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RESEARCH

Assessment of Pollination Deficit in Pumpkin (*Cucurbita maxima* Duchesne) Farms in *Machakos*, Kenya

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ABSTRACT

Purpose: *Animal-mediated pollination services are essential for food production on farms. Deficient pollination leads to lack or low fruit set, in pollinator-dependent crops, and consequently reduced yield. Cucurbits largely depend on honeybees; however, its colonies are reportedly declining globally. This study indicated sufficient pollination of Cucurbita maxima Duchesne in the farm by natural pollinators and therefore man assisted pollen transmission had no significant change in the yield characteristics of the pumpkin.*

Research Method: *This study was conducted on cucurbit farms in Machakos County, to assess possible pollination deficit in cucurbits production. Treatments involved supplemental pollination with Hypotrigona spp, manual pollination and natural pollination in a randomized complete block design with a farm being a block. Data was collected on fruit set and yield characteristics.*

Findings and Values: *The variation in magnitude of fruit and seed weight, latitudinal and longitudinal length of fruits and ovary, number of developed and undeveloped seeds per fruit were not significant because of subjecting flowers to various pollination methods. The results imply adequate and efficient pollination for pumpkin production within the study sites. Recent studies stipulating the loss of bees in agricultural ecosystems serve as a caution to farmers, as it may lead to low fruit production in the farms. Current study provides an evidence of enough natural pollinators within the study sites. With proper field practices, compatible with natural biodiversity, high yields for pumpkin production is not threatened by inadequate pollination. These findings are beneficial in pollinator conservation planning, especially in smallholder farming systems relying on natural and incidental pollination.*

Keywords: *Cucurbits, Fruit formation, Pollination deficit, Stingless bees.*

INTRODUCTION

Pollination is demanded for a continued emergence of flowering plants within cultivated and wild ecosystems. It results in the formation of fruit and seed development in flowering plants (Carvalheiro 2021). This only happen after a successful dispersal of male gametes to female flowers in cross-pollinated plants. It has been noted that about 78% of existing flowering plants

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rely on insects for pollen transmission (Khalifa *et al*. 2021). This portrays that most of the food consumed by people is a result of pollination. Pollination accounts for 87% in the production of crops utilized as food by people in the world (Khalifa *et al*. 2021). Natural and managed bees provide most of the pollination of these crops (Nayak *et al*. 2020). Previous research inform that the honeybee alone contributes an ecological service equivalent to € 147 million (equivalent to USD 102 million) annually worldwide (Hung *et al*. 2018).

Some cucurbits grow even in conditions prevalent in arid and semi-arid places because they are warm seasoned crops (Kumar & Reddy 2021). They are versatile in uses as most of their parts are edible. Traditional dishes such as pumpkins and leafy vegetables provide affordable and nutritious food to low- income families in dry areas (Rödlach 2011). In Kenya, consumption of pumpkin leaves and fruit is common. Some communities even consume pumpkin flowers and tender shoots, nutritious as vegetables (Roy *et al*. 2004). Cucurbits are self-incompatible crops that cannot self-pollinate due to a large distance between male and female flowers, and their production of large, heavy and sticky pollen grains (Sentil *et al*. 2022). Therefore, they require an efficient means of carrying the pollen grains from the anthers to stigmas for seed development and fruit formation (Fayeun *et al*. 2016).

Several research on Cucurbitaceae show that the major pollinator in farms is the honeybee (*Apis mellifera* L.), either natural or rented. Recent research has indicated a decline of honeybees in many farms across the world (Komala 2021, Nath *et al*. 2023). There is compelling evidence that small-scale farmers in Kenya, who grow crops requiring bees for pollination, do not keep hives (Kasina 2013). A previous study by Kitivo *et al*. (2021) has indicated a notable loss of insect pollination in *Machakos*, Kenya, because of the use of certain agrochemicals by farmers. The causes of bee decline have brought a major effect on the yield of crops that largely rely on the honeybee for pollen delivery (Neov *et al*. 2019). Pollination deficit or shortage is the lack of sufficient pollen delivery to the female flowers to trigger maximum fertilization of ovules for quality and large fruits. This is mainly caused by a low turnout of foraging bees during anthesis, leading to inadequate pollination. Recent studies have reported *Hypotrigona* spp as an efficient and alternative pollinator to *Apis mellifera* in cucumber and Ash gourd (Chauhan & Singh 2022, Kiatoko *et al*. 2022). There is a need to investigate pollination deficit of cucurbits growing in Kenya because it has not been established. The objectives of this study were 1) Assessment of possible pollination deficit in pumpkin farms and 2) Investigate whether *Hypotrigona* spp can complement honeybees in pollination of curcubits, with three treatments.

MATERIALS AND METHODS

Study area

This research was conducted in *Machakos* County, Eastern Kenya, which lies at 0º41.01’ South and 1º36’ South and longitudes 37º46’ East and 38º51’ East. The county occupies an area approximating 63,320.4 km^2 with an altitude of 785 m to 1,601 m above sea level. The area is characterized by high temperatures of up to 29°C. The main economic activity in most farms is agriculture. The soils are freely draining, shallow, and mostly sandy, hosting grasslands and sparse acacia trees as the main vegetation (*Machakos* County Integrated Development Plan 2019).

Experimental design

This research was conducted from November 2019 to March 2020 for season one and between July and November 2020 for season two and employed a randomized complete block design with a farm being a block. The study involved three treatments: (i) hand-pollination, (ii) installation of beehives in pollinator farms and (iii) control farms without hives. Sixteen farms were randomly selected for beehives installation, becoming natural pollination while the rest sixteen farms served as control without hives.

Thirty-two farmers who participated in this work were selected randomly based on their willingness to offer their farms for this study.

Each participating farmer was provided with 170 certified pumpkin seeds (Dola F1 variety) obtained KALRO, *Thika*. In each farm, 120 pumpkin crops were established and farmers managed them. The crops were planted at a distance of 2m by 2m. The distance between selected farms was approximately 5 km apart. In natural pollination farms, two beehives were installed to increase pollinators' availability and enhance pollen delivery. All flowers set for natural pollination were exposed to unconditioned visitation by insects.

About 480 flower buds were randomly selected for hand-pollination. In each pollinator farm, approximately 30 flowers were covered in thin mesh netting to prevent activity by any natural pollinators. These flowers were pollinated manually by collecting pollen using a pollen brush from different male flowers of other plants and carefully rubbing over the stigmas. Post pollination the flowers were covered to prevent further pollination by bees and other insects. The aim of additional bees and hand-pollination were anticipated to increase pollen conveyance in pollinator farms for abundant fruit production than in control farms.

Data collection

Mature pumpkin fruits post-pollination were harvested on 21st and 22nd March 2020 in season one from all study sites. In season two, the harvesting in all farms was done on 1st and 2nd November 2020. Harvesting of mature fruits was conducted same time in all sites to prevent further growing in some fruits. Data was collected on yield parameters including fruit and seed weight, longitudinal and latitudinal length of fruit and ovary, number of developed and undeveloped seeds production per fruit, this was done at harvest time. The weight of fruit and seed was recorded in grams using a digital weighing machine while fruit and ovary length were measured using a meter rule (cm). The amount of developed and undeveloped seeds produced per fruit was counted physically and recorded. These procedures are in line with previous work (Kasina *et al*. 2013, Petersen *et al*. 2014).

Statistical analysis

Data were entered in excel for further processing after cleaning it. The R software version 4.0.2 (R core Team 2022) was used for the analysis. Mean values ANOVA statistics were sought in the analysis and separation of significant ones was performed using the Turkey's HSD test.

RESULTS AND DISCUSSION

Average fruit weight, longitudinal and latitudinal length of ovary and fruit

The weight of pumpkin fruits produced during season 1 (November 2019) did not differ significantly between the treatments ($X^2 = 2.069$, df = 1, p =0 .355), (Table 1). Hand–pollination in pumpkins did not increase the weight of fruit as expected. In season 2 (July 2020), weight of pumpkin fruit did not differ significantly among the three treatments ($X^2 = 2.79$, df = 1, p = 0.06). The longitudinal lengths of fruit ovary harvested from the three treatments did not differ significantly across two seasons (p = 0.167 and p = 0.447). The latitudinal diameters of the fruit ovary of hand-pollination, open-pollination and stingless bee pollination did not vary significantly in two seasons (p = 0.0087 and p = 0.37). The circumference of the fruits harvested from the three treatments of stingless bee pollination, open pollination (control) and hand-pollination did not vary significantly in season 1 (p = 0.991 and 0.091). In season 2, a significant difference was observed in longitudinal length of fruit of the three treatments (p = 0.01) but not in the latitudinal length (p = 0.0070).

Seed production per fruit

The mean seed weight per fruit differed significantly in the three pollination treatments in season 1 (p = 0.01457) but not in season 2 (p = 0.078), (Table 2). The model predicting quantity of developed seed produced per fruit resulting from flowers pollinated by stingless bees, hand or naturally differed significantly across seasons 1 and 2 (p = 0.00042 and 0.0001), respectively. Significant difference was also observed in the number of under-developed seeds per fruit between hand-pollination and

Table 1. Fruit parameters of pumpkins (*Cucurbita maxima*) harvested in two seasons from pollinated flowers in different treatment farms at *Machakos*, Eastern Kenya.

Season	Treatment	Fruit weight (g)	Ovary longitudinal length (cm)	Ovary latitudinal length (cm)	Fruit longitudinal length (cm)	Fruit latitudinal length (cm)
Season 1 (Nov. 2019)	Control	2840 ± 279^{a}	13.2 ± 0.5^{a}	12.8 ± 0.5^{a}	58.6 ± 2.3^{a}	60.6 ± 2.5^{a}
	Hand pollination	3250 ± 288^{a}	12.2 ± 0.5^{a}	12.0 ± 0.4^{a}	58.0 ± 1.9^{a}	61.1 ± 2.1^{a}
	Natural pollination	2906 ± 201^{a}	13.9 ± 0.5^{a}	14.2 ± 0.4^{b}	59.5 ± 2.2^{a}	67.5 ± 1.5^{a}
	χ^2-value	2.069	3.574	9.475	0.0162	4.803
	p-value	0.355	0.167	0.0087	0.991	0.091
Season 2 (Dec. 2020)	Control	3134 ± 258^{a}	13.0 ± 0.8^{a}	13.0 ± 0.8^{a}	60.1 ± 3.0^{ab}	61.4 ± 3.1^{a}
	Hand pollination	3272 ± 187^{a}	12.4 ± 0.6^{a}	11.8 ± 0.5^{a}	50.7 ± 2.2^{a}	53.5 ± 2.6^{a}
	Natural pollination	2989 ± 538^{a}	10.9 ± 1.9^{a}	10.7 ± 1.8^{a}	61.1 ± 3.4^{b}	57.0 ± 3.7^{a}
	χ^2-value	5.414	1.606	1.968	8.096	10.717
	p-value	0.066	0.447	0.373	0.017	0.007

Similar superscripted letters in the same column for each season indicate no significant difference ($\alpha = 0.05$).

the other two treatments in season 1 while in season 2, the difference was not significant across all three treatments (p = 1.00). These results indicate that the available bees within the pumpkin cucurbits farms in Kenya were sufficient in enhancing fruit and seed production as required. The amount and sizes of pumpkin yield harvested from the study sites confirm that enough ovule fertilization is required for good pumpkin fruits and seeds. The results of this study indicate that there is no pollination deficit in the production of pumpkin fruits in the study sites. This is because the honeybees and other pollinators of pumpkins were able to pollinate pumpkin flowers that produced fruit features, similar with those of hand-pollinated flowers and those assisted by additional bees in supplemental pollination. During this study, the pumpkin flowers were also observed to have a high dependency on honeybees for pollination, thus suggesting the importance of practicing apiculture by food and fruit producers. This is essential to fruit farmers who use fruit weight for setting the market prices. This will minimize any possible use of hand-pollination during food production, reported to be ineffective, especially in the determination of stigma receptiveness and pollen maturity (Adler & Hazzard 2009). Hand-pollination was also found to be labor intensive and not certain especially in timing pollen and stigma maturity. Since there are a number of local bee species including honeybees in Kenya that occur in all types of agricultural landscapes, cucurbits production is guaranteed since field losses caused by pollination deficit is non-existent or greatly reduced. The finding

Table 2. Seed parameters of pumpkins (*Cucurbita maxima*) harvested in two seasons from pollinated flowers in different treatment farms at *Machakos*, Eastern Kenya.

Season	Treatment	Seed weight (g)	Number of developed seeds	Number of undeveloped seeds
Season 1 (Nov. 2019)	Control	39.5 ± 2.1^{c}	389 ± 31^{b}	19.6 ± 5.5^{b}
	Hand pollination	31.3 ± 1.6^{a}	251 ± 20^{a}	5.6 ± 2.2^{a}
	Natural pollination	34.4 ± 2.1^{b}	327 ± 21^{b}	17.8 ± 3.9^{b}
	χ^2-value	8.4578	15.546	33.122
	p-value	0.01457^{*}	0.000421^{***}	$1.0001\text{e-}08^{***}$
Season 2 (Dec. 2020)	Control	45.3 ± 3.3^{a}	281 ± 18^{b}	3.9 ± 1.1^{a}
	Hand pollination	32.4 ± 2.1^{a}	214 ± 19^{a}	1.7 ± 0.4^{a}
	Natural pollination	35.2 ± 6.4^{a}	321 ± 18^{c}	3.4 ± 0.9^{a}
	χ^2-value	5.083	18.104	4.240
	p-value	0.078	0.0001	0.120

Similar superscripted letters in the same column for each season indicate no significant difference ($\alpha = 0.05$).

of this work also conquer work by Winfree *et al.* (2008) that established absence of pollination deficit in pumpkin farming in Northern USA. This provides an insight to the farmers on the need of preserving natural habitats for the bees. The only challenge with farm owners in maintaining the bees within their surrounding is their aggressiveness when manhandled. These farmers require an intensive training on the behavior of bees, especially during flower foraging. The fruit growers need to understand the importance of renting honeybee colonies around their farms to be available at the crop flowering stage in order to increase crop yield and produce profit. The findings of this study further corroborate the results of previous work by Kasina *et al.* (2013) that observed that there were enough bee colonies within farms near *Kakamega* forest, western Kenya, to pollinate butternut squash, *Cucurbita moschata* D.

The managers of food and fruit crops should avoid application of chemicals and especially at flowering stage, which negatively affect bees as previously seen in a sunflower farm (Nderitu *et al.* 2007). Where use of synthetic insecticide is mandatory, application should be done in the afternoon when pumpkin flowers have folded and no bees are foraging. This lowers bee killings of the flower visitors. Continuous extension of cultivated areas towards inhabited places have has been recognized in Kenya to lower breeding sites of pollinators, leading to their losses (Martins & Johnson 2009). People should avoid this and instead sensitize on the need for conserving the ecological conditions that encourage multiplication of crop pollinators. The bee ecosystems within the crop farms in *Machakos* are able to provide adequate pollination service to cucurbits and other agricultural crops (Kasina *et al.* 2013). The pollination service providers should be protected to ensure that this service results in a continuous supply of food to the market. The present work found that stingless bees (*Hypotrigona* spp.) might not have a significant role in the pollination of pumpkin (*Cucurbita maxima* D.). This may possibly be attributed to the biology of pumpkin flowers that seems not to be compatible with the small size of stingless bee (*Hypotrigona* spp.) making it difficult for them to pick their heavy and sticky pollen grains, and exit the flowers.

CONCLUSION

The finding of this study suggests that there are enough floral pollinators for cucurbits in the farms at *Machakos*. The cucurbits farmers do not have to worry about the reported decline of honeybees' colonies in other places but they need to conserve the environment around their farms to protect these pollinators to ensure sustainable and adequate pollination service for their crops.

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