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

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ABSTRACT

Aims: To determine the effect of pollinators and how they affect the reproductive performance of okra cultivated in the forest region of Ghana.

Study design: The experiment was conducted in a randomized complete block design (RCBD) in a split-plot arrangement with three treatment and three replications.

Place and Duration of Study: The experiment was conducted on an experimental farm of the Department of Horticulture of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana during the minor rainy season of 2011 and repeated during the major rainy season of 2012.

Methodology: Nine subplots, each measuring 4 m × 6 m were raised with an alley of 2 m between the plots and blocks. Okra seeds were sown at two seeds per hole at a spacing of 80cm × 60cm and thinned to one plant per stand one week after germination. The three treatments were insecticide application, net-covered plants and a control which was neither sprayed nor covered. Basal NPK fertilizer was applied to all the plots at a rate of 10 g per plant. Data were collected on insects that visited the flowers for pollination, numbers of flower sets, numbers of aborted flowers, fruit set, numbers of fruits and number of seeds per pod in ten randomly selected plants on each plot.

Results: Honeybees were the main pollinators of okra flower. Many of the other insects found the plant were not involved in pollination of the flowers. There were no significant differences ($P > 0.05$) in the numbers of flowers per plant and numbers of aborted flowers, but significant differences ($P < 0.05$) were recorded in the numbers of pods per plant, yield per plant and the numbers of seed per pod. Honeybee numbers were significantly different on the different treatments.

Conclusion: It was observed that even though the net-covered plant recorded some yield, insect pollinated flower recorded better yield, therefore conservation of honeybees as pollinators of okra flowers will improve the yield of this crop.

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

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

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

Many fruit vegetables require some cross pollination by insects and other arthropods for effective fruiting and high yields. Where insect associated pollination is not achieved, yields achieved may only reflect that proportion that is mediated by selfing or pollination by other means. This indicates that, although self-compatible plants do not require outcross pollen for fertilization, they often produce more seeds and/or larger

fruits (Greenleaf and Kremen, 2006), more vigorous offspring (Marshall, 1991) and/or show greater recruitment into the next generation when cross-pollinated (Herrera, 2000).

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

In Ghana, knowledge of farmers in pollination is limited and so many farmers lump pollinators together with insect pests, and do not explicitly manage to conserve them, 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.

2. MATERIALS AND METHODS

2.1 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 ^{o}C and 32.1^{o}C respectively (Addo-Fordjour *et al*., 2007).

2.2 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 m^2 per subplot and an overall area of 308 m^2 for the whole experiment. The variety of okra used for the experiment was 'asontem', an early maturing variety developed by the Crop Research Institute of the Council for Scientific and Industrial Research (CSIR).

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

The three plots in each block were treated with either insecticide, covered with net (caging) or used as control (no insecticide application and no net covering) on the 6th week after germination when flower buds started appearing. The insecticide used was Cymethoate Super EC (a combination of 36 g Cypermethrin and 400 g

Dimethoate per litre). Application of the insecticide was done every other week starting from the 6th week after germination when flower buds started appearing up to the 12th week at the rate of 10 ml of insecticide per 7.5 litres of water and applied using a knapsack sprayer.

2.3 Data collection

Honeybees (*Apis mellifera*) numbers were counted starting from the 6th week after 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.

2.4 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 $P<0.05$.

3. RESULTS

3.1 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 ($P < 0.05$).

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156 **3.2 Insects encountered on okra plants**

157 **3.2.1 *Apis mellifera***

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

166

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

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	Minor season, 2011			Major season, 2012		
170						
171		Control	Insecticide	Net	Control	Insecticide	Net
172	7–8 AM	$11.50^{a}\pm1.5$	$10.75^{a}\pm2.4$	0.00	$12.30^{a}\pm2.5$	$10.70^{a}\pm2.5$	0.00
173	1 –2 PM	$2.01^{b}\pm0.5$	$2.50^{b}\pm0.4$	0.00	$3.10^{b}\pm0.4$	$2.25^{b}\pm0.3$	0.00
174	5 – 6 PM	$7.03^{b}\pm1.3$	$6.50^{b}\pm1.8$	0.00	$5.75^{b}\pm0.7$	$4.20^{b}\pm0.8$	0.00

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

176 **Other insects found on okra plant**

177 Apart from *Apis mellifera*, which is the main pollinator of okra flowers, a number of insects were found on the
178 plant. These included: the flower beetle, *Chiloloba acuta*; the golden wasp, *Vespa magnifica*; carpenter bee,
179 *Xylocopa* sp. the cotton stainer, *Dysdercus superstitiousus*; lemon butterfly, *Papilio machon* and the bumble
180 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
C. acuta	2.1	0.0	0.0	1.0	1.2	0.0
V. magnifica	2.0	1.0	0.0	3.1	2.0	0.0
Xylocopa sp.	1.1	1.0	0.0	1.9	1.8	0.0
D. supestitiousus	2.0	5.2	0.0	4.1	3.9	0.0
P. machon	1.0	1.0	0.0	2.2	1.0	0.0
Bumbus 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.

4. DISCUSSION

4.1 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).

4.2 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 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).

4.3 Number of aborted flowers per plant

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

4.4 Yield in kilogramme per plant:

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

4.5 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'Ela *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.

4.6 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).

5. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abdul, N. (2009). The potential for breeding okra (*Abelmoschus esculentus* (L) Moench) for stress tolerance. PhD thesis, University of Agriculture, Faisalabad, Pakistan. pp54-67. Online at URL:prr.hec.gov.pk/Thesis/136S.pdf.

Abrol, D. P. (1989). Studies on ecology and behaviour of insect pollinators frequenting strawberry blossoms and their impact on yield and fruit quality. *Trop. Ecol*., 30(1): 96-100.

Addo-Fordjour, P., Yeboah-Gyan, K., Lawson, B. W. L., Akanwariwiak, W. G. (2007). Diversity and distribution of ferns on the campus of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. *Journal of Science and Technology* (27) 1: 35-44.

Ahmad, S., Mahmood,A., Malik, A.J., Karim A., Kumbha, R M.B. (2003) Response of okra to water stress. *Sarhad J. Agri.* 19(1):73-79.

Al- Ghzawi, A.M., Zaittoun, S.T., Makadmeh, I., Al –Tawaha, A.R.M. (2003). The impact of wild bees on the pollination of eight okra genotypes under semi-arid Mediterranean conditions. *Int. J. Agric. Biol.,* 5: 409-411.

API **(**2007). Crops, Browse and Pollinators: An Initial Stock taking. : Online at URL *:www.fao.org/docrep/010/a1504e/a1504e00.htm.*

Azo'o Ela, M., Ali, M., Fohouo, F. N. T., Messi, J. (2012). The importance of a single floral visit of *Eucara macrognatha* and *Tetralonia fraterna* (Hymenoptera: Apidae) in the pollination and the yields of *Abelmoschus esculentus* in Maroua, Cameroon. *African Journal of Agricultural Research* Vol. 7(18), pp. 2853-2857. Available online at http://www.academicjournals.org/AJAR.

Azo'o**,** M. E., Fohouo ,F.N.T., Messi, J. (2011). Influence of the Foraging Activity of the Entomofauna on Okra (*Abelmoschus esculentus*) Seed Yield*. International Journal for Agriculture and Biology*. 13: 761-765. Online:www.fspublishers.org.

Cane, J. H., Tepedino, V. J. (2001). Causes and extent of declines among native North American invertebrate pollinators: detection, evidence, and consequences. *Conservation Ecology*5(1):1. [online] URL: http://www.consecol.org/vol5/iss1/art1/(accessed on 17 November 2011).

Corbet, S.A., Fussell, M., Ake, R., Fraser, A., Gunson, C., Savage, A., Smith, K. (1993).Temperature and the pollinating activity of social bees. *Ecological Entomology,* 18: 17-30.

Free, J. B. (1976). Insect pollination of tropical crops. *Report of the Central Association of Beekeepers*.pp 12.

Greenleaf, S.*,* Kremen, C. (2006)*.* Wild bee species increase tomato production but respond differently to surrounding land use in Northern California*. Biol. Conserv.,* 13: 81–87*.*

Gulsen, O., Karagul, S., Abak, K. (2007). Diversity and relationships among Turkish germplasm by SRAP and Phenotypic marker polymorphism. *Biologia, Bratislava*, 62(1): 41-45.

Herrera, C.M. (2000). Flower-to-seedling consequences of different pollination regimes in an insect-pollinated shrub. *Ecology*, 81, 15–29.

Klein, A. M., Vaissiere, B. E., Cane, J. H., Steffan-Dewinter, I., Cunnigham, S. A., Kremen, C., Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proc. R. Soc.,* 274(2): 303-313.

Manzoor-ul- haq., Rafie-ul-Din M., Ghaffar, A. (1978). Effect of insect pollination on fruit bearing in kinnow mandarin (*Citrus reticulata*) and physical and chemical properties of fruit. *J. Apic. Res.,* 17, 47-9.

Marshall, D.L. *(*1991*).* Nonrandom mating in wild radish: variation in pollen donor success and effects of multiple paternities among one- to six-donor pollinations*. Am. J. Bot.,* 78*,* 1401–1418*.*

Martin, F. W., Roberts, R. (1990). Milling and uses of okra seed meal at the household level. *J. Agric.* Univ., 16:21– 27.

Martin, F.W., Rhodes, A.M., (1983). Seed characteristics of okra and related *Abelmoschus* species qualities plantarum. *Pl. Foods Human Nutr.,* 33: 41-49.

Mbagwu, J.S.C., Adesipe, F.A. (1987). Response of three okra (*Abelmoschus esculentus* L. Moench) cultivars to irrigation at specific growth stages*. Scien. Hort*., 31(1-2): 35-43.

McGregor, S. E. (1976). Insect pollination of cultivated crop plants. Agriculture Handbook No. 496, *Agricultural Research Service, USDA, Washington*, DC.

Mesquida, J., Le Guen, J., Tasei, J. N., Carre, S., Morin, G. (1990). Effect of pollination treatments on reproductive organ abortion rates, yield and crossing rates in 2 lines of spring faba bean (*Vicia faba* L. var *equina* Steudel). *Apidologie*, 21: 511-525. Online at http://dx.doi.org/10.1051/apido:

Miliczky, E. R., Osgood, E. A. (1979). The effects of spraying with sevin-4-oil on insect pollinators and pollination in a spruce-fir forest. Life Sciences and Agriculture Experiment Station University of Maine at Orono. *Technical Bulletin*.90.

Mishra, R. C., Kumar, J., Gupta, J.K. (1987). Effect of mode of pollination on fruit characteristics of okra. *Abelmoschus esculentus* (L.) Moench. *Proc. Indian. Nat. Sci. Acad. B* 53: 157-160.

NARP (1993). National Agricultural Research Project, *Horticultural crops*. Vol. 3, July 1993. NARP, CSIR, Accra.

Oppong-Sekyere, D., Akromah, R., Nyamah, E.Y., Brenyah, E., Yeboah, S. (2011) Characterization of okra (*Abelmoschus spp.* L.) germplasm based on morphological characters in Ghana. *Journal of Plant Breeding and Crop Science* Vol. 3(13), pp. 367-378. Available online http://www.academicjournals.org/jpbcs.

Partap, T. (2001). Mountain agriculture, marginal land and sustainable livelihoods: Challenges and opportunities. *International Symposium on Mountain Agriculture in HKH Region* (21-24 May 2001). ICIMOD, Kathmandu, Nepal.

Posey, A. F., Katayama, R. W., Burleigh, J. G. (1986). The abundance and daily visitation patterns of bees (Hymenoptera: Apoidea) on oil seed sunflower, *Helianthus annuus* L. in Southeastern Arkansas. *J. Kansas Entomol. Soc.* 59:494–499.

Purseglove, J. W. (1974). Tropical Crops: Dicotyledons. *Longman Group*, EUA, London, pp.17–30. 1993.

Pushpalatha, B.T. (2008). Effect of seed priming on storability and field performance in okra (*Abelmoschus esculentus* (L.) Moench) Msc. Thesis ,University of Agricultural Sciences, Dharwad. *Hortic.* 288:103–10.

Robinson, W.E., Morse, R.A. (1989). The value of honeybees as pollinators of US crops. *American Bee Journal.* 129 (1): 477-487.

SAS Institute (2011). Statistical Analysis Systems. SAS/STAT User's Guide. Cary N.C. SAS Institute Incorporation.

Sawadogo, M., Zombre, G., Balma, D. (2006). Behaviour of different ecotypes of okra (*Abelmoschus esculentus* L.) under water deficit during budding and flowering phases. *Biotechnol. Agron. Soc. Environ.* 10 (1) 43–54.

Seghatoleslami, M.J., Kafi, M., Majidi, I., Nour-Mohammadi, G., Darvish, F. (2007). Effect of water stress at different growth stages on yield and water use efficiency of five genotypes of proso millet (*Panicum miliaceum*) in South Khorasan. *Science and Technology of Agriculture and Natural Resources.* 1: 215-226..

Singh, M. P. (1984). Studies on the activities of some insect pollinators on jujube (*Zizyphus mauritiana* Lamk.). *Entomong*. 9:177-180.

Sinnadurai, S. (1973). Vegetable Production in Ghana. *Acta Hort.* (ISHS) 33:25-28.

Sona Thampi, K., Indira, V. (2000). Nutritive value and organoleptic evaluation of thamaravenda genotypes (*Abelmoschus caillei* L.). *J. Tropical Agric.*, 38: 38-40.

Stanghellini, M. S., Ambrose, J. T., Schultheis, J. R. (1997). The effects of honey bee and bumble bee pollination on fruit set and abortion of cucumber and watermelon. *American Bee Journal* 137: 386-391.

Tanda, A.S. (1984). Insect pollination in okra (*Abelmoschus esculentus*). *Proc. III Ent. Orient. Symp. Kariavattom*, India. 25.

Tanda, A.S. (1985). Floral biology, pollen disposal and foraging behaviour of honeybees in okra (*Abelmoschus esculentus*). *J. Apic. Res.* 24: 225-227.

Vickery, M. L., Vickery, B. N. (1979). Plant Products of Tropical Africa. Macmillan Press Ltd. London, 67pp.