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Research Paper

POLLINATION AND REPRODUCTIVE RELATIONSHIP OF FOUR MANGROVES SPECIES IN ZANZIBAR, TANZANIA

Abdalla Ibrahim Ali[1], Eunice W. Kairu[2], Zakia M Abubakar[1] and Islam S.S. Mchenga[3]

[1]Department of Natural Sciences, The State University of Zanzibar, P.O. Box 146, Zanzibar, Tanzania
[2]Department of Zoological Sciences, Kenyatta University, P.O. Box 43844, Nairobi, Kenya
[3]Society for Environmental Research and Conservation, P.O. Box 2477, Zanzibar, Tanzania.

Abstract

Relationship between flowers and fruits can occur as a result of several factors; including temperature, soil, rainfall, light intensity, plant resources, and genetic structure. This study was designed to investigate effect of pollination on buds, flowers, fruit sets and fruits of four mangroves species namely *Rhizophora mucronata, Bruguiera gymnorhiza*, *Ceriops tagal and Avicennia marina*. A branch free from pest and diseases have been randomly selected and observations were carried out twice a week in 9 months (July 2013 to March 2014). Results showed that, there were significant differences in the number of buds, flowers, fruit set, visitors, visits and fruits in all four mangrove species. There were variations of relationships among reproduction variables. A strong relationship was observed between buds and flowers in all species. Increase number of flowers concurrently increases number of fruit set in all species, although *A. marina* shown a weak relationship. We concluded that the increases number of mangroves fruits not only depends on number of fruit set and other reproduction variables, but also there was other abiotic and biotic factors required intensive investigation.

Key words: Bud, Flower, Fruit, Pollination, Visitors, Visits.

INTRODUCTION

Many research studies have reported the importance of pollination and pollinators in fruit and seed production [1]. However, some studies have indicated that pollinators may actually lower reproduction by the plant due to removal of large amounts of pollen from flowers or even by depositing very little pollen [2, 3]. A study by Aluri [4] reported that in *Ceriops tagal* mangrove sp, the stigma attains receptivity on the second day and remains receptive up to 6 days but, peak receptivity occurs in 3rd -5th day. He also found that there was increased insects flower foraging during the peak receptivity period, since, the nectar sugar concentration is 35-50%. The common sugars include fructose, sucrose and dextrose with the first relatively more dominant.

Trees may control the behavior of pollinators by adjusting floral design and exhibit flowering to maximize pollination efficiency. Pollinator communities differ in their visitation rate and in the effectiveness of each taxon at transferring pollen [5, 6]. Pollinators regularly have considerable spatial and temporal variation in their visitation rates to a single plant species [7, 8, 9]. The success of pollination is primarily determined by visitation rates [10, 11]. Flowers are generally

visited repeatedly over the course of a day. The visitors belong to various species of insects that seem to be effective pollinators and that are generalist floral foragers [12].
Flowering is a critical step in fructification. Lack of flowers means no fruit and the crop load may be limited by the number of flowers formed [13]. The influence of flower intensity on the percentage of fruit set and final fruit reported in clementine mandarin showed that out of 15 thousand flowers, only 3 thousands produced fruit. This indicated that the number of flowers had no effect on crop yield [13]. The proportion of ivy flowers, *Hedera helix* (Araliaceae), that developed into fruits was significantly reduced in the absence of flower pollinator, *Vespula* wasp [14].
This study was designed to investigate the relationship between the number of pollinators and the number of flowers, fruit sets and fruits of four mangroves species in two sites. The aim was to establish baseline information on the relationship between reproduction variables.

MATERIAL AND METHODS

Study area

Zanzibar is a tropical island located between latitude 04° 50” and 06° 30” South, and longitude 39°10” and 39° 50” in the Indian Ocean, 25–50 kilometres off the coast of the Tanzania mainland. The study was conducted in two mangroves forest sites: Michamvi and Nyeke in the Southern region of Zanzibar. Michamvi Chwaka Bay located about 60 km south-east of Zanzibar township in the South Region. The site situated at 614’ S and 39 49’ E in Chwaka bay marine conservation area, the distance to Nyeke sites are approximately 25km. Nyeke mangroves forest located between Uzi Island and Unguja Ukuu village in the southern part of Zanzibar in the Indian Ocean between 619’ and 624` S and 39 25` E. The mangrove forest is found both in sandy and rocky shore in the northern tip and the southern part of the island. The mangrove forest is lie within Menai Bay Conservation area and nearby Jozani Chwaka Bay National Park. Eight species are commonly grow in both sites include *Avicenia marina*, *Rhizophora mucronata*, *Bruguiera gymnorrhiza* , *Ceriops tagal* , *Pemphis acidula, Xylocarpus sp, Lumnitzera racemosa* and *Sonneratia alba*.

Data collection

At each study site, 80 trees belonging to four mangroves species namely *Rhizophora mucronata, Bruguiera gymnorhiza*, *Ceriops tagal and Avicennia marina* were selected. The distance between the trees was approximately 25m. Red flags were placed on top all selected trees for easy identification of the plots during data collection. A branch free from pest and diseases was randomly selected from each tree. The selected branches were tagged with permanent labels that indicated the plant species and date the tree was tagged. All selected branches were 1.5m high from the ground to avoid being destroyed by sea water during high tides. Petroleum jelly was smeared on the woody part to deter invertebrates from moving onto the flowers and fruits.

To take care of the flowering alternation within the same tree, another branch was selected and observed. Observations were carried out twice a week in every month for a period of 9 months (July 2013 to March 2014). Data collected included the number of flower buds, number of flowers, number of insect visitors to the flowers, number of visits, number of fruit set and number of fruits. To avoid double count, permanent white marker and tagged labels were placed on buds, flowers and fruits. For each treatment, flower visitors and visitation frequencies were counted from 30 selected flowers for a 30 minute period on selected branches of mangrove trees. Thereafter, all insect visitors and visit frequencies of four mangroves species were recorded. This exercise was carried out during peak flowering period (from day buds produced to the day fruit produced) for each mangrove species.

The observation of insect visitors and visiting frequencies was done between 06.00 to 10.00am Visitation rates of insects pollinators were determined by counting the number of insect visits to flowers on one to several umbels under observation. A visit was defined as all visits done by flying insects to the selected flowers, and all visits were counted, regardless if the same insect visited the same flower several times. Observations were performed by three trained technicians. A visitor was defined as an individual insect visiting flowers, it was recorded as one visitor even if visiting many flowers. A fruit set was defined as conversion of flower to fruit initiation showing successful fertilization.

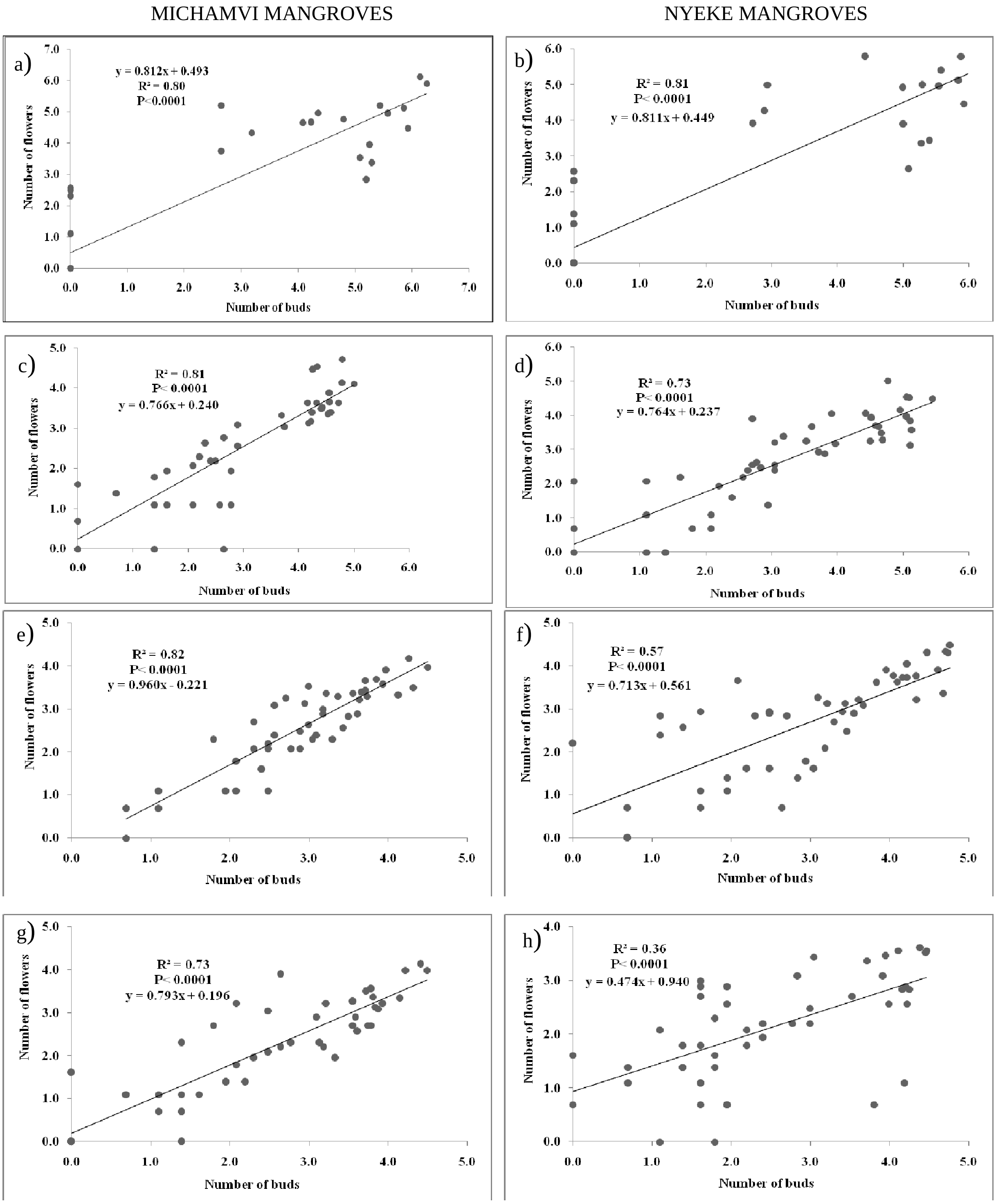
Data analysis

All study parameters were compared with each other using Linear Regression Analysis. Mean separation was done using F-Statistics. Coefficient of determination, R^2, was used to see the strength of the linear association between x and y (explanatory and response variables respectively). The data was log transformed ($1 + \log_{10\,x}$ (LN)) for ease of plotting the regression line and accuracy. Regression categories are: (a) 0.6 to 1 is very strong relationship, (b) 0.3 to 0.59 is strong relationship, (c) 0.1 to 0.29 is very weak relationship, (d) if R^2 is zero (nonlinear) shows no relationship between two variables. All data were analyzed using the statistical software R version 2014 Mac OS X 10.5 (pr. March 2014 this is version 3.0.3), R Commander of library ('RcmdrPlugin.NMBU') of University of Life Sciences, Norway. Significant difference was tested at $P< 0.05$.

RESULTS

Relationship between number buds and number of flowers

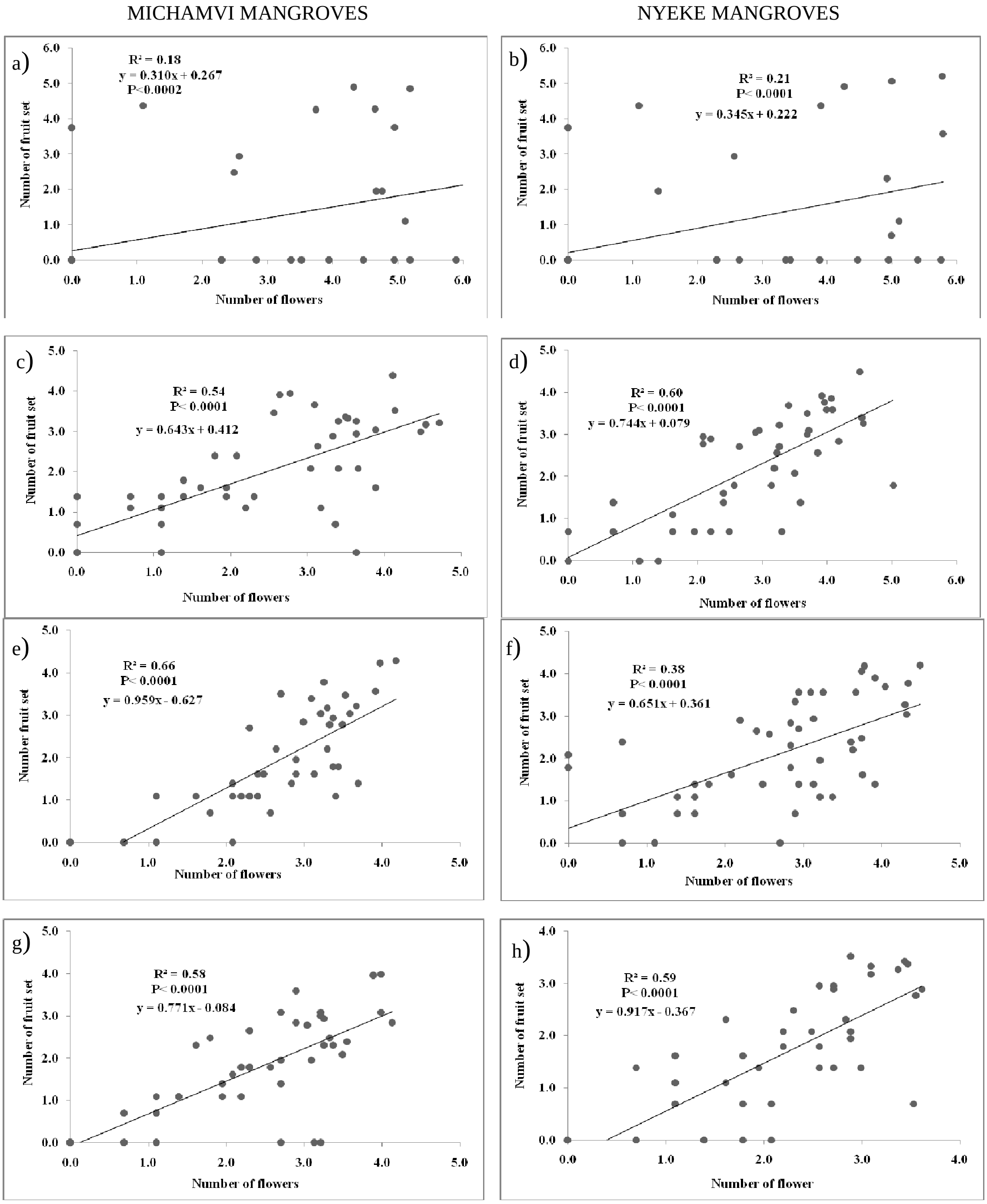
Results of regression of number of flowers against the number of buds are shown in Figures 1a-1h. There were significant differences in the number buds and flowers in all four mangroves species. A strong relationship were found between number of buds and flowers in *A. marina* at Michamvi (df =47, $R^2 = 0.80$, $P< 0.0001$, F= 192.1) and Nyeke sites (df=46, $R^2 = 0.80$, P= 0.0001, F= 199.9; Figure 1a and b). Similarly, there were significant relationship between number of buds and flowers in *Ceriops tagal* and *Bruguiera gymnorrhiza* at Michamvi (df=47, $R^2 = 0.81$, $P< 0.0001$, F= 206.5 and df=47, $R^2 = 0.82$, P= 0.0001, F= 225.6 respectively) than Nyeke sites (df=46, $R^2 = 0.73$, $P< 0.0001$, F= 126.4 and df=46, $R^2 = 0.57$, $p< 0.0001$, F= 64.15 respectively) (Figure 1c-f). The least relationship between number of bud and flower were recorded for *R. mucranata* at Nyeke sites (df=46, $R^2 = 0.36$, P= 0.0001, F= 26.95; Figure1h).



Figures 1e-h. Realationship between number of buds and number of flowers, Michamvi Mangrove forest (n= 48), Nyeke Mangrove forest (n= 47). *Avicennia marina* (a-b), *Ceriops tagal* (c-d), *Bruguiera gymnorrhiza* (e-f), *Rhizophora mucranata* (g-h).

Relationship between number of flowers and number of fruit set

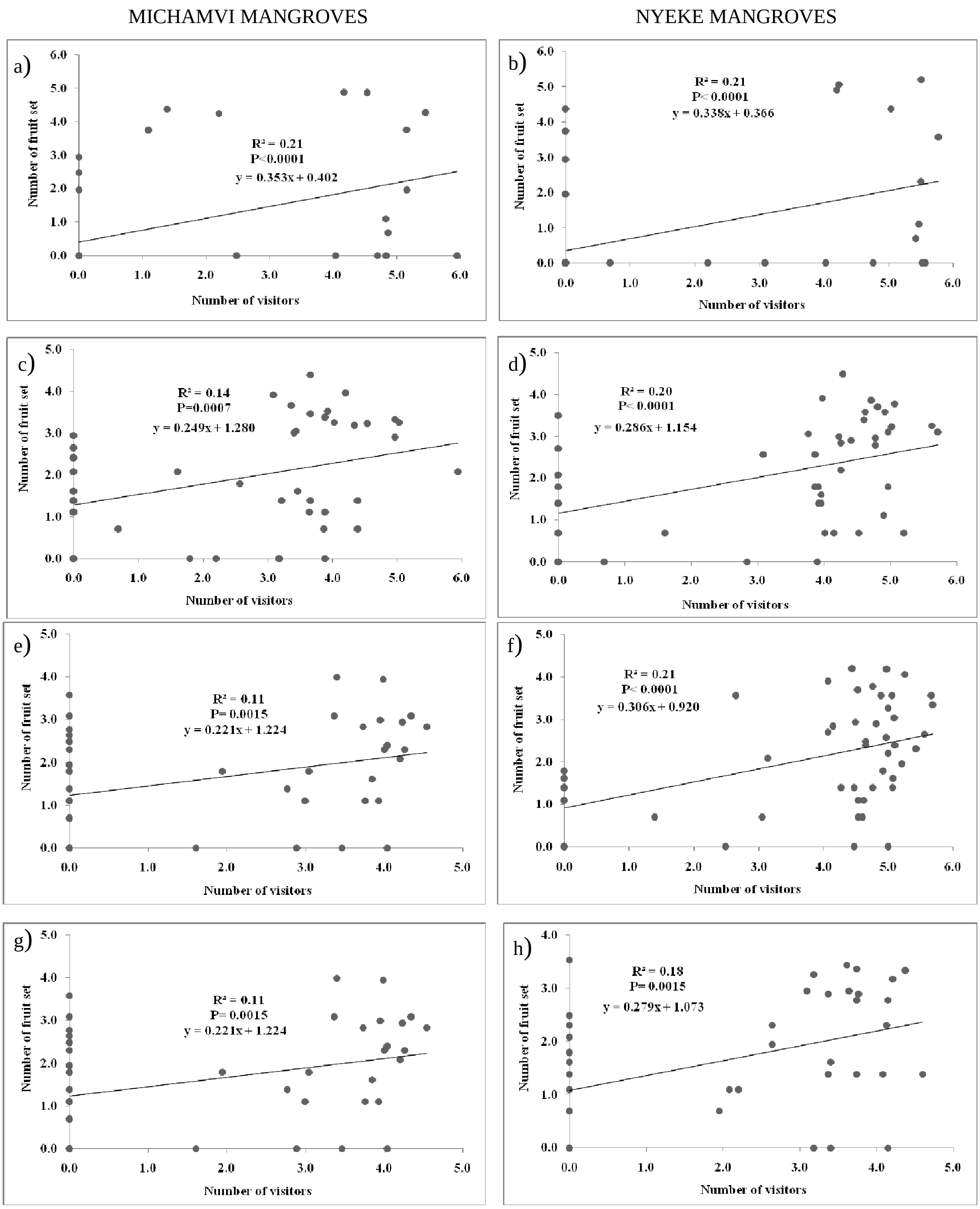
The relationship between number of flowers and number of fruits is shown in Figures 2a-2h. Although the number of fruits was dependent on the number of flowers, the relationship between the two variables was very weak in *A. marina* at Michamvi (df =47, R^2 = 0.18, P= 0.0002, F= 10.52; Nyeke (df=46, R^2 = 0.21, P< 0.0001, F= 12.28).



Figures 2. Relationship between number of flowers and number of fruit set, Michamvi Mangrove forest (n= 48), Nyeke Mangrove forest (n= 47). *Avicennia marina* (a-b), *Ceriops tagal* (c-d), *Bruguiera gymnorrhiza* (e-f), *Rhizophora mucranata* (g-h).

Relationship between number of flower visitors and number of fruit set

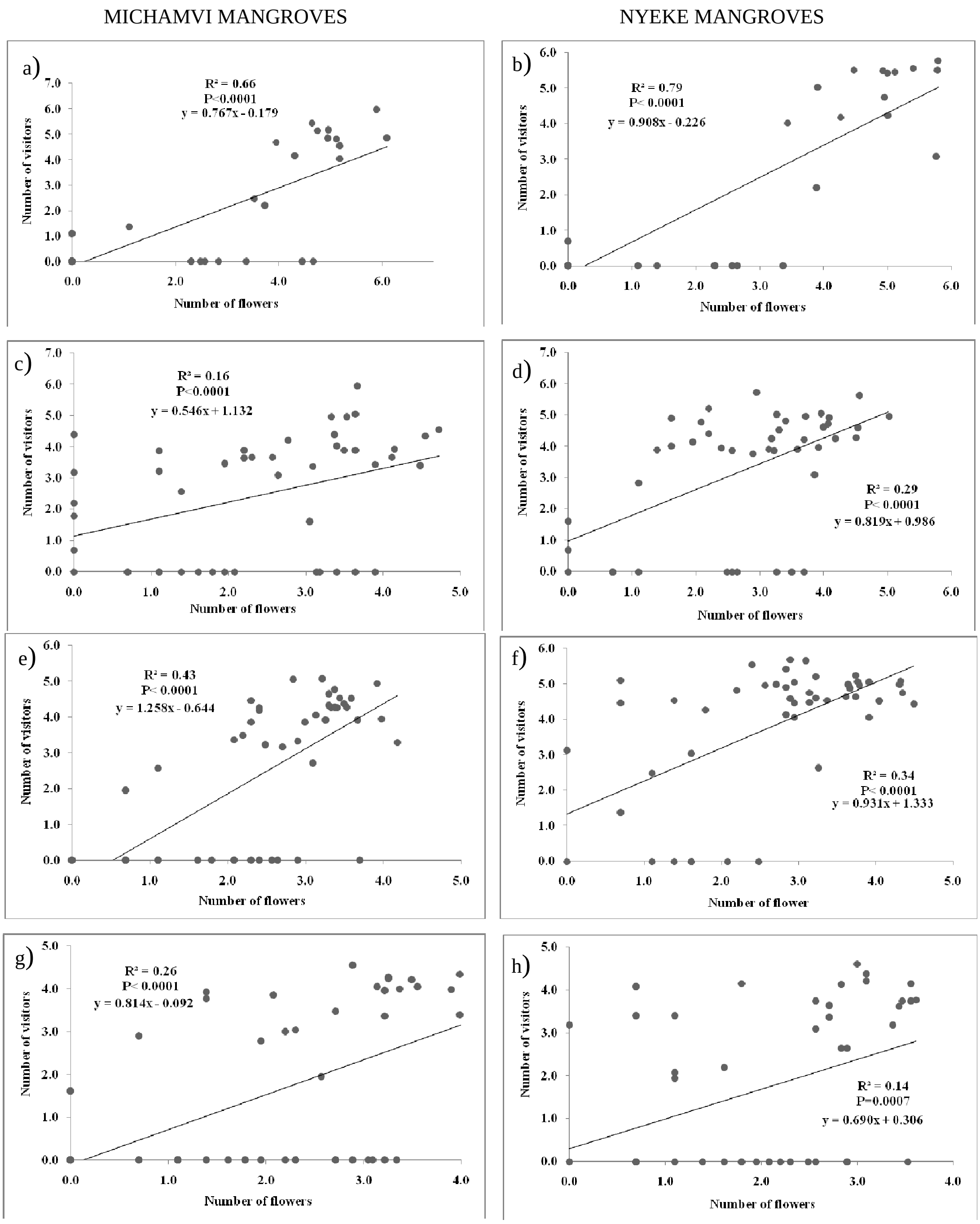
The results show that there were significant differences between number of insect visitors and fruit set in all four species of mangroves. Further, the relationship between the number of flower visitors and fruit set varied among mangrove species. However, relationship between fruit set and number of visitors was generally very weak with R^2 ranging from 0.11 to 0.28 (Fig. 3a-3h).



Figures 3 (a-h): Relatinship between number of fruit set and number of visitors , Michamvi Mangrove forest (n= 48), Nyeke Mangrove forest (n= 47). *Avicennia marina* (a-b), *Ceriops tagal* (c-d), *Bruguiera gymnorrhiza* (e-f), *Rhizophora mucranata* (g-h).

Relationship between number visitors and number of flowers

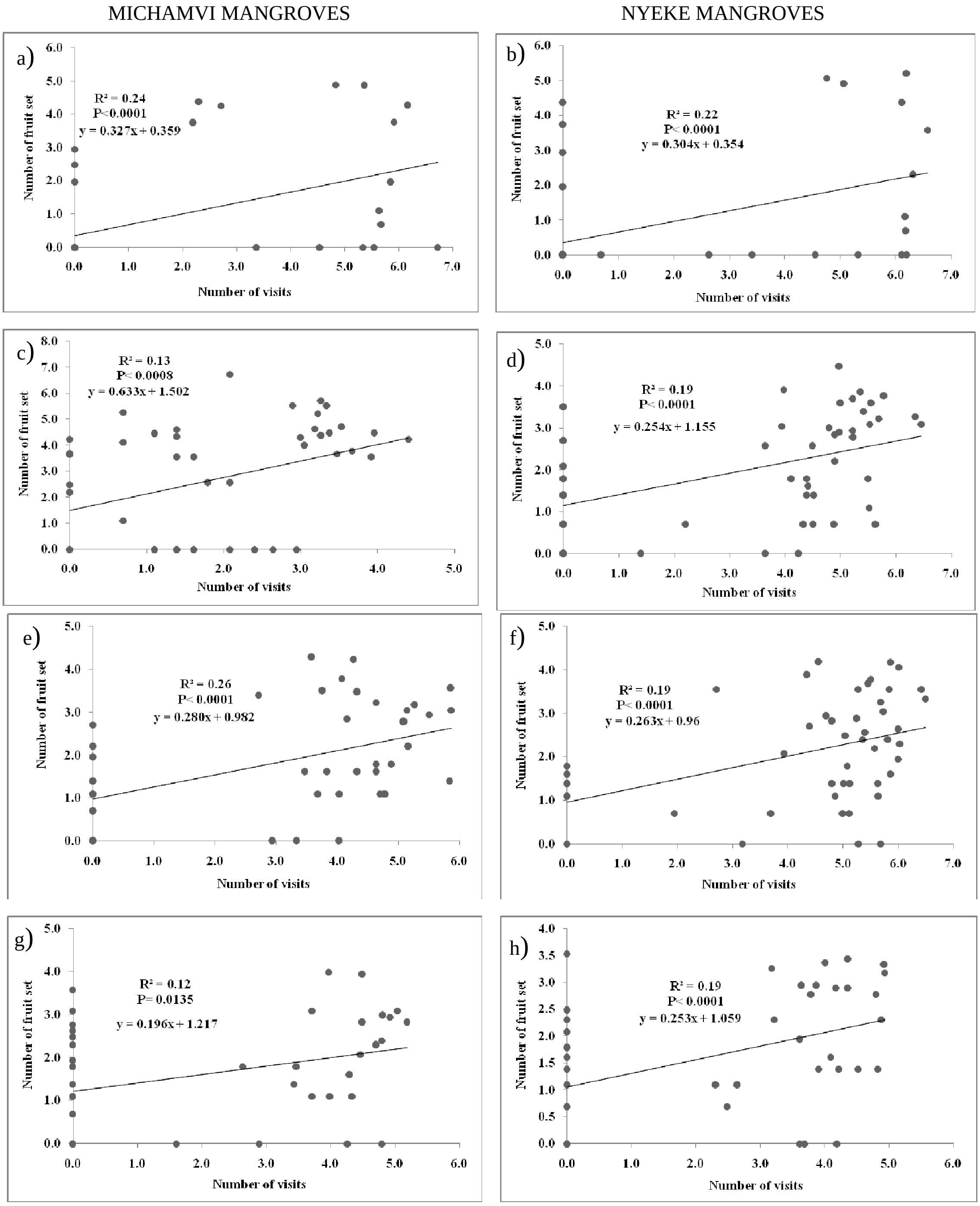
The findings revealed that, there were significant differences in number of visitors and flowers among all the four mangrove species. Generally, there was a significant relationship between number of visitors and number of flowers. However, the relationship was very weak in *C. tagal,* in Michamvi (df = 47, R^2 = 0.16, P< 0.0001, F= 9.57) and in Nyeke (df=46, R^2 = 0.29, P< 0.0001, F= 19.61) (Fig. 4c and 4d). Similarly, a very weak relationship was observed *R. mucranata* in both sites (Fig. 4g and 4h).



Figures 4 (a-h). Relatioship between number of flower and number of visitors, Michamvi Mangrove forest (n= 48), Nyeke Mangrove forest (n= 47). *Avicennia marina* (a-b*), Ceriops tagal* (c-d), *Bruguiera gymnorrhiza* (e-f), *Rhizophora mucranata* (g-h)

Relationship between number visits and fruit set

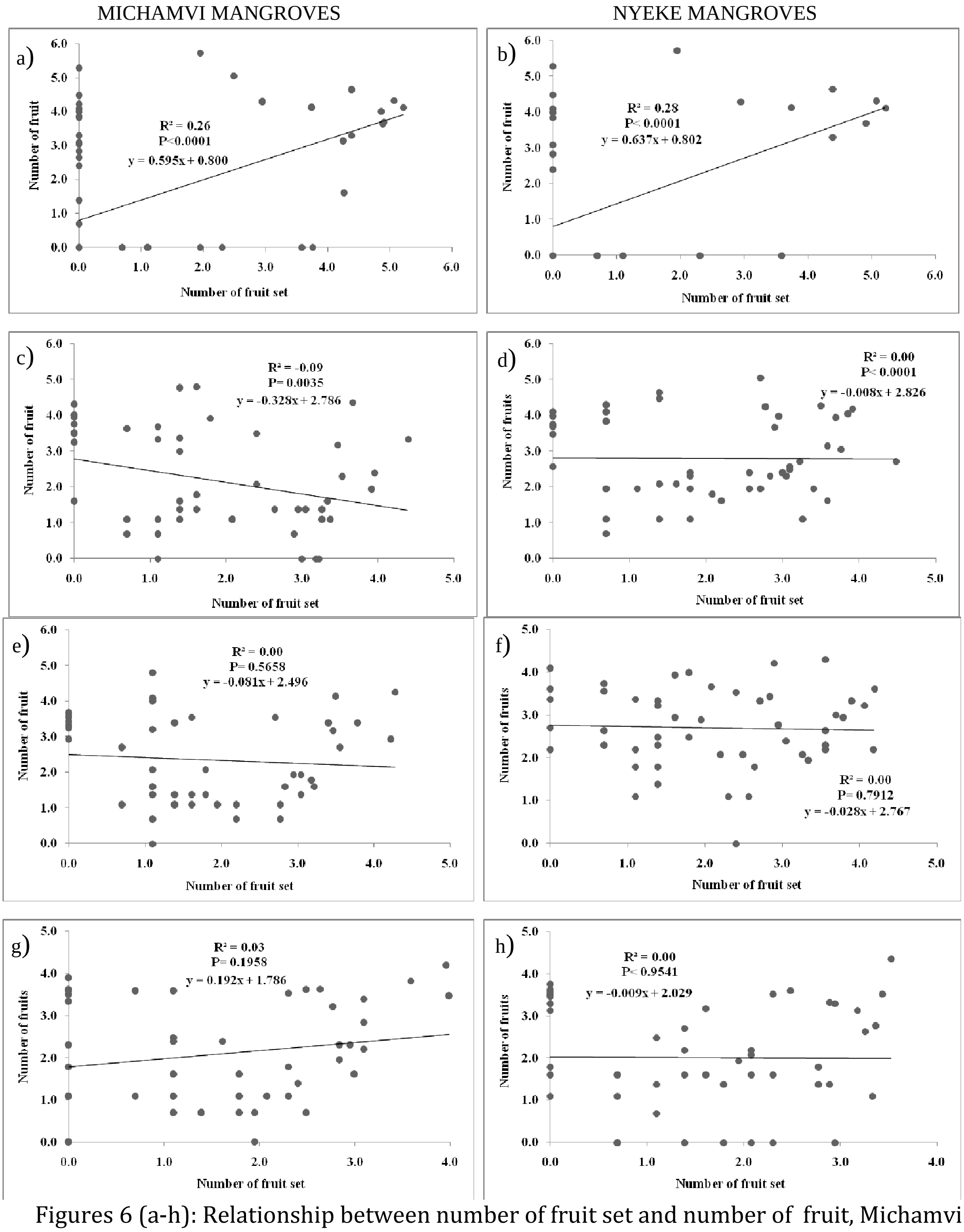
The results indicated that there were significant differences between number visits and fruit set in all four mangroves species. The relationship between number of visits and fruit set was weak for all mangrove species in both sites with R^2 ranging from 0.12 to 0.26 (Fig. 5a-5h).



Figures 5 (a-h): Relationship between number of visits and number of fruit set, Michamvi Mangrove forest (n= 48), Nyeke Mangrove forest (n= 47). *Avicennia marina* (a-b), *Ceriops tagal* (c-d), *Bruguiera gymnorrhiza* (e-f), *Rhizophora mucranata* (g-h)

Relationship between number fruit and fruit set

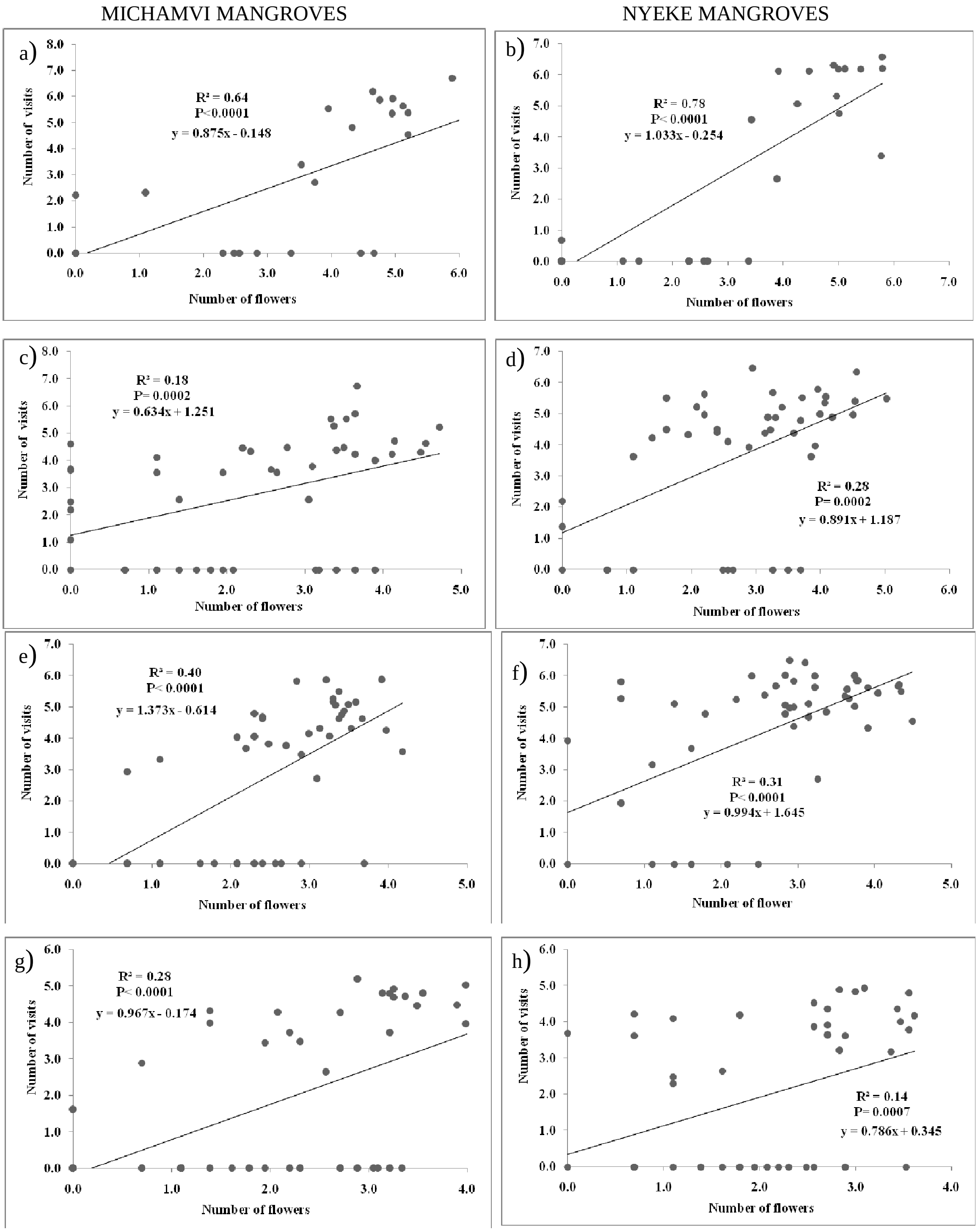
There was a positive relationship between number of fruit set and number of fruits produced by *A. marina*. The relationship was stronger in Nyeke than in Michamvi. However, *C. tagal,* showed an inverse relationship at Michamvi site where the more the fruit set, the lower the number of fruits produced. The remaining two species of mangroves showed no relationship between number of fruits set and number of fruits produced (Figure 6 a-h).



Figures 6 (a-h): Relationship between number of fruit set and number of fruit, Michamvi Mangrove forest (n= 48), Nyeke Mangrove forest (n= 47). *Avicennia marina* (a and b), *Ceriops tagal* (c and d), *Bruguiera gymnorrhiza* (e and f), *Rhizophora mucranata* (g and h).

Relationship between number flowers and number of visits

The relationship between number of flowers and number of visits for the four mangrove species is shown in Figures 7a-7h. There was a positive relationship for all mangrove species in both sites. Increases number of flower concurrently the higher the number of insect flower visit. However, the relationship was strongest in *A. marina* in both sites.



Figures 7 (a-h): Relationship between number of flowers and numbers of visits, Michamvi mangrove forest (n=48), Nyeke mangrove forest (n=47). *Avicennia marina* (a and b), *Ceriops tagal* (c and d), *Bruguiera gymnorrhiza* (e and f), *Rhizophora mucranata* (g and h).

DISCUSSION

Results from all mangroves species in both Michamvi and Nyeke revealed significant relationship between the mean number of flower buds and the flowers production. Thus, suggesting that reduction of flower buds will affect flower production. The relationship between fruits set and number of flowers was positive but weak. Fruit initiations not only depended on the number of flowers produced but also other factors probably nutrients availability and the rate of absorption from the soil to reproductive area. Variation of nutrients and salinity has been reported to affects plant species productivity requirements and growth rates [15]. On the other hand, Kearns and Inouye [16] found that changes in pollinator's communities during flowering not only reduces seed set but also reduces composition of pollen load taken by pollinators.

The study also underscored that increase of the number of insect flower visitors and visiting frequency did not have a big effect on fruit sets. This could be because not all visitors are pollinators or there could be other factors responsible. Differences in flower visit duration among pollinators have been implicated in influencing pollinator effectiveness. Visit duration is positively related to both pollinators' efficiencies and effectiveness [6, 9, 17]. However, it was noticed that increase of number of flowers in *A. marina* similarly increased insect flower visitors and visiting frequency in both study sites. In both mangrove sites the findings revealed a weak relationship between fruit set and number of fruits. *A. marina* fruits had shown slight increase when number of fruit set increases, and many of immature fruits were observed to abort. Plants and trees maintained their reproduction through nutrients available within the plant. Plant resources play a major role in increasing or reducing fruit set and fruits in many tropical tree populations [18]. A study conducted by Pestana [19] revealed that increases in the concentrations of N, Mg and Fe in orange flowers from trees grown in calcareous soil led to a greater fruit set and maturation index. The percentage of flowers that produced mature harvested fruit was not significantly different between the off- and on crop years, indicating that fruit set was dependent largely on the initial number of flowers [20]. Beside soil plant nutrients, Andrew [21], pointed out that temperature and pollen-pistil interaction was found to play an important role on fertilization and fruit set in cherries.

In the case of *C. tagal,* very strong relationships were detected between flower buds and flowers in both sites, and negative relationship between fruit set and fruits in Nyeke mangrove forest. The findings indicated that an increase of flower buds correspondingly increased the number of flowers. The number of fruits declined with increasing fruit set in this species in Michamvi site, whereas in Nyeke there was no relationship between fruit set and fruits found. In addition, the finding showed that the relationship between fruit sets and number fruits are not concurrent in Nyeke site, but the number of fruits remained constant with increasing fruit set. In many plant species, including pepper, fruit size and fruit set have been reported to be positively correlated with seed number [22, 23].

Presence of a developing fruit can inhibit subsequent set and growth of a young fruit and this may be caused by competition for available assimilates, by dominance due to production of plant growth regulators from the developing fruit, or by a combination of competition and dominance [24, 25, 26]. It was hypothesized that many plant produce auxin and export from the earlier-developed fruit may also inhibits auxin export of the later-developed fruits [26].

The research findings indicated that there was a weak relationship between the number flowers produced and number of insects' visitors and visiting frequencies. In this study, the presence of developing flowers was not found to attract insects at higher rates. In Australia the pattern of insect visitation recorded was different between mangroves species *A. marina* and *A. mellifera* in the Sydney region of New South Wales. *A. marina* is visited by a broad suite of insect species [27].

The two study sites are different in landscape and natural vegetation. Nyeke site is situated about one kilometer from Jozani National Park and surrounded by fruit trees such as mango, jack fruit, papaya, avocado, banana, citrus and many vegetables farms while Michamvi study is more than 20 kilometers from Jozani National Park. The site is surrounded by coral land with few fruit trees. This difference could explain why generally the relationship between number of flowers and insect flower visitors was stronger in Nyeke than in Michamvi. The visitors could be coming from the surrounding areas. The availability of pollinators may be affected not only by population size itself but also by the landscape that surrounds a focal population.

Even if two populations of plant species are the same size and have the same extent of floral display, pollinator availability necessarily will be different depending on the potential

pollinators abundance, which may be related to the amount of available resources for pollinator species [28].
To summarize, the present study findings suggest that the initial amount of mangroves fruits will depend on the number of viable buds, flower, fruit sets, visitors and visits. This is also concluded that, the increase in number of fruits did not depend on fruit set, except for *A. marina*. The insect visitors and visiting rates were shown to be important but also depend on other abiotic and biotic factors.

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