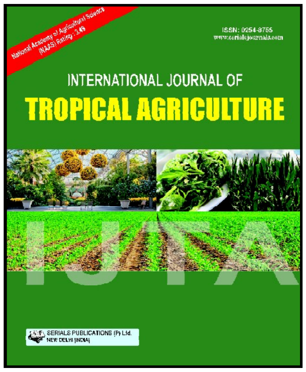

INTERNATIONAL JOURNAL OF TROPICAL AGRICULTURE

ISSN : 0254-8755

available at http: www.serialsjournals.com

Volume 36 • Number 4 • 2018

Frequency of Pollinator visit and Fruit Production in Cucumber (*Cucumis sativus* L.)

Leena P. T.* **and M. Nasser****

* *Department of Zoology, Pazhassi Raja NSS College, Mattanur, Kannur, Kerala, India-670702, E-mail: leena.n.nambiar@gmail.com*
** *Department of Zoology, University of Calicut, Kerala, India-673635, E-mail: na_sher@yahoo.co.in*

Abstract: Studies on Cucumber (Cucumis sativus L.), was carried out in commercial vegetable farm in Kerala, India. Observations were done at different phases in the flowering season to understand the frequency of pollinator visit and their effect on fruit production. Insects belonging to the orders, Hymenoptera, Coleoptera and Lepidoptera were the common visitors. Pollinator visit was highest during the midphase of flowering season. Results indicate that pollinator visit had a positive influence on fruit production in the crop.

Key words: Cucumber, Pollinator, Fruit production

INTRODUCTION

Pollination is a key concept in fruit production that must be understood in order to maximize productivity and yield. The importance of insect pollination in the production of fruits and vegetables is well documented. Almost all commercially grown vine crops (Cucurbitaceae) rely on insect pollination to set fruit (Motes, 1977). According to Kevan and Phillips (2001), pollination systems in many agricultural areas today are threatened by an inadequate number or complete lack of sustainably managed pollinators, either indigenous or imported. Pollination by insects is largely unique to the angiosperms, and diversification of pollination systems has been one of the most important factors in the radiation and abundant success of this group of plants (Regal, 1977; Crepet, 1984; Willemstein, 1987).

MATERIALS AND METHODS

The crop selected for this study was annual unisexual vine crop cucumber (Family: Cucurbitaceae) which require insect pollination for fruit set and attract a wide variety of insect visitors to their flowers. It is very popular and widely cultivated vegetable in India. It is a monoecious subtropical trailing annual. The cucumber flowers are solitary, axillate and the yellow petals are quite similar in size and shape. The pistillate flower is easily recognized by the large ovary at the base of the flower. The ovary is sparsely covered with spiny growths. The pistillate flower has three thick stigma lobes atop and a short broad style. The fruit is pendulous and oblong. Objectives of this study were to identify insect pollinators of this crop, their foraging dynamics in relation to different pomological aspects.

Pollinator visit and fruit production in the cucumber was studied in the field at Madayi which is located between 12º1'N and 75º15'E in Kerala as per the experimental design by Stanghellini *et al.* (1997), with certain modifications. The study was conducted on a randomized complete block design of crops with 6 replicates of 2 beds for each. There were 2 beds /replicate and 12 hills /bed. All crops were grown on raised bed of 2m wide and 6m length. The field was directly seeded with 3-5 seeds /hill. Upon emergence (germination) the plants were thinned to one /hill. Spacing between beds was 1.5 m with interplant spacing of 1m and the inter-replicate spacing of 10m. Each replicate measured 33sq.m.with sequential plantings.

To quantify pollinator visitation and its consequences on fruit set observations were made on randomly selected plants. One plant from each bed was selected for observation. To quantify pollinator visitation each staminate and pistillate flower in a plant were observed for five minutes. 12 staminate and 12 pistillate flowers were observed on each day i.e. 4 staminate and 4 pistillate flowers each during each diurnal phase. Observations were carried out in three diurnal phases - initial phase (idp), middle phase (mdp) and late phase (ldp) according to the longevity of flowers and peak time of pollinator visitation [idp: 0630 h.-0830 h., mdp: 0830 h.-1030 h., ldp: 1030 h.-1230 h.]. In order to find out the longevity of flowers (opening and closing time of flowers) they were observed from early morning to late evening. Duration of each phase was two hours. They were made for 12 days during initial phase (ISP), 18 days during middle phase (MSP) and 12 days during late phase (LSP) of flowering season. Observations were separated into two hour intervals for each species. On all cultivars, the insects visited per minute in individual flower were quantified over the course of floral anthesis. An insect landing on any part of the flower was counted as a visit. The insect was counted as a pollinator if it went so far into the flower that contact with anthers and pistils was probable. All plot area and foraging insects were chosen randomly for observation. During field study, pollinators were caught by sweeping with a long handled insect net and later identified.

Bagging experiment was done to test the effect of insect visitation on fruit setting. Pistillate flowers were bagged in the early evening before anthesis to control insect visits on the following day. On the day of treatment selected pistillate flowers were unbagged in each phase and insect visits were allowed on each flower. After each flower had received the visits the bags were resealed and tagged with treatment type and date in each phases of pollination. The no visit controls remained bagged for the entire day of anthesis. All bags were removed from the flowers after 1900 h. of the day of treatment after the insect activity in the field ceased.

In all experiments the developing fruits were allowed to mature to a maximum size. All treatment and control flowers that aborted were recorded. The fruits from different samples were handpicked. The harvested fruits were counted. The number of fruits formed in different controlled pollinated samples were recorded. Fruits were analysed according to the shape and size variations and sorted them as normal small sized, normal medium sized, normal optimum sized, malformed and aborted. Size was measured by measuring the length (l) and breadth (b) of fruits. [(lb): small size ≤ 15 cm. x 4 cm.; medium size ≤ 20 cm. x 6 cm.; optimum size d"25 cm. x 8 cm.]. Fruits which had normal shape and growth were categorized as normal fruits. And those shapeless and undergrown were included in the category of malformed fruits.

The sampling period per day was restricted to morning intervals based upon observation on anther dehiscence, stigmatic receptivity and peak foraging activity. Individual plants of the test cultivars were chosen randomly each day for treatment. All observations were made on warm sunny days. The data from each diurnal phase and seasonal phase were pooled for analysis. Statistica '99 version was used to carry out all statistical analysis.

RESULTS

Pollinators

Total 16 species of insect were recorded from 3 orders during the study. The most abundant order was the Hymenoptera, including families Apidae, Halictidae, Xylocopidae followed by Coleoptera. Much less abundant was Lepidoptera (Table1). Coleopterans were the earliest and latest visitors of the day and season.

Table 1
List of pollinators

Order	*Family*	*Species*
Hymenoptera	Halictidae	*Halictus taprobanae* Cameron
		Halictus timidus Smith
		Tetragonula iridipennis Smith
	Apidae	*Ceratina heiroglyphica* Smith
		Apis cerana Fabricius
		Amegilla parhypate Lieftinck
		Apis dorsata Fabricius
		Apis florea Fabricius
		Braunsapis picitarsis Cameron
		Ceratina smaragdula Fabricius
	Xylocopidae	*Xylocopa aestuans* Linnaeus
		Xylocopa tenuiscapa Westwood
Coleoptera	Chrysomelidae	Chrysomelidae *Aulacophora lewisii* Baly
		Aulacophora foveicollis Lucas
Lepidoptera	Sphingidae	*Cephonodes picus* Cramer
		Macroglossum troglodytus Boisduval

Frequency of Pollinator visit

The number of insects visited the flowers increased from initial phase to middle phase of the day and season. Thereafter a continuous decline in pollinator number was observed (Table 2). It was observed that a mean of 17.83 and 15.25 hymenopterans and 3.66 and 2.33 coleopterans visited the male (♂) and female (♀) flowers /day respectively in the initial phase (ISP) of the season. In middle phase (MSP) a mean of 22.08 and 19.25 hymenopterans, 2.25 and 1.75 coleopterans and 0.58 and 0.58 lepidopterans visited the male (♂) and female (♀) flowers /day respectively. In late phase (LSP) of the season a mean of 13.33 and 11.66 hymenopterans and 4.41 and 2.41

coleopterans visited the male (♂) and female (♀) flowers /day respectively. Highest frequency of visit was observed in middle diurnal phase of middle phase of season. Lowest frequency of visit was observed in late diurnal phase of late phase of season. Hymenopterans were the most frequent visitors. Significant difference was found in visitation frequency shown by different orders of insects [ISP ($p<0.05$); MSP ($p<0.05$); LSP ($p<0.05$). *Halictus taprobanae* was the most frequent pollinator. It was followed by *Ceratina heiroglyphica, Halictus timidus, Tetragonula iridipennis and Apis cerana*. They were regular, consistent and made the higher number of visits compared to other insects, at all sites. The visitation frequency shown by different species of insects varied significantly [ISP ($p<0.05$); MSP ($p<0.05$); LSP ($p<0.05$)]. No significant difference in visitation frequency on staminate (♂) and pistillate (♀) flowers [ISP ($p>0.05$); MSP ($p>0.05$); LSP ($p>0.05$)] was observed. Frequency of visitation during different diurnal phases varied significantly [ISP ($p<0.05$); MSP ($p<0.05$); LSP ($p<0.05$)]. Different seasonal phases also showed significant differences in visitation frequency ($p<0.05$).

Table 2
Frequency of Pollinator visit

Seasonal Phases	*Sex of Flower*	*Diurnal Phases*		
		Idp	*mdp*	*ldp*
ISP	♂	6.74	10.83	3.91
	♀	5.58	9.24	2.74
MSP	♂	7.9	12.49	4.49
	♀	6.91	11.24	3.41
LSP	♂	5.82	9.16	2.74
	♀	4.49	8.25	1.33

ISP - Initial phase of season　idp - initial phase of day　♂ -Male flower
MSP - Middle phase of season　mdp - middle phase of day　♀ -Female flower
LSP - Late phase of season　ldp - late phase of day

Fruit Production

From the bagging experiment it was observed that percentage of fruit set increased from initial phase to middle phase and then decreased to late phase of the day and season (Table 3). All non pollinated flowers were aborted. Highest fruit set was recorded in middle seasonal phase. Lowest fruit set was recorded in late seasonal phase. Percentage of fruits within seasonal phases such as ISP ($p<0.05$); MSP ($p<0.05$); LSP ($p<0.05$) and between the seasonal phases were significantly different ($p<0.05$).

Table 3
Percentage of Fruit Production in different phases of flowering season

Seasonal Phases	*Diurnal Phases*		
	Idp	*mdp*	*ldp*
ISP	10%	18.57%	5.71%
MSP	12.85%	21.42%	7.14%
LSP	8.57%	10%	5.71%

ISP - Initial phase of season; idp - initial phase of day; ♂ - Male flower
MSP - Middle phase of season; mdp - middle phase of day; ♀ -Female flower
LSP - Late phase of season; ldp - late phase of day

Nature of Fruits

Fruits with varied shape and size were produced in the different phases of season. When size was measured in terms of length (l) and breadth (b) it was found that fruits formed in different diurnal and seasonal phases were differed in the maximum size they attained. By comparing each other fruits with lb ≤ 15 cm. x 4 cm. were included in small sized ones, ≤ 20 cm. x 6 cm. and d" 25 cm. x 8 cm. were included in the group of medium and optimum sized ones respectively. Also on the basis of shape the fruits were categorized into normal and malformed ones. So four categories like small normal, medium normal, optimum normal and malformed fruits were observed when size and shape were considered together for the assessment of nature of fruits [ISP (idp)=10% small normal; (mdp)=18.57% medium normal; (ldp)=5.71% malformed; MSP (idp)=12.85% medium normal; (mdp)=21.42% optimum normal; (ldp)=7.14% small normal; LSP (idp)=8.57% malformed; (mdp)=10% small normal; (ldp)=5.71% malformed]. All non pollinated flowers were aborted in all phases. Majority of fruits formed in the initial and middle phase were normal shaped and in late phase were malformed (Fig. 1). Size and shape of the fruits varied significantly within seasonal phases [ISP ($p<0.05$); MSP ($p<0.05$); LSP ($p<0.05$)] and between the seasonal phases ($p<0.05$).

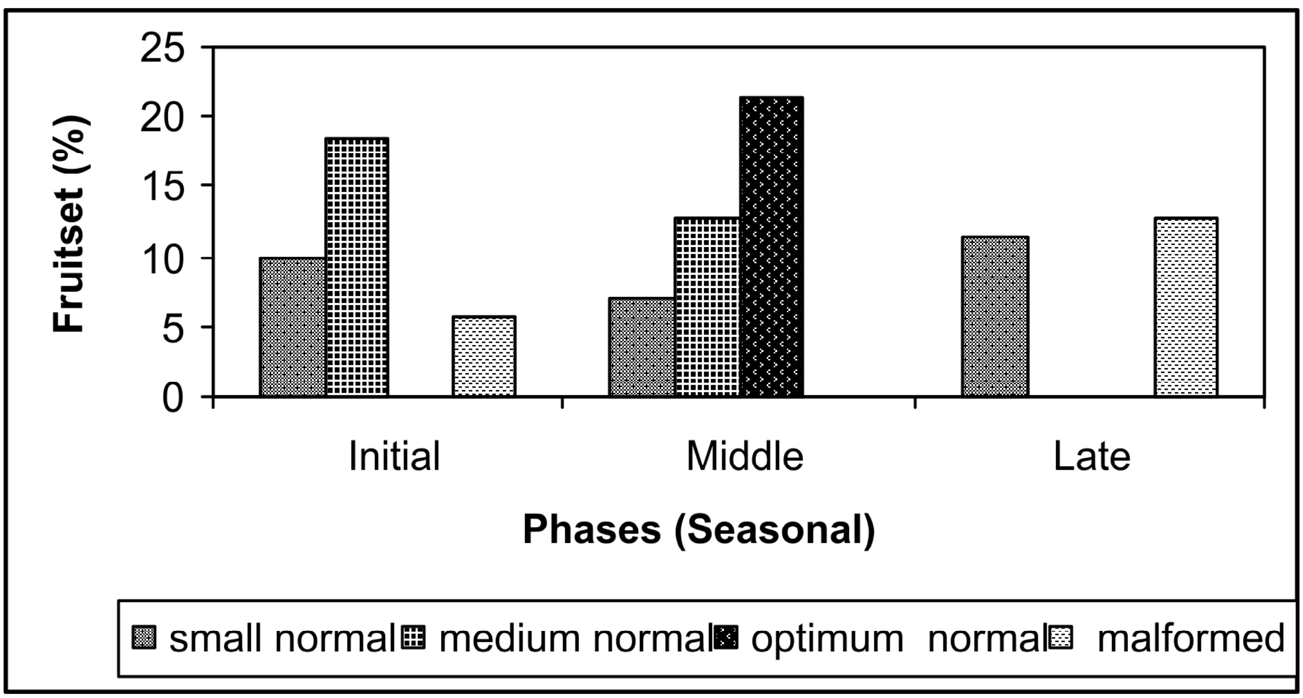

Figure 1: Percentage of fruit production in different phases of season

Correlation between frequency of pollinator visit and fruit production

High positive correlation was found between frequency of pollinator visit and fruit set (r=0.93) (Fig.2) in cucumber.

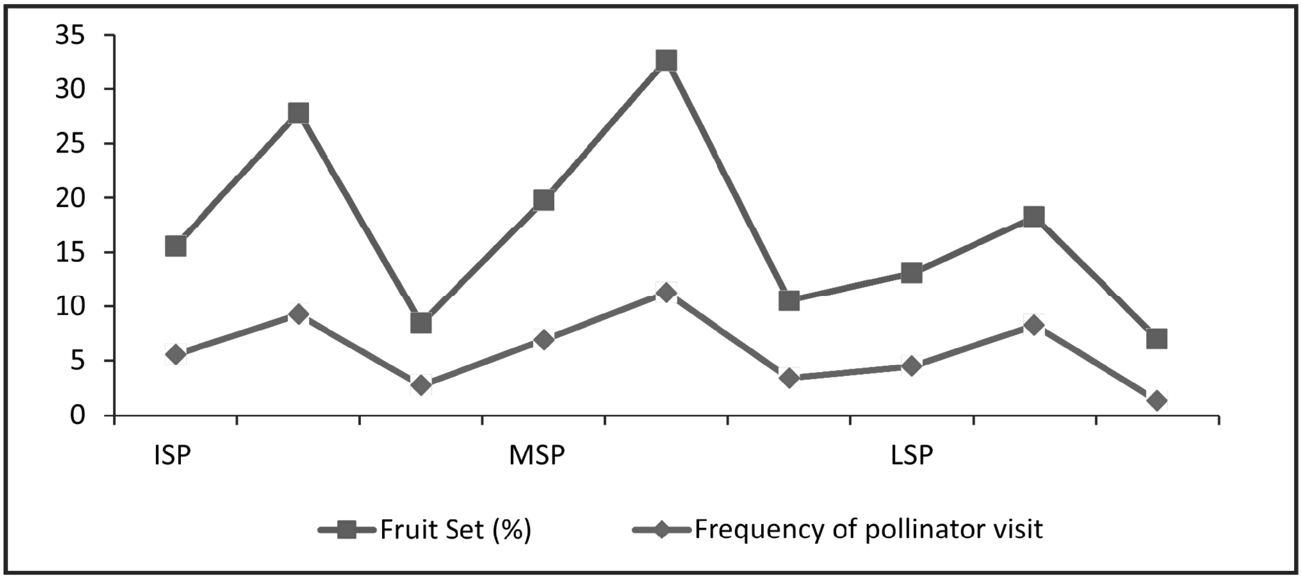

Figure 2: Correlation between frequency of pollinator visit and percentage of fruit set

DISCUSSION

The need for insect pollination of cucurbits has been known for years (Woyke and Bronikowska, 1984). Due to the unique flowering habit of cucurbits, there is only a small window of opportunity for pollination to occur. If they are not pollinated during that time, the flowers abort and drop from the vine. When pollination occurs but is incomplete, fruits do not develop properly (Motes, 1977).

The results of the present study demonstrate the importance of insects in the pollination of cucumber. It was found that insects belonging to three different orders such as Hymenoptera, Lepidoptera and Coleoptera were visiting the flowers of this crop. The relative contribution of Hymenoptera to this crop was major compared to other pollinators. Other visitors could be seen as complementary pollinators. The indigenous bees *Halictus taprobanae*, *Halictus timidus*, *Ceratina heiroglyphica, Tetragonula iridipennis* and *Apis cerana* were the major species found in this study. *Halictus taprobanae* had higher frequency of flower visitation in cucumber and were regular visitors. Tepedino (1981) opined that there may be indigenous flower visitors for native crop species that are at least as adequate as pollinators. According to Free (1993) bees such as the Asian honeybee (*Apis cerana* F.) and dwarf honeybee (*Apis florea* F.) are the prevalent ones compared to *A. mellifera*, in Asiatic cucurbit fields. Stanghellini *et al.* (2002) also stated that in their native ranges, cucumber and muskmelon plants may be visited and pollinated by bee species that are smaller in size than the European honeybees (*Apis mellifera* L.) or North American *Bombus* spp. But Connor and Martin (1969) have ruled that native bees cannot and should not be relied upon as pollinators. The results of this study oppose this conclusion, as these indigenous bees were regular and consistent pollinators of the crop under study. Practically all authorities give primary credit to the honey bee in pollinating cucurbits (Thompson *et al.,* 1955, Langridge, 1952; Nevkryta, 1953; Sanduleac, 1959; Verdieva and Ismarlova, 1960; Wiolfenbarger, 1962; Skrebtsova, 1964). In the present study not only the honey bees but the solitary bees also were found to be the most frequent pollinators of this crop. This was also observed by Leena and Nasser (2015, 2017), Jaycox *et al.* (1975), and Rosa (1925) in other cucurbit crops. Michelbacher *et al.* (1964) also credit both honeybees and wild bees. Not only hymenopterans but also coleopterans like *Aulacophora lewisii* and *Aulacophora foveicollis* and Lepidopterans like *Cephonodes picus* and *Macroglossum troglodytus* also have been identified as pollinators in the present study. This was supported by Tontz (1944), Annand (1926) and Durham (1928) who have identified insect groups such as ants, thrips and cucumber beetles respectively as possible pollinators of cucurbits. Hurd (1966) also stated that other insects such as cucumber scarabs, meloid beetles, flies and moths were involved in pollination but to a lesser extent than bees.

A quantitative approach to the seasonal and diurnal changes in number of foragers gives a detailed description of some aspects of the synchrony with phenology. Whatever be the time of opening of the flower, the commencement of insect visit was found shortly after sunrise and end by noon with maximum activity in the midphase of pollination period. According to Pandey and Yadava (1970) for effective cross pollination to occur, pollen availability and stigma receptivity must be synchronized with the time of visits by pollinators to the flowers. Seaton *et al.* (1936) also stated that stigma is receptive throughout the day but most receptive in the early morning and that several hundred pollen grains should reach the stigma for most effective pollination. The number of foragers changed significantly over the day and over the season. Willis and Kevan (1995) reported the same effect in pumpkin**.** Also in the studies of Stanghellini *et al***.** (2002) the total number of bees increased over time of day on cucumber, muskmelon and watermelon**.** The middle phase of flowering received the largest number of visits. The decline at midday may have been due to excessive heat as opined by Pandey and Yadava (1970)**.**

Gender of flower has been reported as a factor in unisexual species in determining the pollinator visit (Kay *et al.*, 1984; Agren *et al.,* 1986; Bierzychudek, 1987; Schemske *et al.,*1996). But no significant variation in pollinator visit was found between pistillate and staminate flowers even though the staminate flowers normally outnumber the pistillate flowers in all crops. This was supported by Alex (1957) and Stephen (1970) who stated that pistillate and staminate flowers are about equally attractive in cucumbers. This was also observed by Battaglini (1969) in pumpkin.

The studies demonstrate the absolute necessity of insect pollination on fruit set in the cucumber species studied as there was 100 percent abortion of all pistillate flowers that received no entomophilous visitation when they were covered with nylon nets. As visit number increased, there was a highly significant decrease in the number of flowers that aborted. The results showed that percentage of fruit set was much higher in insect pollinated plants than in those isolated from insect visits. Total abortion of female flowers in the absence of insect visitation found in these experiments confirms the results of other studies on cucumber (Rahmlow, 1970; Morris, 1968), watermelon (Spangler and Moffett, 1979; Adlerz, 1966), cantaloupe (Iselin *et al.*, 1974; Rosa, 1924) and squash (Skinner and Lovett, 1992; Cauto *et al.,* 1990). The fact is that non pollinated cucurbit flowers, with the exception of those of parthenocarpic cultivars, will not produce fruit (McGregor, 1976). The numbers of fruit set on the bagged inflorescences were almost negligible, where as there was some set on every unbagged inflorescence, indicating the effectiveness of pollinating insects **(**Pandey and Yadava, 1970). The studies of Stanghellini *et al.* (1997) also demonstrate the absolute necessity of insect pollination on fruit set in non parthenocarpic cucumber and water melon varieties as there was 100 percent abortion for all pistillate flowers that received no entomophilous visitation.

This study also revealed that percentage of fruits with greater growth and normal shape was in the middle diurnal phase (mdp) of middle phase

(MSP) of season. It was due to greater number of pollinators and higher pollen deposition. Malformed fruits were higher in late pollination phase as compared to those in other phases. Flowers that received inadequate pollination resulted in the formation of malformed fruits as stated by Hodges and Baxendale (1995). Anderson (1941) also stated that malformed fruits in cucumbers were the result of poor pollination resulting from too few bee visits per flower. Higher frequencies of insect visit resulted in more number of maximum sized fruits in the plots at harvest which was in concordance with the studies of Free (1968) who found that pollination by honeybees increased percentage of well formed fruits in strawberry. Nye and Anderson (1974) also reported that plots of strawberry caged with honeybees produced fewer malformed fruits. So it is very clear that insect pollination is essential for fruit quality, which is in conformity with the studies on strawberry by Abrol (1989).

It was found that maximum pollination took place in the middle diurnal phase of middle phase of season. This phase is most attractive in terms of higher frequency of visit of insects. The high diversity and high frequency of pollinators observed during the present study has resulted in better pollination of the cucumber. A positive correlation was found between fruit production and number of insects. From an applied stance, evaluation of the role of flower visitors is necessary to enable objective decisions to be reached over the choice of pollinators to maximize crop pollination (Torchio, 1990).

REFERENCES

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.

Adlerz, W.C. (1966). Honeybee visit numbers and watermelon pollination. *J. Econ. Entomol.*, 59: 28-30.

Agren, J.; Elmqvist, T. and A. Tunlid. (1986). Pollination deceit, floral sex ratios and seed set in dioecious *Rubus chamaemorus* L. *Oecologia*, 70:332-338.

Alex, A. H. (1957). Honeybee aid pollination of cucumbers and cantaloupes. *Glean. Bee Cult.* 85(7):398-400.

Anderson, W. S. (1941). Growing cucumbers for pickling in Mississippi. *Bull. Miss. Agric. Exp. Stn.,* 355:17.

Annand, P. N. (1926). Thysanoptera and the pollination of flowers. *Am. Nat.* 60:177-182.

Battaglini, M. B. (1969). The importance of honeybees for fertilizing *Cucurbita pepo*. *Apicolt.,* 35(1):9-12.

Bierzychudek, P. (1987). Pollinators increase the cost of sex by avoiding female flowers. *Ecology*. 68:444-447.

Cauto, R. H. N.; Periera, J. M. S. and L. A. Cauto. (1990). Effects of pollination in *Cucurbita pepo* (summer squash). *Cientifica,* 18(1):21-27.

Connor, L. J. (1969). Honey bee pollination requirements of hybrid cucumbers, *Cucumis sativus* L. *M.Sc. Thesis*, Michigan State Univ., East Lansing.*Abstr. In Amer. Bee J.,* 114(12):457.

Crepet, W. L. (1984). Advanced (constant) insect pollination and mechanisms: pattern of evolution and implications vis-à-vis angiosperm diversity. *Annuals of the Missouri Botanical Garden*, 71:607-630.

Durham. G. B. (1928). Pollen carriers in summer squash. *Jour. Econ. Ent.,* 21:436.

Free, J. B. (1968). The pollination of strawberries by honey bees. *J. Hort. Sci.,* 43:107-111

Free, J. B. (1993). Insect pollination of crops, *2nd. Ed.* Academic press, London, U. K. pp:544

Hodges, L. and F. Baxendale. (1995). Bee pollination of cucurbit crops. Nabraska Cooperative Extension (NF 91-56).

Hurd, P.D. Jr. (1966). The pollination of pumpkins, gourds and squashes (Genus *Cucurbita*). *Bee World*, 47(1): 97-98.

Iselin, W. A., Jensen, M. H. and H. G. Spangler. (1974). The pollination of melons in air inflated greenhouses by honeybees. *Environ. Entomol.* 3(4):664- 666.

Jaycox, E. R., Guynn, G., Rhodes, A. M. and J. S. Vandemark. (1975). Observation on pumpkin pollination in Illinois. *Amer. Bee. J.*, 115(4):139-140.

Kay, Q. O. N., Lack, A. J., Bamber, F. C., and C. R. Davies, (1984). Differences between sexes in floral morphology, nectar production and insect visits in a dioecious species, *Silene dioica*. *New Phytol.*, 98:515-529.

Kevan, P. G. and T. P. Phillips. (2001). The economic impacts of pollinator declines: An approach to assessing the consequences" *Conservation Ecology,* 5(1):8.

Langridge, D. F. (1952). Pollination experiment on pumpkins. Agricultural Department's work. *Austral. Bee Jour.*, 33:84.

Leena, P. T. and M. Nasser. (2015). Effect of insect pollination on fruit production in the cucurbit crop, Ashgourd (*Benincasa hispida* Thunb.& Cogn.). *Int. J. of Tropical Agri.*, 33 (2):831-835

Leena, P. T. and M. Nasser. (2017). Temporal variation in pollinator diversity and its effect on fruit production in Muskmelon, (*Cucumis melo* L.). *Int. J. of Tropical Agri.,* 35(4):1099-1106.

McGregor, S. E. (1976). Insect pollination of cultivated crop plants. *Agriculture Handbook*, 496:306-312.USDA, Washington, DC.

Michelbacher, A. E., Smith. R. F. and P. D. Hurd Jr. (1964). Bees are essential in pollination of squashes, gourds and pumpkins. *Calif. Agr.,* 18(5):2-4.

Morris, H. (1968). pollination of cucumbers. *Glean. Bee Cult.* 1:14-16.

Motes, J. E. (1977). Pickling cucumbers: Production harvesting. Mich. St. *Univ. Ext. Bull.* 837:8.

Nevkryta, A. N. (1953). Insects pollinating cucurbit crops. *Kiev Akad. Nauk. Ukrain SSR.* pp:92.

Nye, W. P. and J. L. Anderson. (1974). Insect pollinators frequenting strawberry blossoms and the affect of honeybees on yield and fruit quality. *J. Amer. Soc. Hort. Sci.*, 99: 40-44.

Pandey, R. S. and R. P. S. Yadava. (1970). Pollination of litchi (*Litchi chinensis* by insects with special preference to honey bees. *Journal of Apicultural Research,* 9(2):103-105.

Rahmlow, H. J. (1970). Cucumbers need the honeybee. *Glean. Bee Cult.* 98(10):585- 587, 634.

Regal, R. (1977). Ecology and evolution of flowering plant dominance. *Science*, 196: 622 - 629.

Rosa, J. T. (1924). Fruiting habit and pollination of cantaloupe. *Proc. Amer. Soc. Hort. Sci.*, 21:51-57.

Rosa, J. T. (1925). Pollination and fruiting habit of the watermelon. Proc. *Amer. Soc. Hort. Sci.* 21:51-57.

Sanduleac, E. (1959). Data on the entomophilous pollination and the selection of cucurbitaceae. *Lucr. Stiint Stat. Cent. Seri. Apic.*, 1:129-132.

Schemske D.; Agren, J.; J. le Corf. (1996). Deceit pollination in the monoecious neotropical herb *Begonia oaxacana* (Begoniaceae). In: Lloyd D.G.B, Barrett S.C.H. (eds) Floral biology. Studies on floral evolution in animal pollinated plants. Chapman and Hall, New York., pp:292-318.

Seaton, H. L.; Hutson, R. and J. H. Muncie. (1936). The production of cucumbers for pickling purposes. *Spec. Bull. Mich. Agr. Exp. Stn.*, 273: 31.

Sedgley, M., and P. B. Scholefield. (1980). Stigma secretion in the watermelon before and after pollination. *Bot. Gaz.*, 141(4):428-434.

Skinner, J. A., and G. Lovett. (1992). Is one visit enough? Squash pollination in Tennessee. *Amer. Bee J.,* 132 (12):815.

Skrebtsova, N. D. (1964). Use of pollinating activity of honey bees for developing hybrid vegetable seed. *Trud. Nauch Issled. Inst. Pchelovod. Selsk. Khoz. Rybnoe*, pp: 223-245.

Spangler, H. G., and J. O. Moffett. (1979). Pollination of melons in greenhouses. *Glean. Bee Cult.,* 107:17-18.

Stanghellini, M. S.; Ambrose, J. T. and J. R. Schultheis. (1997). The effects of honey bee and bumble bee pollination on fruit set and abortion of cucumber and water melon. *Am. Bee J.*, 37(5):386-391.

Stanghellini, M. S.; Schultheis, J. R. and J. T. Ambrose. (2002). Pollen mobilization in selected

Cucurbitaceae and the putative effects of pollinator abundance on pollen depletion rates. *J. Amer. Soc. Hort. Sci.,* 127(5):729-736. .

Stephen, W. A. (1970). Honey bees for cucumber pollination. *Am. Bee J.,* 110: 132-133.

Tepedino,V. J. (1981). The pollination efficiency of squash bee (*Peponapis pruinosa)* and the honeybee (*Apis mellifera*) on summer squash (*Cucurbita pepo*). *Journal of the Kansas Entomological Society,* 54(2):359-377.

Thompson, R. C.; Doolittle, S. P. and D. J. Caffrey. (1955). Growing pumpkins and squashes. *U. S. Dept. Agr. Farmer's Bul.*, 2086:30.

Tontz, C. (1944). Ants pinch hit for bees. Glean. *Bee Cult.,* 72:482.

Torchio, P. F. (1990). Diversification of pollination strategies for U.S. crops. *Environ. Entomol.,* 19(6):1646-1656.

Verdieva, M. G. and M. K. Ismarlova. (1960). The influence of bee pollination on the increase of the crop from seed squash. *Pchelovodstvo*, 37(9): 4041.

Willemstein, S. C. (1987). An evolutionary basis for pollination ecology. *E. J. Brill*, Leiden.

Willis, D. S. and P. G. Kevan. (1995). Foraging dynamics of *Peponapis pruinosa* (Hymenoptera: Anthophoridae) on pumpkin (*Cucurbita pepo*) in Southern Ontario. *Canada Entomol.*, 127(2):167-175.

Wiolfenbarger, D. O. (1962). Honeybees increase squash yields. *Fla. Agr. Expt. Sta. Sunshine State Agr. Res. Rpt.*, 7(1):15, 19, 310.

Woyke, H. W. and K. Bronikowska. (1984). The influence of honeybee population on pickling cucumber yield. In V International Symposium on Pollination, Versailles, 27-30 september 1983. Les Colloques de I'INRA, Paris. pp: 323-327.