

Original Research Article

**The effect of pollinators and pollination on fruit set and fruit yield of okra
(*Abelmoschus esculentus* (L.) Moench) in the forest region of Ghana.**

ABSTRACT

The indiscriminate application of chemical insecticides on crops has resulted in reduction in the numbers of beneficiary insects which provide pollination services. Reduction in pollination services leads to reduction in crop yields of which okra is no exception. This study was conducted in the minor rainy season of 2011 and major rainy season of 2012 on the experimental farm of Department of Horticulture of Kwame Nkrumah University of Science and Technology Kumasi, Ghana to investigate the effect of pollinators and pollination on the reproductive performance of okra (*Abelmoschus esculentus* (L.) Moench.). The experiment was conducted in a Randomized Complete Block Design (RCBD) involving three treatments with three replications. The treatments were a control, insecticide application and net-covered plants. The parameters studied were the number of flowers per plant, number of aborted flowers per plant, number of fruits per plant, yield per plant, number of seeds per pod and the number of honeybee visitation in a day. The results indicated no significant difference ($P>0.05$) in number of flowers per plant and number of aborted flowers per plant but significant differences ($P<0.05$) were recorded in the number of pods per plant, yield per plant and number of seeds per pod. Honeybee visitation also showed significant differences between treatments. Even though the number of aborted flowers did not show significant differences, among the treatments, the net-covered plants recorded the largest number of aborted flowers than the control and the insecticide-treated plants for both planting seasons. Conservation of honeybees as pollinators of flowers of cultivated plants will go a long way to increase food production.

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench.) is a member of the family Malvaceae. It is an annual fruit vegetable crop grown in tropical and subtropical parts of the world. Although okra is primarily a rain fed crop, it also does well under irrigated conditions during the dry season (Pushpalatha, 2008). It is primarily a garden vegetable plant, grown for its immature

33 fruits, which are consumed when cooked either alone or in combination with other foods
34 (McGregor, 1976).

35 The green tender fruits of okra are highly nutritious, containing 107 mg of calcium and 8.9
36 mg of Iron for every 1000g edible portion and fair amounts of vitamins A, B and C. It is
37 also rich in protein and crude fibre (Sona Thampi and Indira, 2000). The fruits are very
38 mucilaginous and are used to thicken soup (Vickery and Vickery, 1979). The immature okra
39 pods are used in soups, stir-fries, and stews. Okra seeds are reportedly used as substitutes or
40 additives in feed compounds (Purseglove, 1974), in the preparation of okra seed meal and a
41 number of baked products (Martin and Roberts, 1990) and in blood plasma replacement
42 (Vickery and Vickery, 1979). Apart from its nutritive value the stem and fruit sheath are
43 used in the manufacture of paper as they contain some crude fibre (Sharma and Arora,
44 1993).

45 The production of okra in the world as of 2007, was estimated at 4.8 million tons with India
46 leading the production by 70% followed by Nigeria (15%), Pakistan (2%), Ghana (2%),
47 Egypt (1.7%) and Iraq (1.7%) (Gulsen *et al.*, 2007). In Ghana, okra is produced in large
48 quantities in the Brong Ahafo, Ashanti, Northern, Volta, Greater Accra and Central
49 Regions, and under good management, 10- 15 t /ha of yield can be obtained (NARP, 1993).
50 It is a vegetable which one finds in a fresh state in almost all markets in Ghana, during the
51 rainy season and in a dehydrated form during the dry season, particularly in Northern Ghana
52 due to its strong commercial value for poor women farmers and its vital importance as food
53 diet among the inhabitants of the cities and villages (Oppong-Sekyere *et al.*, 2011). In
54 Ghana, it is the fourth most popular vegetable after tomatoes, pepper, and garden eggs
55 (Sinnadurai, 1973).

56 Many fruit vegetables require some cross pollination by insects and other arthropods for
57 effective fruiting and high yields. Where insect associated pollination is not achieved, yields
58 achieved may only reflect that proportion that is mediated by selfing or pollination by other
59 means. This indicates that, although self-compatible plants do not require outcross pollen
60 for fertilization, they often produce more seeds and/or larger fruits (Greenleaf and Kremen,
61 2006), more vigorous offspring (Marshall, 1991) and/or show greater recruitment into the
62 next generation when cross-pollinated (Herrera, 2000).

63 Lack of sufficient number of suitable pollinators causes decline in fruit and seed production
64 (Partap, 2001). Over 80% of the total pollination activities are performed by insects, and
65 bees contribute nearly 80% of the total insect pollination, and therefore, they are considered
66 the best pollinators (Robinson and Morse, 1989). Another value of pollination lies in its
67 effect on quality and efficiency of crop production. Inadequate pollination can result not
68 only in reduced yields but also in delayed yield and a high percentage of culls or inferior
69 fruits (McGregor, 1976). In okra, there is a positive correlation between the number of seeds
70 in a pod and its weight, and insect pollination increases the number of seeds present in a pod
71 (Free, 1976). In Punjab, India a 19% increase in yield in okra was reported due to intensive
72 bee pollination (Tanda, 1984). Similarly, Mishra *et al.* (1987) found that the weight and
73 length of capsules and number of seeds per capsule were significantly larger in open
74 pollinated than in bagged flowers. Azo'o *et al.* (2011) reported that the mean number of
75 matured seeds is higher in open-pollinated plants and smaller in self-pollinated plants.

76 In Ghana, knowledge of farmers in pollination is limited and so many farmers lump
77 pollinators together with insect pests, and do not explicitly manage to conserve them,
78 although pollinators may contribute substantially to yields at no cost to the farmer. Farmers

would appreciate more extension information on pollination services (API, 2007), however, no study has been done in Ghana on the contribution of pollinators to the yield of okra especially in the forest region of Ghana. According to Cane and Tepedino (2001) if pollinators are in decline it should be possible to measure the results of their absence as reductions in fruit or seed production in natural or agricultural ecosystems. This study therefore sought to determine the effect of pollinators and pollination on reproductive performance (flower set, fruit set, fruit yield and fruit quality) of okra cultivated in the forest region of Ghana.

MATERIALS AND METHODS

Study area

This study was conducted on the experimental farm of the Department of Horticulture of the Kwame Nkrumah University of Science and Technology during the minor season of 2011 and major season of 2012. The experimental farm was located near the University campus in the forest ecological zone (06° 41' N, 01° 33' W) of Ghana, and is 361.4 m above sea level. The area has an annual rainfall of about 730 mm and mean annual maximum and minimum temperatures of 21.5 °C and 32.1°C respectively (Addo-Fordjour *et al.*, 2007).

Experimental Design

The study was conducted in a randomized complete block design (RCBD) in a split-plot arrangement with three treatments and three replications. The three treatments were: control (no insecticide application at flowering stage and no net covering); insecticide application and net-covered plant. A subplot measured 4 m x 6 m with 2 m alley between plots and blocks giving a total area of 24 m² per subplot and an overall area of 308 m² for the whole

102 experiment. The variety of okra used for the experiment was ‘asontem’, an early maturing
103 variety developed by the Crop Research Institute of the Council for Scientific and Industrial
104 Research (CSIR).

105 Land clearing was done manually with a cutlass. A single tractor ploughing and harrowing
106 operation was carried out in both seasons. Two seeds were sown per hole and thinned to one
107 plant per stand one week after germination. Okra seeds were sown at a spacing of 80cm x
108 60cm per stand to give an approximate plant density of 70 plants per subplot amounting to
109 29,167 plants per hectare. Two manual weeding operations were carried out in each season
110 using the hand-hoe. Subsequent weed growth was controlled by hand pulling. Basal NPK
111 fertilizer (15-15-15) was applied to all plots including the control at the rate of 10 g per plant
112 four weeks after planting.

113 The three plots in each block were treated with either insecticide, covered with net (caging)
114 or used as control (no insecticide application and no net covering) on the 6th week after
115 germination when flower buds started appearing. The insecticide used was Cymethoate
116 Super EC (a combination of 36 g Cypermethrin and 400 g Dimethoate per litre). Application
117 of the insecticide was done every other week starting from the 6th week after germination
118 when flower buds started appearing up to the 12th week at the rate of 10 ml of insecticide per
119 7.5 litres of water and applied using a knapsack sprayer.

120

121 **Data collection**

122 Honeybees (*Apis mellifera*) numbers were counted starting from the 6th week after
123 germination when flower bud formation had just begun. Other insects which were seen on

the plant were also counted separately. This was done whilst taking a transect walk along the field. Counting was done weekly in the morning, afternoon and evening up to the 12th week after germination in both seasons. From ten randomly sampled plants in each plot, the number of flower sets, number of aborted flowers, number of fruit sets and yield were obtained and their means calculated. Counting was started in the 6th week after germination and continued over a five week period. The mean number of seeds per pod was also obtained from ten randomly selected dry pods from each plot. These were split open and the number of seeds in each pod was counted.

Data Analysis

Data collected were analyzed with the Statistical Analysis Systems (SAS, 2011) using the General Linear Module (GLM) Procedure. Analysis of variance (ANOVA) was performed and where the difference was significant the means were separated using the Student's Newman Keul's (SNK) test. Significant difference was set at $P < 0.05$.

RESULTS

Vegetative and reproductive performance of okra

Analysis of the data showed no significant differences ($P > 0.05$) in the number of flowers per plant and number of aborted flowers per plant in both the major and minor seasons. The control however recorded the largest number of flowers whilst the net-covered plants recorded the largest number of aborted flowers in the two seasons (Tables 1 and 2). In both the major and minor seasons, the means differed significantly in number of pods harvested per plant, yield per plant and number of seeds per pod. The control plots recorded the largest numbers in all these parameters whilst the least was recorded in the net covered plants

(Tables 1 and 2). In both seasons, the numbers of harvested pods' yield per plant and number of seeds per pod on the insecticide-sprayed and the control plots were significantly larger than those on the net-covered plants (Tables 1 and 2).

Table 1. Reproductive performance of okra (Minor season, 2011).

Treatment	No. of flowers per plant	No. of pods per plant per pod	No. of aborted flowers per plant	Yield per plant	No. of seeds per pod
Control	18.50 ±1.30 ^a	10.77±0.74 ^a	7.67 ±0.86 ^a	0.34±0.03 ^a	79.43±2.17 ^a
Insecticide	18.47 ±0.98 ^a	10.77 ±0.68 ^a	7.70 ±0.61 ^a	0.30±0.02 ^a	78.17 ±2.02 ^a
Net	17.60 ±0.91 ^a	8.70 ±0.44 ^b	8.90 ±0.65 ^a	0.20±0.01 ^b	69.86±2.24 ^b

Within columns means with different letters are significantly different (P < 0.05).

Table 2. Reproductive performance of okra (Major season, 2012).

Treatment	No. of flowers per plant	No. of pods per plant per pod	No. of aborted flowers per plant	Yield per plant	No. of seeds per pod
Control	17.63 ±1.65 ^a	10.40 ±0.85 ^a	7.07 ±0.86 ^a	0.24±0.01 ^a	76.57±1.84 ^a
Insecticide	16.87 ±1.00 ^a	9.60 ±0.47 ^a	7.17 ±0.56 ^a	0.21±0.00 ^b	74.17 ±1.95 ^a
Net	16.77 ±0.75 ^a	8.23 ±0.34 ^b	8.67 ±0.76 ^a	0.14±0.00 ^c	66.27±2.01 ^b

Within columns means with different letters are significantly different (P < 0.05).

Insects encountered on okra plants

The main insect encountered as pollinators of okra flowers was the honeybee, *Apis mellifera*. In addition, other insects which were of minor importance as pollinators were found on okra plant. Honeybees counted in the three treatments indicated significant differences in bee numbers among the treatments ($P < 0.05$) in all the three periods of the day in both the major and minor seasons (Table. 3). The control plots recorded the largest numbers of bees in both morning (7 – 8 AM) and evening (5 – 6 PM) for both the minor and major seasons. No bees were recorded on the plants covered with net in all the periods in both seasons. During the period of observation, the largest numbers of bees were recorded in the mornings and the least in the afternoons (1 – 2 PM).

Table 3: Numbers of *Apis mellifera* visiting okra flowers (Minor season, 2011 and major season, 2012) at different periods of the day.

	Minor season, 2011			Major season, 2012		
	Control	Insecticide	Net	Control	Insecticide	Net
7–8 AM	11.50 ^a ±1.5	10.75 ^a ±2.4	0.00	12.30 ^a ±2.5	10.70 ^a ±2.5	0.00
1 –2 PM	2.01 ^b ±0.5	2.50 ^b ±0.4	0.00	3.10 ^b ±0.4	2.25 ^b ±0.3	0.00
5 – 6 PM	7.03 ^b ±1.3	6.50 ^b ±1.8	0.00	5.75 ^b ±0.7	4.20 ^b ±0.8	0.00

Within columns means with the same letter are not significantly different ($P > 0.05$).

Other insects found on okra plant

Apart from *Apis mellifera*, which is the main pollinator of okra flowers, a number of insects were found on the plant. These included: the flower beetle, *Chiloloba acuta*; the golden

wasp, *Vespa magnifica*; carpenter bee, *Xylocopa* sp. the cotton stainer, *Dysdercus superstitionus*; lemon butterfly, *Papilio machon* and the bumble bee, *Bumbus* sp. The numbers of these insects encountered on the plants are listed in Table 4 below.

Table 4: Numbers of other insects found on okra plants (Minor and major seasons)

Minor season (2011)				Major season (2012)		
Insect	Control	Insecticide	Net	Control	Insecticide	Net
<i>C. acuta</i>	2.1	0.0	0.0	1.0	1.2	0.0
<i>V. magnifica</i>	2.0	1.0	0.0	3.1	2.0	0.0
<i>Xylocopa</i> sp.	1.1	1.0	0.0	1.9	1.8	0.0
<i>D. superstitionus</i>	2.0	5.2	0.0	4.1	3.9	0.0
<i>P. machon</i>	1.0	1.0	0.0	2.2	1.0	0.0
<i>Bumbus</i> sp.	2.0	0.0	0.0	1.0	1.0	0.0

Small numbers of these insects were recorded on all treatments for both seasons; however, the control plants recorded larger numbers while the net-covered plants recorded none of them at all.

Discussion

Number of flowers per plant:

The results indicated that the number of flowers per plant was neither affected by insecticide application nor covering the plants with a net. Thus, insect pollination did not significantly affect the number of flowers per plant. Similar observation was made by Al-Ghzawi *et al.* (2003) who reported no significant differences between insect and self-pollinated flowers with regard to number of flowers formed. The minor season, however, recorded larger numbers of flowers in all the treatments than the major season. This could be attributed to the fact that, rainfall pattern within the first three months after planting was better in the

minor season than in the major season. Heavy rainfall during the flowering period in the major season resulted in flower drop, accounting for the fewer flowers formed during the major season. Severe water stress at the flowering stage, however, could have a detrimental effect on pod yield as reported by Ahmad *et al.* (2003); Sawadogo *et al.* (2006); and Seghatoleslami *et al.* (2007). Severe water stress at the pod filling stage will, however, lead to yield reduction as reported by Mbagwu and Adesipe (1987).

Number of pods harvested per plant:

The number of pods harvested showed that honeybee pollination had a significant effect on the number of flowers that were transformed into mature pods. Significantly more pods were formed on the control and insecticide-sprayed plots than on the net-covered plots in both seasons. This was due to the fact that flowers on the net-covered plots were self pollinated while those on the other plots were insect pollinated. When the plants were covered with the net insects did not have access to their flowers and were thus self pollinated leading to production of fewer pods. Al- Ghzawi *et al.* (2003) stated that insect-pollinated plants produce a larger number of young pods and mature pods due to greater transformation of flowers into young pods. Surprisingly insecticide application did not significantly reduce pod formation contrary to the widely held view that these chemical insecticides reduce cross pollination by killing non-target insects including bees. This was an indication that insecticide application did not affect pollinator source. A significant reduction in pollinating force may have serious effects on fruit and seed set in insect-pollinated plants which are in bloom at, or shortly after the time of spraying (Miliczky and Osgood, 1979).

235

236 **Number of aborted flowers per plant**

237 The number of aborted flowers in the net covered plants was largest but no significant
 238 difference ($P>0.05$) was observed among the treatments in both the major and minor
 239 seasons. This was rather contrary to previous study by Mesquida *et al.* (1990) who reported
 240 significant differences in flower abortion rates between insect-pollinated and self pollinated
 241 flowers. The large number of aborted flowers in the net-covered plants was due to the
 242 absence of insect pollination as observed by Al-Ghzawi *et al.* (2003). A study carried out by
 243 Stanghellini *et al.* (1997) on the effects of honeybee (*A. mellifera* L.) and bumblebee
 244 (*Bombus impatiens* Cresson) pollination on fruit set and abortion of cucumber (*C. sativus*
 245 L.) and watermelon, *C. lanatus* Thunb.), revealed that as the number of bee visits to flowers
 246 increased, the number of fruits aborted decreased. It was observed that percentage flower
 247 abortion was generally high ranging from 40%-51% and 41-50% in the major and minor
 248 seasons respectively. In the major season, flower abortion could be attributed to heavy
 249 rainfall whilst in the minor season unfavourable weather conditions such as drought could
 250 result in flower abortion as reported by Abdul (2009) who stated that, water stress during
 251 bud formation, flowering and grain filling period reduces yield due to abortion of ovule,
 252 embryo and sterility of pollen.

253 **Yield in kilogramme per plant:**

254 The results in both seasons showed that yields of okra in open pollinated plants were higher
 255 than that of the self-pollinated plants. Even though okra may be a self-pollinated plant, yield
 256 improved when there was insect pollination. A study by Manzoor- ul-haq *et al.* (1978) on
 257 the effect of *Apis dorsata* and *A. florea* on fruit bearing in kinnow mandarin (*Citrus*

reticulate) found significantly more fruit set, bigger fruit size and larger number of seeds on branches accessible to insect pollinators than those from which insects were repelled or excluded. Similarly, Abrol (1989) in his studies on ecology and behaviour of insect pollinators frequenting strawberry blossoms and their impact on yield and fruit quality observed a higher percentage of fruit set and well formed fruits in open pollinated plants compared to those where pollinating insects were not allowed access.

Number of seeds per pod:

As a result of insect visitation larger numbers of seeds per pod were recorded in the open pollinated plants (control and insecticide -treated plots) than in the self pollinated plants. This was due to adequate pollination which resulted in fertilization of more ovules which developed into more matured seeds in the open-pollinated plants. The small number of seeds per pod recorded in the net covered plot was the result of seed abortion due to lack of fertilization resulting from inadequate pollination. A study by Azo'El *et al.* (2012) stated that, the mean number of aborted seeds was larger in the fruits from flowers that were isolated for autonomous self-pollination than those that received a single visit of *T. fraterna* and *Eucara macrognatha*. Thus some insect pollination is necessary for effective fruit formation and larger number of seeds.

The honeybee and other insects' visitation to the okra plant:

Several insects were found on the plants but their numbers and effects were insignificant compared to the honeybee and the housefly. Except the honeybee, the other insects did not play any role in pollination of the okra flowers because they were either found on the leaves or on the periphery of the flowers. The honeybee was the main pollinator of the okra flower

because it was usually found deep inside the flower. Klein *et al.* (2007) also reported that in many plant species, the honey bee (*Apis mellifera*) seems to be the main pollinator insect. Honeybee number was largest on the control but no bees were recorded in the net covered plants as they remained covered throughout the study period. The largest number of bees was recorded in the morning whilst the least was recorded in the afternoon in both seasons. The difference could be due to temperature differences at these times of the day. Higher temperatures during the afternoon reduced flight activity by bees and reduced pollination effectiveness as reported by Corbet *et al.* (1993). Studies on the abundance and daily visitation patterns of bees on oil seed sunflower, *Helianthus annuus* in Southeastern Arkansas showed that peak activity of bees occurred at 0800 hr and 0900 hr with greatly reduced numbers during afternoon hours (Posey *et al.*, 1986).

Conclusion: In general, the observation from the study was that insect pollination did not have any significant effect on the number of flowers per plant; however, insect pollination reduced the number of flowers aborted, increased number of fruits per plant, yield per plant and number of seeds per pod. Insect pollination therefore improved the reproductive performance of okra. Some level of insect pollination is therefore necessary for better yield even in plants that could be self-pollinated.

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