.
Y × H	2	0.241	0.08	n.s.
C × H	1	4.505	3.46	n.s.
Residual	684	3.060		
Cochran's test^y	C = 0.074 (n.s.)			

Pair-wise *a posteriori* comparisons.	
Fruit	watermelon > cucumber > pumpkin

d.f.: degree of freedom. MS: mean square estimates. n.s.: not significant at $P < 0.05$, ***: significant at $P < 0.001$, **: at $P < 0.01$; *: at $P < 0.05$, ^{y} Cochran's test: homogeneity of variances was obtained after 4th root transformation of the data.

built preference of an insect. We established equal number of plants of each host, in mono and ploy-cropped plots and we adjusted planting dates in order to achieve uniform fruiting among hosts. There was an equal likelihood of *Z. cucurbitae* to land and oviposit on the three hosts. The effects of learning, is to favour the most abundant host [28] and that was not the case in the current study. The decision to accept or reject hosts is also likely to be highly influenced by an insect's current egg load and available future opportunities to lay eggs [27]. This could be the case in open field crops and not in crops under cage. Insects released into cages were maintained in cohorts, initially separated by sexes, and allowed to mate after release into cages.

Growing crops under cage or in open field did not affect infestation rate of *Z. cucurbitae* in fruits. However, difficulties in designing cage experiments limited our ability to examine pattern of oviposition among females in the population [12]. For example competition among the females for oviposition sites may lead to a more uniform distribution of eggs than it would occur if females were tested individually [12].

The current study did not evaluate nutritional quality of hosts. However, according to optimal foraging models suggest that when highly preferred, good quality hosts are common, an insect will be very discriminating against poor quality hosts, but the level of choosiness will decline when high quality hosts are less common.
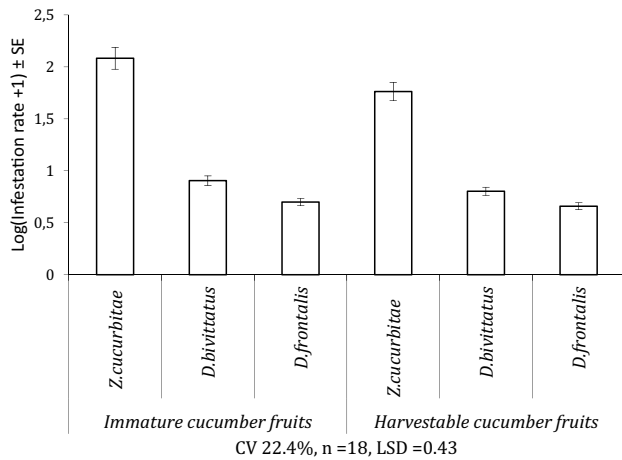
Figure 3. Infestation rate of cucurbit fruit fly species in cucumber fruit stages.

Figure 4. Incidence of cucurbit fruit fly species in cucumber fruit stages.

3.2 Host dominance

Dominance was examined for three fruit fly species, *Z. cucurbitae*, *D. bivittatus* and *D. frontalis* in two stages of cucumber. The weight of immature cucumber fruits ranged from 107 to 131 g while the weight of harvestable fruits ranged from 283 to 329 g. Incidences of cucurbit fruit flies in cucumber fruit stages varied significantly among fruit fly species ($F = 41.28$; $df = 2$; $P = 0.001$) but not between cucumber fruit stages ($F = 6.93$; $df = 1$; $P = 0.025$). The highest incidence (0.75) was recorded in immature cucumber fruits with *Z. cucurbitae* followed by *D. bivittatus* (0.23) while the lowest (0.16) was recorded in mature cucumber fruits with *D. frontalis* (*figure 3*).

Significant differences on infestation rates among cucurbit fruit fly species ($F = 135.73$; $df = 2$; $P = 0.001$) and between cucumber fruit stages ($F = 110.24$; $df = 1$; $P = 0.01$) were observed. The highest infestation rate (120 flies kg^{-1} fruit) was recorded in immature cucumber fruit infested by *Z. cucurbitae* followed by the same pest (57 flies kg^{-1} fruit) in mature cucumber fruit while the lowest infestation rate (5 flies kg^{-1} fruit) was recorded in mature cucumber fruits infested by *D. frontalis* (*figure 4*).

Among the three fruit fly species infesting cucumber *Z. cucurbitae* had significantly higher incidence compared to *D. bivittatus* and *D. frontalis* in both immature and harvestable cucumber fruits. The incidences of cucurbit fruit flies in cucumber differed depending on the level of maturity of the fruit. Generally for all selected cucurbit fruit fly species, the incidences in cucumber were lower in harvestable than in immature stages. Lower incidences of cucurbit fruit fly species in harvestable stage compared to immature stage could have been caused by hard epidermis of harvestable cucumber fruits reducing the ability of oviposition by the pests. Adult female fruit flies preferred unopened flowers and young fruits for egg laying [28]. Cucurbit fruit fly (*Z. cucurbitae*) caused more damage on immature than harvestable squash fruit [29]. Generally, the females prefer to lay eggs in soft tender fruit tissues by piercing them with the ovipositor [5]. The maximum incidence (0.75) of *Z. cucurbitae* at immature cucumber fruit
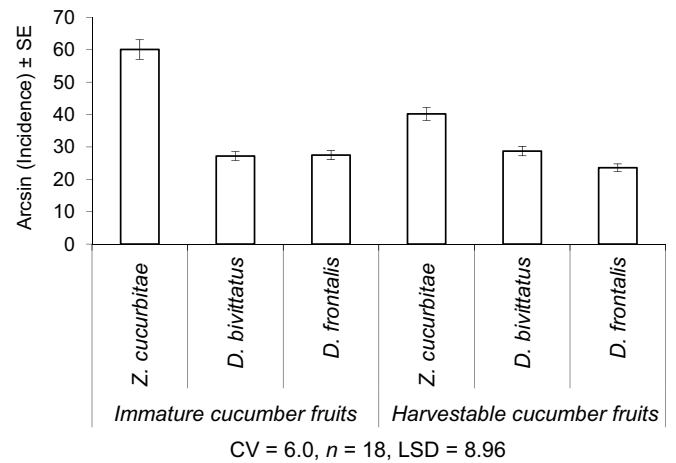
stage was slightly higher than reported previously [4, 23]. Differences in age of fruit and pest pressure could explain the reason.

Of the three fruit fly species *Z. cucurbitae* had high infestation rate followed by *D. bivittatus* and *D. frontalis* in both cucumber fruit stages. High infestation rate of *Z. cucurbitae* in both cucumber fruit stages compared to *D. bivittatus* and *D. frontalis* could have been attributed to demographic strategy, exploitative competition and larval interference (including cannibalism) [29]. In a previous study [5], *Z. cucurbitae* had shorter egg incubation period and shorter durations of immature stages. Generally, *Bactrocera* species are best adapted to exploit and to compete with other species in the same ecological niche [5].

4 Conclusion

The present study tried to evaluate host preference of *Z. cucurbitae* in three cucurbitaceous vegetables, under choice and no-choice, as well as under cage and no cage. The preference was high for watermelon in all the situations. The preference was lowest in pumpkin. In open field experiments, *Z. cucurbitae* dominated *D. bivittatus* and *D. frontalis* in terms of infestation rates and incidences in cucumber. Management of fruit flies in cucurbitaceous vegetables should focus on the dominant *Z. cucurbitae*.

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