Avocado *(Persea americana)* floral calendar and diurnal visitation rates of its pollinators in Murang'a, Kenya

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ABSTRACT

Aim: This study was carried out to determine the avocado floral calendar and the diurnal visitation rates of its insect pollinators in farmers' fields in Murang'a County, Kenya.

Method and Materials: Investigations were done in twelve farms and in each farm, five mature avocado trees were randomly selected maintaining a minimum distance of about 10 m and 200 m from tree to tree and farm to farm, respectively. Data were collected for three blooming seasons (August-September 2015; April-May 2016 and August-September 2016). Data included the percentage flushing, flower buds, flowering, fruiting, flower visitors' identity, time of the day and time (seconds) taken by an individual on the flower per visit. Additionally, the number of male and female flowers was recorded. Observations were done only under good weather conditions between 0900-1700 h.

Results: Two avocado flowering seasons in a year were recorded; one from August to October and the other from February to May with March and September as the peak blooming months. Female phase flowers were recorded between 0900-1659 h while male phase flowers appeared between 1200-1759 h registering an overlap from 1200-1659 h, peaking between 1300-1359 h. Honey bees, blow flies, hoverflies and wasps were the major avocado flower visitors. All avocado flower visitors were observed during the daily overlapping period of the male and female phase flowers.

Conclusion: The study confirms that insects are important avocado pollinators and their management is paramount for improved yields.

Keywords: Avocado, blooming, diurnal visitation, insect pollination, overlap, yields.

Introduction

Pollination of both wild and cultivated plants is effected mostly by insects such as bees, moths, flies, wasps, butterflies and beetles [1,2,3] among other invertebrates. Many horticultural crops are dependent on insect pollination resulting to higher yields [1,3,4]. Crops differ in theirpollination requirements as well as their dependence on insect pollinators [5]. In order for plants to 'select out' a subgroup of pollinators from the broad taxonomic collection potentially available, they either open flowers or make floral rewards available to pollinators at different times of the daily cycle [6].

Visitation rate has been proposed as an accurate measure of pollinators' contribution to overall reproductive effectiveness [7,8,9]: the more the visitsof a pollinator makes it more efficient in effecting pollination service. Various studies have shown spatial and temporal variations in the visitation rate of pollinators [10,11].Among these, plant features including floral structure and the spatial and temporal arrangement of flowers have been documented [12,13].Hence,it is needed to understand the relation between these plant characteristics and the flower visitors.

Avocado (*Persea americana,* Mill) is an important fruit consumed locally as well as an export crop from Kenya [14,15] hence a major source of nutrition and income for Kenyan farmers. Many countries around the world have recorded declining trends in avocado fruit production, this being partly attributed to inadequate insect pollination [16,17,18] since avocado relies mainly on insect pollinators for improved yields [19,20].

A single avocado flower is bisexual, opening twice, first as a female stage and secondly as a male (pollen releasing stage) the next day, but at different times of the day [21,22]. Both opening and closing of each flower population (female and male) occur concurrently within the tree, and

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the cultivar with an intermediate closing [1,2,23]. This avocado flowering behaviour inhibits effective self-pollination (within a flower), permits close-pollination (between neighbouring flowers within a tree) and reassures cross-pollination (between different cultivars) [22,23].
Close-pollination occurs frequently during the daily self-overlap period of male and female-stage flowers within the tree (or a cultivar) [21,25,26]. The efficiency of close-pollination depends on the percent composition of female and pollen carrying male-stage flowers, length of their self-overlapping period and on pollinator activity [1,21,26]. In most avocado cultivars, a daily regular self-overlap phase of 1-3 hours exists between female-stage flowers and pollen releasing male-stage flowers of the same tree [1,21,23].

In its native environment, a wide range of insect taxa are considered to be pollinators of avocado including bees, wasps (Hymenoptera) and flies (Diptera) [27]. Honey bees are well-thought-out as the key pollinators in many commercial orchards [18] visiting both female and male-stage avocado flowers [21,24]. Various bee and non-bee insect species have been considered as potentialpollinators of avocado worldwide [28], but in Kenya there has been little research into which insect species visit avocado flowers and its phenology.

The findings of this study enhance the understanding of avocado pollination needs and guides in its utilization for the crop productivity through developing pollination management plan for the crop in Kenya. In addition, the study will provide information that could be used to formulate and improve policies and extension guidance for avocado. The study also opens more avenues for research leading to understanding more on avocado pollination in Kenya.
Avocado is one of the main source of livelihood in the area. One of the key aspects of avocado production is provision of pollination service, which assures fruit set and hence productivity. There is limited information about avocado pollination needs in Kenya. Therefore, there is no supporting evidence on importance of pollination in avocado production and majority of farmers in Kenya are not aware of the role pollination plays in crop production. Specifically, we address the question, 'what is the degree of matching between the daily floral cycle of avocadoand the diurnal visitation rates of its pollinators across avocado orchards located in Murang'a County, Kenya?'Present study was carried out to determine diurnal visitation rates of insects pollinating avocado and to investigate floral calendar of avocado in Kandara, Murang'a County.

Methods and Materials

This study was carried out to document avocado floral calendar and the diurnal visitation rates of its pollinators in farmers' fields at Kandara which is longitudes 36º51'E, 37º7'48"E and latitudes 0º47'24"S, 0º58'12"Sin Murang'a County. Twelve farms were randomly selected in *Upper Midland 2* (UM2) agro-ecological zone of Kandara which leads in exported avocado variety 'Hass' production. In each farm, five mature avocado trees were randomly selected maintaining a minimum distance of about 10 m and 200 m from tree to tree and farm to farm, respectively. Data in all the farms and trees were collected for three flowering seasons (September-October 2015; April-May 2016 and August-October 2016).

On each tree, observations were done for about 10 minutes in every farm, weekly throughout the blooming period. Data included the identity of flower visitor, number of individuals observed visiting per species, time of the day, the time (seconds) taken by an individual on the flower per visit, the percentage flushing, flower buds, flowering and fruiting. In addition, the number of male and female flowers was recorded between 0900 - 1700 h. Each sampling started from a different farm to ensure unbiased observations. It was assumed that the number of flower visitors entering each tree was equivalent to the number of visitors exiting in the environment and the same assumption was used to compensate the possibility of one flower visitor being counted twice.

Further, minimizing duration of observation ensured avoidance of double counting. Data collection was initiated from the onset of the blooming period, that is, when 10% or more of the plants had started to bloom. The observations were done only under good weather conditions: temperature of 15°C and above, low wind speed, no rain, and dry vegetation [29] with at least three samplings per season. The flowering phase of each tree was recorded. Male phase flowers were distinguished by the presence of extended stamens and anthers (usually dehiscing pollen), while for female phase flowers, non-dehiscing

anthers were positioned prostate against the petals.

Data presentation

Data on percentage flushing, flower buds, flowering and fruiting were entered in excel data sheets and monthly interactions graphs plotted. In addition, number of male and female phase flowers was counted and hourly flower phenology graphs generated. Data on avocado flower visitors, number of each species found visiting avocado flowers and time of the day they visited were recorded and entered into excel data sheets. Graphs on the numbers of flower visitors were plotted against time.

Results

Floral calendar of avocado in Kandara, Murang'a County

The results from this study show that there were two avocado flowering seasons in a year in Murang'a County. One is from August to October and the other from February to May. March and September are the peak blooming months. Results have shown that when fruiting and flushing are at their peak, flowering and flower buds are at their lowest and vice versa (Fig. 1). Highest flushing and fruiting are in May and November, thus indicating two seasons of either annually. The study also shows that there are no times when avocado trees had no fruits in the year and also vegetative growth was continuous (Fig. 1).

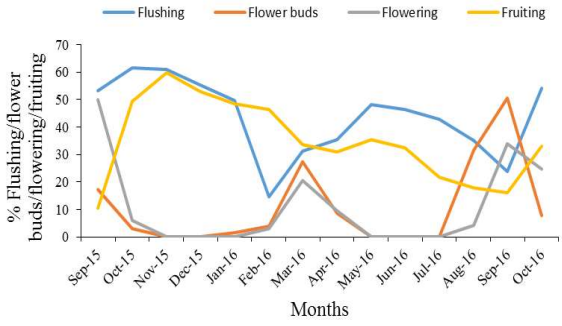

Fig. 1: % flushing, %flower buds, %flowering and % fruiting relationships of avocado in Kandara, Murang'a for 3 seasons

Female and male flower's opening in a day across seasons showed that female flowers opened from 0900 - 1659 h. The male flowers' opening started from 1200 - 1759 h. Male and female flowers overlapped from 1200 - 1659 h lasting between 2-3 hours but with the highest overlap from 1300 - 1359 h. Highest number of open female phase flowers was noted between 1100 - 1159 h while the highest male phase flowers' population was recorded between 1400 - 1459 h (Fig. 2).

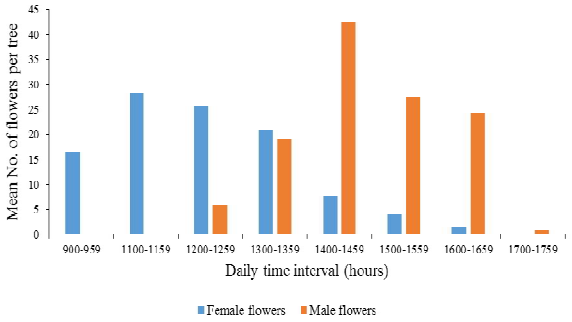

Figure 2: Diurnal avocado male and female flowers opening in Kandara for 3 seasons.

Diurnal visitation rates of avocado flower visitors

Combined visits for each flower visitor for the three seasons showed that honey bees had the highest visits at all times of the day with highest visits of 362 between 1500 - 1559 h. Blow flies were second in total number of visits with a highest of 29 visits between 1300 - 1359 h while hoverflies and wasps had highest avocado flower visits of 11 and 18, respectively between 1200 - 1259 h (Fig. 3).

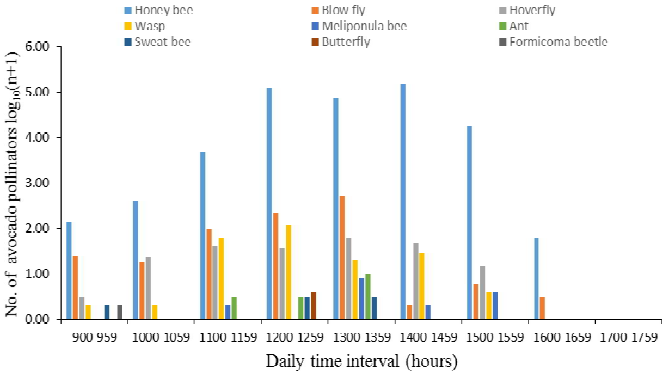

Fig. 3: Diurnal visitation rates of avocado flower visitors in Kandara for three seasons

Discussion

The two periods of flower opening, the protogynous dichogamy and the overlap between the female and male phase flower opening were confirmed. This is in agreement with [21,23] that female avocado flowers opens from morning to afternoon and the male phase flower opening starts from afternoon to evening with an overlap of 1-3 hours.

Several insects were found visiting avocado flowers in Kandara. These included honey bees, blow flies, hoverflies, wasps, ants, *meliponula*

bees, *halictus* bees, butterflies and beetles. This is in agreement with other findings that avocado pollination is effected by insects from different taxa [21, 22, 27, 30, 31, 32] and flower pollination is effected by different insect species [3]. Honey bees were the most active insects observed visiting the avocado flowers in each time of the day throughout the study period. Similar observations were also made [21,22,24] that honey bees are its main pollinators in most agricultural landscapes. There was considerable variation both among major groups (Hymenopterans and Dipterans), in the timing of foraging on flowers but both could be seen during the male and female phase flower overlapping period. Similar results were noted [6], that the various major pollinating groups of insects (Hymenoptera, Diptera and Lepidoptera) were observed during the self-overlapping period of the male and female phase flowers of a Mediterranean shrub with flower behaviour similar to avocado.

Conclusion

In this study, honey bees were observed as the most abundant and frequent insect flower visitors of avocado in almost every time of the day throughout the study period. An overlap between the male and female flowers during the 3 seasons was confirmed ranging from 2-3 hours. The overlap is highly important for close-pollination, which is the most effective type of pollination especially in Kandara where pure stands of Hass variety are under cultivation. Blow flies, hoverflies and wasps could also be effective pollinators especially when honey bees' visitations are low.

To improve on avocado pollination, bee hives could be placed in avocado orchards to increase honey bees' activity which results to increased avocado yields. Protection of the natural forests and habitats could increase flower visitors diversity and abundance and also act as pollinators' nesting sites hence a possibility of increased flower visits from insects resulting to increased avocado yields.

Recommendations of pollen load studies for each main species observed.Visiting avocado flowers bedetermined to differentiate the avocado flower visitors from pollinators since not all flower visitors are pollinators.Continuous monitoring of avocado flower visitors' populations within Kandara and the whole of Kenya is required which helps in understanding the pollinators' stability and pollination dependency for other crops in Kenya as well as for the purposes of pollination management planning and policy formulations.

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