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EFFECT OF HONEYBEE VISITS TO APPLE FLOWERS ON FRUIT SET AND FRUIT CHARACTERISTICS

Yehia[1], T.A., M.A. Abd Al-Fattah[2], El-Dereny, Sarah, H[2].

1- Department of Pomology, Faculty of Agriculture, Cairo University, Giza, Egypt

2- Department of Economic Entomology & Pesticides, Faculty of Agriculture, Cairo University, Giza, Egypt

ABSTRACT

The present investigation was carried out on Anna and Dorsett Golden apple trees during two successive seasons 2006 and 2007. It aimed to study the effects of number of honeybee visits/ flower on fruit set and fruit characteristics of the studied cultivars. Several sequential treatments were applied from 1 bee visit/ flower up to ten bee visits/ flower besides zero visit (self pollination) and open pollination treatments. Results of the present study showed direct improvements as a result of increased bee visits/ flower which was reflected on significant increase in fruit set%, number of seeds/ fruit and average seed weight.

Moreover, indirect effects of activated bee visits/ flower were expressed as significant increment in fruit weight which averaged 19.2 g for Anna apple fruit as a result of zero bee visit/ flower and increased significantly to 37.45 g for only one bee visit/ flower and continued its significant increment to reach 106.3 g for 10 bee visits/ flower in season 2006. Similar trend was observed for Dorsett Golden during both seasons of the study.

Consequently, significant improvements in fruit volume, fruit length, diameter, shape index, TSS% and firmness were recorded and presented. Thus, it can be recommended from results of the present study to maintain sufficient honey bee colonies in Anna and Dorsett Golden apple orchards that offer at least ten bee visits/ flower to increase fruit set and to achieve satisfactory improvement in yield and fruit characteristics.

Key Words: apples- pollination- honeybee- fruit set- fruit characteristics

INTRODUCTION

Apple fruits are classified into grades depending on fruit shape and other characteristics that affect their commercial price. Thus, apple growers receive only quarter of the price for their fruits that pronounce shape defects (Brault and Oliveira 1995). Apple flowers are hermaphrodite and most commercial cultivars are strongly self incompatible (Westwood 1993). Therefore good harvest depends on effective cross pollination by insects specially honeybees (Free 1993). Most apple cultivars contain 10 ovules, thus 10 pollen grains are necessary for formation of ten 10 seeds/ fruit which depends on density of honeybee colonies and their efficiency (Benedek and Nyeki, 1995 and Yehia *et al.,* 1999b) which is also affected by pollinizer cultivar density and distribution (DeGrandi-Hoffman *et al.,* 1985 and Brookfield *et al.,* 1996). Efficiency of pollen removal was studied in four apple cultivars and was concluded that honeybees increased pollen delivery in apple orchards and considered one of the most effective pollinators for pollen removal and deposition (Thomson and Goodell, 2001). The number of fertilized ovules in Anna apple fruits increased by cross pollination which reduced fruit drop and improved fruit shape and other characteristics (Brookfield *et al.,* 1996; Hegazy 1998 and Yehia *et al.,* 1999a) as they provide important source of growth hormones such as auxins (Fourez, 1995 and Stino *et al.,* 2001). It was found that sequentially increasing the density of bee colonies in apple orchards from 2.5/ ha as recommended previously (Mayer, 1994) to 5 colonies/ ha increased the number of bees/ tree which directly increased the amount of pollination which was expressed in higher fruit set and fruit characteristics (Stern *et al.,* 2001). Number of insect visits/ flower was found to influence commercial 'Red Delicious' apple fruit set as one visit increased fruit set (27.4%) and fruit size (>70 mm diameter), thus flower visiting rates is an important factor for improving apple productivity (Vicens and Bosch, 2000).

In this respect, any technique that would improve honeybees activity and their efficiency in the apple orchard should improve orchard yield and productivity efficiency (DeGrandi-Hoffman *et al.,* 1985 and Benedek and Nyeki, 1996). Frequency of honeybee visits on apple flowers determine pollination efficiency in terms of levels of fruit set and fruit characteristics. Consequently honeybee management

suggests the number of colonies required to achieve sufficient pollination and minimum fruit thinning (Scheneider *et al.,* 2002).

Therefore the main objective of this study was to determine the influence of increased sequential numbers of honeybee visits/ flower on fruit set and fruit characteristics of Anna and Dorsett apple cultivars.

MATERIALS AND METHODS

The present study was carried out during two successive seasons 2006 and 2007 on 4 years old Anna and Dorsett Golden apple trees budded on MM106 rootstock. Trees were spaced at 4X4 m, planted in the clay loamy soil of Elkanater Research Station, at the orchard of Agriculture Development Systems. Trees chosen for this study were of normal growth, free from any apparent infections and subjected to furrow surface irrigation and the normal horticultural practices.

Five trees were selected from each cultivar and each tree was considered a replicate. Fourty clusters for each pollination type were selected uniformly distributed on different parts of each replicate tree and labeled at first pink stage. At full pink stage, flowers of each cluster were eliminated to the king flower which was covered with pergamin pollination bag and all other lateral flowers were removed, besides another group which was not covered and served as open pollination treatment. At full bloom, group of fourty clusters at each of the replicate trees received the following controlled honeybee visits (pollination treatments):

0 bee visit/ flower (self pollination treatment)	6 visits/ flower
1 visit/ flower	7 visits/ flower
2 visits/ flower	8 visits/ flower
3 visits/ flower	9 visits/ flower
4 visits/ flower	10 visits/ flower
5 visits/ flower	Open bee visit/ flower

Sixty days after full bloom, percentage of final fruit set was determined for the previous pollination treatment from the following formula:

Fruit set % = (number of fruits/ number of flowers) * 100

Representing samples of 25 fruits were collected from each pollination treatment at maturity stage (100-110) days after full bloom according to (Abdelaziz *et al.,* 1985). The effects of the studied

pollination treatments on Anna and Dorsett Golden fruit characteristics were investigated by measuring the following parameters; fruit weight (g), volume (cm^3) fruit length (cm), fruit diameter (cm), fruit shape index (L/D ratio), fruit firmness using pentameter (pressure tester- lb/ $inch^2$), total soluble solids (T.S.S)% in fruit juice using hand refractometer according to (AOAC, 1985), number of seeds and average seed weight/ fruit.

Statistical Analysis

Experimental design followed randomized complete block design with five replicates; each tree was considered a replicate. The obtained data were subjected to analysis of variance (ANOVA) according to Snedecor and Cochran (1980) using MSTAT (1984) software and means of treatments were compared using LSD Waller and Duncan (1969) multiple range test at significance level of (0.05).

RESULTS AND DISCUSSION

1- Fruit set and seed development

Final fruit set percentage was significantly affected by number of bee visits/ flower in both studied cultivars during both seasons 2006 and 2007 (Fig. 1). It is apparent that Anna fruit set percentage was positively correlated with number of honeybee visits as it was only 32 and 34% as a result of one bee visit/ flower and significantly increased due to each increase in bee visits/ flower, where it was enhanced by 10 visits/ flower to reach 80 and 83% during both seasons of the study (Table 1).

Similar trend was observed for Dorsett Golden with higher rates of increment as 10 visits/ flower significantly improved fruit set percentages to 90 and 92% in seasons 2006 and 2007 (Table 2).

Data represented in figure (2) revealed that seed number was related to number of bee visits/ flower in the two studied cultivars during both seasons of the study. Anna apple cv showed almost zero fruit seed content in the unpollinated flowers, single visit/ flower caused significant increment in number of seeds/ fruit as it averaged 1.25 seeds followed by significant increment in seed numbers/ fruit as number of bee visits/ flower increased to reach the highest significant seed number/ fruit as a result of 10 bee visits/ flower with average 9.13 which was not significantly different than that of the open pollinated flowers (9.37 seeds/ fruit) during season 2006. Although

Dorsett apple cultivar responded positively to number of bee visits/ flower as it significantly increased from 2.93 seeds as a result of single bee visit to reach 9.7 seeds/ fruit for ten visits/ flower. It was also found that unpollinated flowers produced an average of 2.59 seeds/ fruit which was not significantly different than that of one bee visit/ flower during 2006 season.

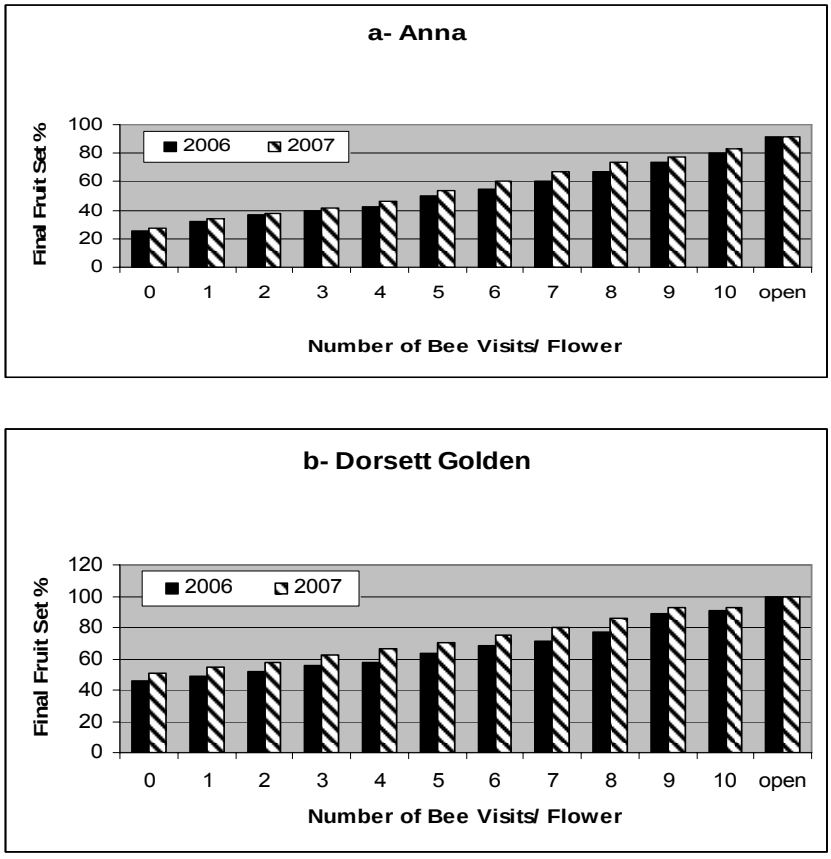

Figure 1: Effect of honeybee visits on percentage of final fruit set

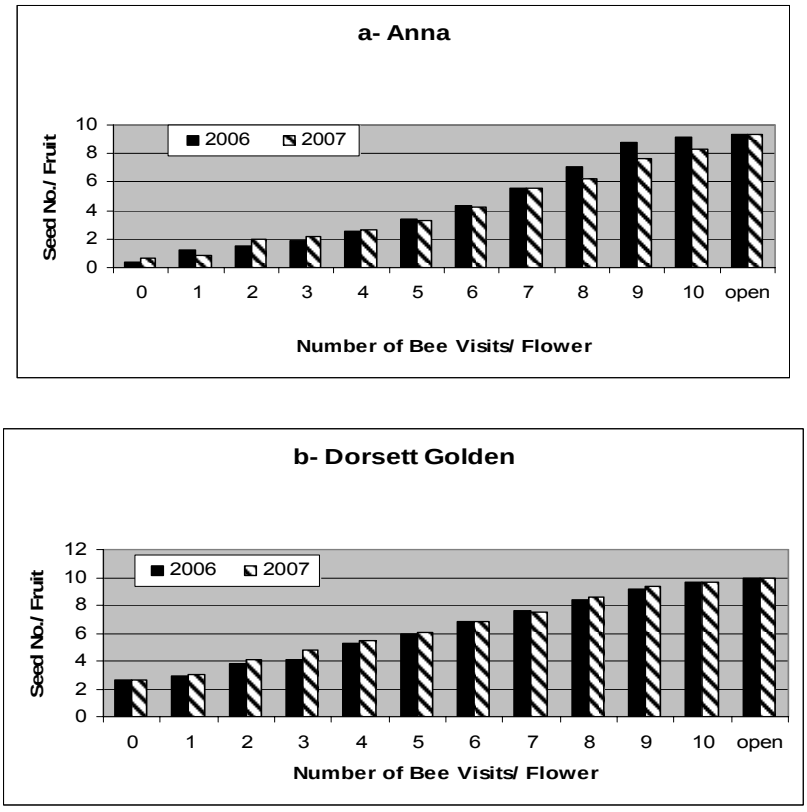

Figure 2: Effect of honeybee visits on seed number/ apple fruit

Similar response was observed for both cultivars in terms of number of seeds/ fruit as a result of different treatments of bee visits/ flower during season 2007.

Seed weight is important parameter which reflects the development of seeds/ fruit and in turn affects all other fruit characteristics (Fig. 3). Results of the present study showed that seed weight was significantly increased with increasing the number of bee visits/ flower from 1 visit (0.03 g) to reach (1.175 g) as a result of 10 bee visits/ flower in Anna apple cultivar during season 2006. Similar trend was observed during season 2007 where the average seed weight increased from 0.03 to 1.067 g as bee visits/ flower increased from 1 to 10 visits for Anna apple flowers. Meanwhile Dorsett apple cultivar

had the same effect of bee visits on average seed weight during both seasons of the study.

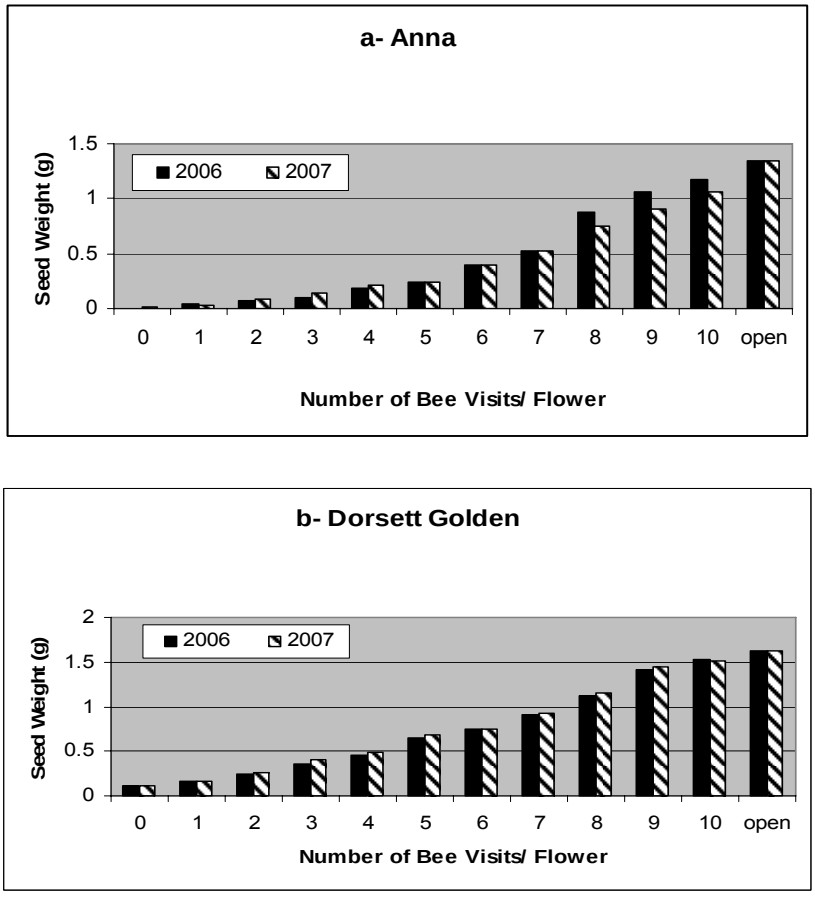

Figure 3: Effect of honeybee visits on apple seed weight

Results of the present investigation are in line with previous findings that increasing bee activity leads to high yield and fruit set in apple orchards (Benedek and Nyeki, 1996 and Scheneider *et al.*, 2002). Also, the incidence of high fruit set percentage of Anna and Dorsett in the treatment zero visit/ flower is referred to self pollination and early thinning of the lateral flowers in each inflorescence. Meanwhile reduced seed development in terms of number and weight at low bee visits confirms previous findings concerning the degree of

compatibility of Dorsett Golden as partly self fruitful while Anna is considered partly self unfruitful (Yehia 1990 and Yehia *et al.,* 1999a).

2- Fruit Characteristics

Figures (4) and (5) show that average fruit weight of Anna and Dorsett apple cultivars were significantly affected by number of bee visits/ flower during both seasons of the study. In season 2006, the lowest significant fruit weight averaged 19.42 g as a result of zero bee visit/ flower, as bee visits increased average fruit weight increased. The single bee visit/ flower significantly resulted in average fruit weight of 37.5 g. Meanwhile, the highest significant fruit weight reached 106.3 g and was produced as a result of 10 visits/ flower which did not significantly differed than that produced from open pollination (109.1 g). Similar trend was observed during season 2007 in both Anna and Dorsett apple cultivars as fruit weight significantly increased with increasing number of bee visits/ flower. Similarly, in both seasons of the study, Anna and Dorsett Golden average fruit volume significantly positively responded to the number of bee visits/ flower.

Fruit length of Anna and Dorsett apple cultivars were significantly affected by number of bee visits/ flower in both seasons of the study (Fig 6). Both Anna and Dorsett fruit lengths averaged 3.54 and 3.24 cm which were the lowest significant fruit lengths as a result of zero bee visit/ flower followed by 4.38 and 3.75 cm for a single bee visit/ flower during season 2006.

It responded significantly to the increase in number of bee visits/ flower as the highest significant fruit length was obtained from 10 bee visits/ flower which was not significantly different than that obtained from open pollinated flowers of Anna cv., fruit length averaged 6.96 and 7.12 cm in both cases, respectively. During season 2007, fruit length of both cultivars showed similar trend where fruit length was significantly increased as a result of increased number of bee visits/ flower

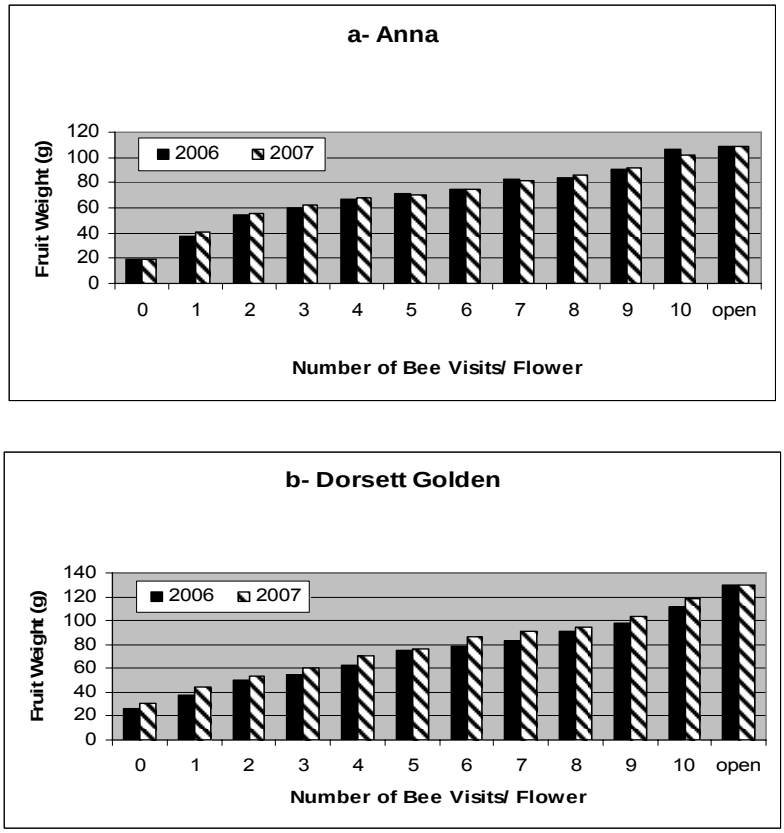

Figure 4: Effect of honeybee visits on apple fruit weight

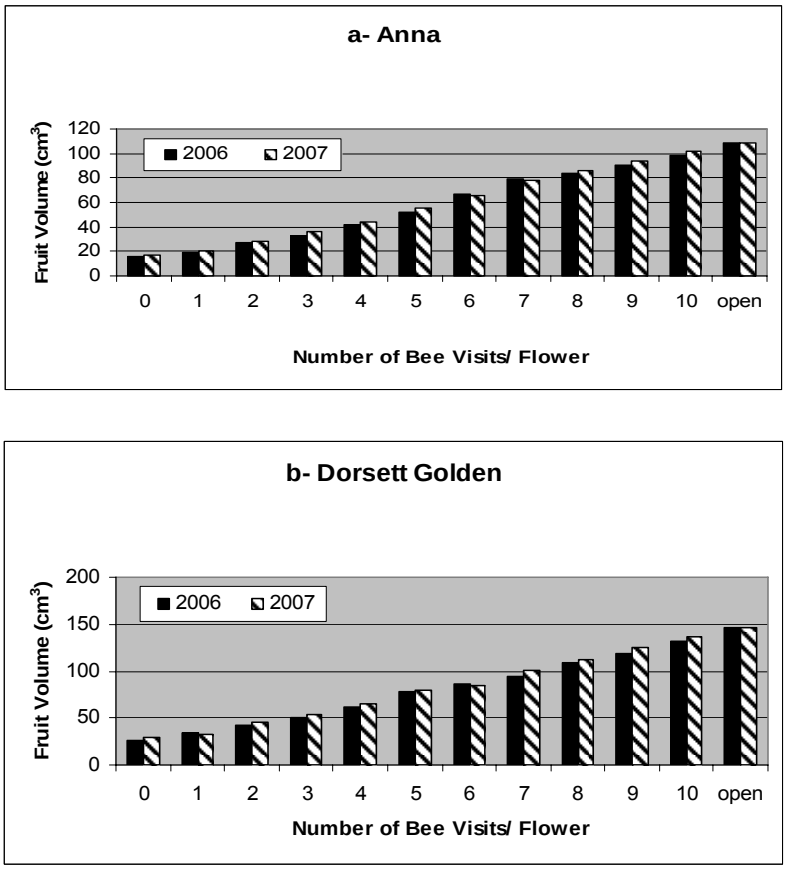

Figure 5: Effect of honeybee visits on apple fruit volume

In addition, fruit diameter of both Anna and Dorsett apple cultivars was significantly increased as number of bee visits/ flower increased in seasons 2006 and 2007. The lowest significant Anna fruit diameter averaged 3.86 and 3.88cm for single visit/ flower, whereas the 10 visits/ flower produced the highest significant fruit diameter which averaged 6.26 and 6.36cm during both seasons of the study (Fig 7).

Figure (8) indicated that fruit shape index was not significantly affected by number of bee visits/ flower in the two studied cultivars during both seasons 2005 and 2006.

Fruit firmness of both Anna and Dorsett apple cultivars was significantly higher as a result of low number of bee visits/ flower and

significant gradual decrease was attained as number of bee visits/ flower increased during seasons 2006 and 2007 (Fig 9). Ten bee visits/flower reduced significantly fruit firmness than other lower number of visits as it averaged 2.85 and 2.45 lb/in^2 in Anna and Dorsett fruit during season 2005. However, unpollinated flowers showed the highest significant fruit firmness followed by single bee visit/ flower in the two studied cultivars.

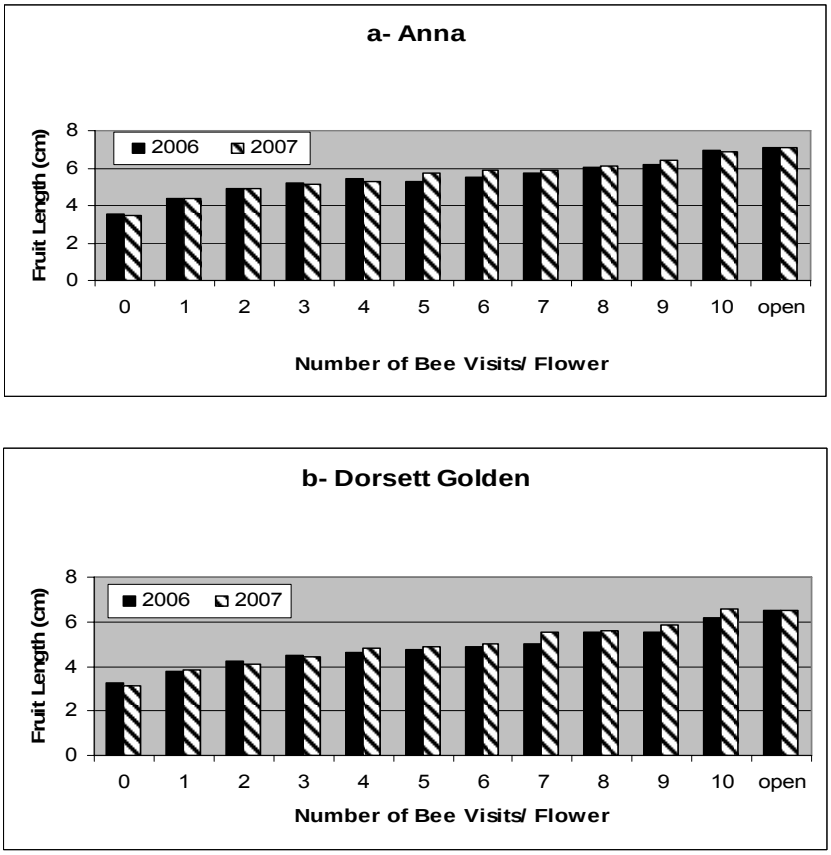

Figure 6: Effect of honeybee visits on apple fruit length

Number of bee visits/ flower significantly affected T.S.S. content of Anna and Dorsett apple cultivars during both seasons of the study (Fig. 10). It was found that the lowest T.S.S. was recorded in the fruits formed from unpollinated flowers which were not significantly

differed from those exposed to single bee visit/ flower, (1.803 and 2.283% respectively). This characteristic positively responded to the increase in bee visits/ flower where it reached the highest significant levels for 10 bee visits/ flower and open pollination. During season 2006, T.S.S averaged 12.68 and 13.21%. in Anna fruit juice respectively.

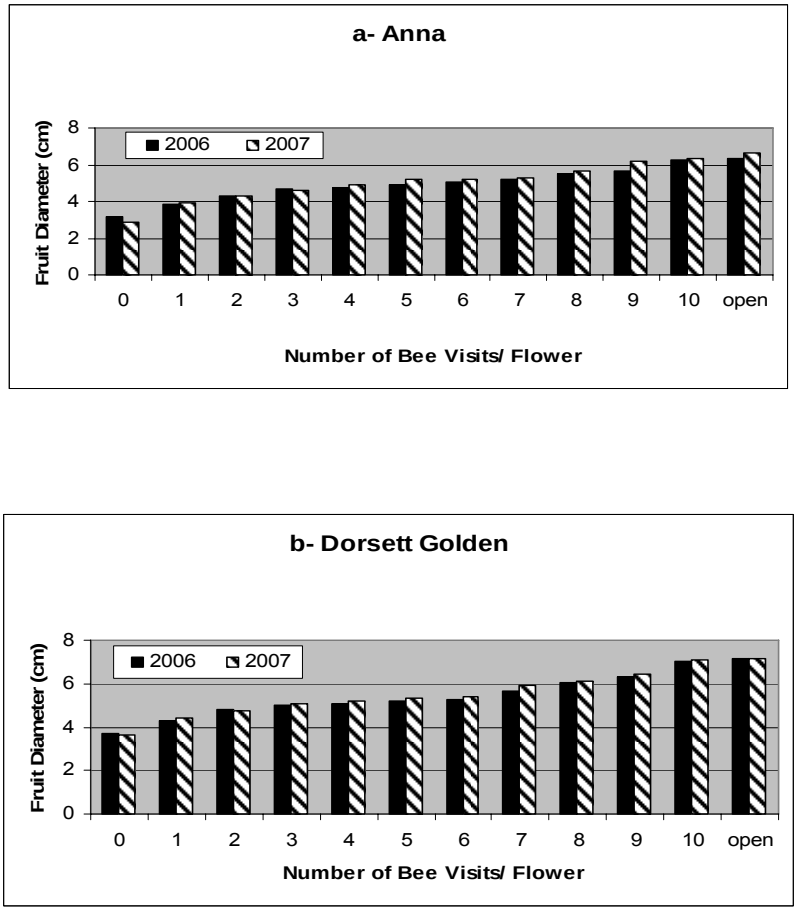

Figure 7: Effect of honeybee visits on apple fruit diameter

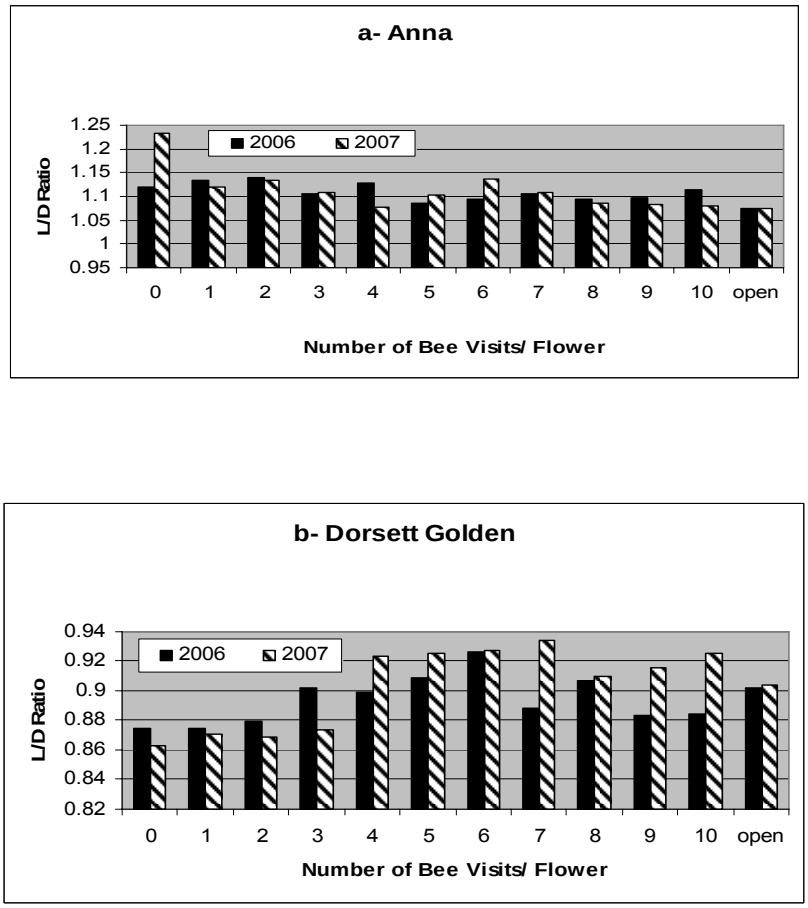

Figure 8: Effect of honeybee visits on apple fruit L/D ratio

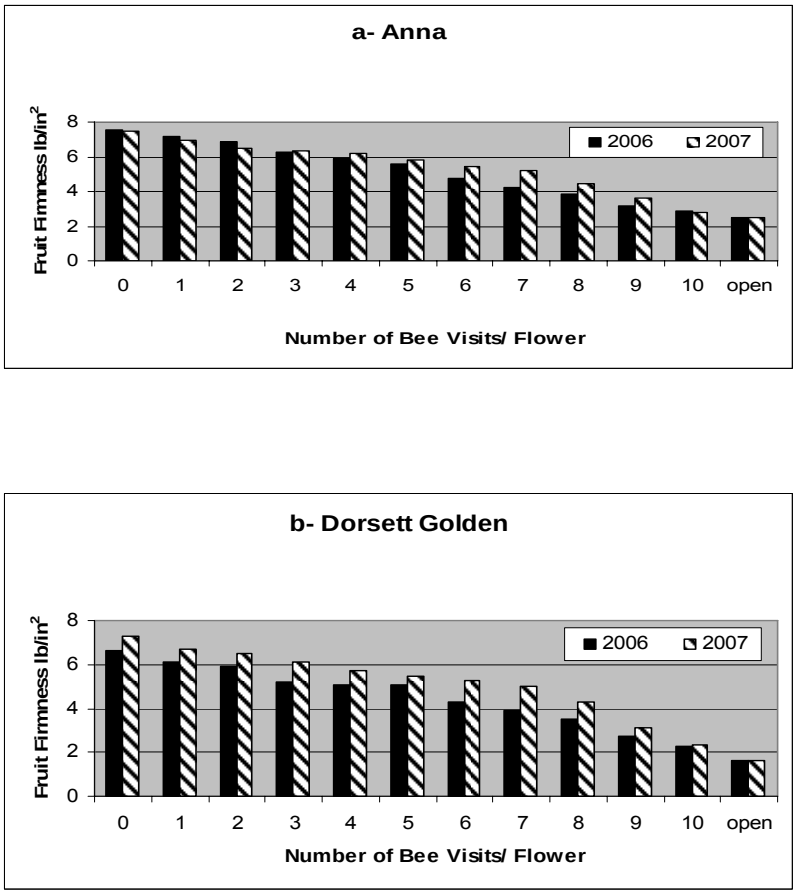

Figure 9: Effect of honeybee visits on apple fruit firmness

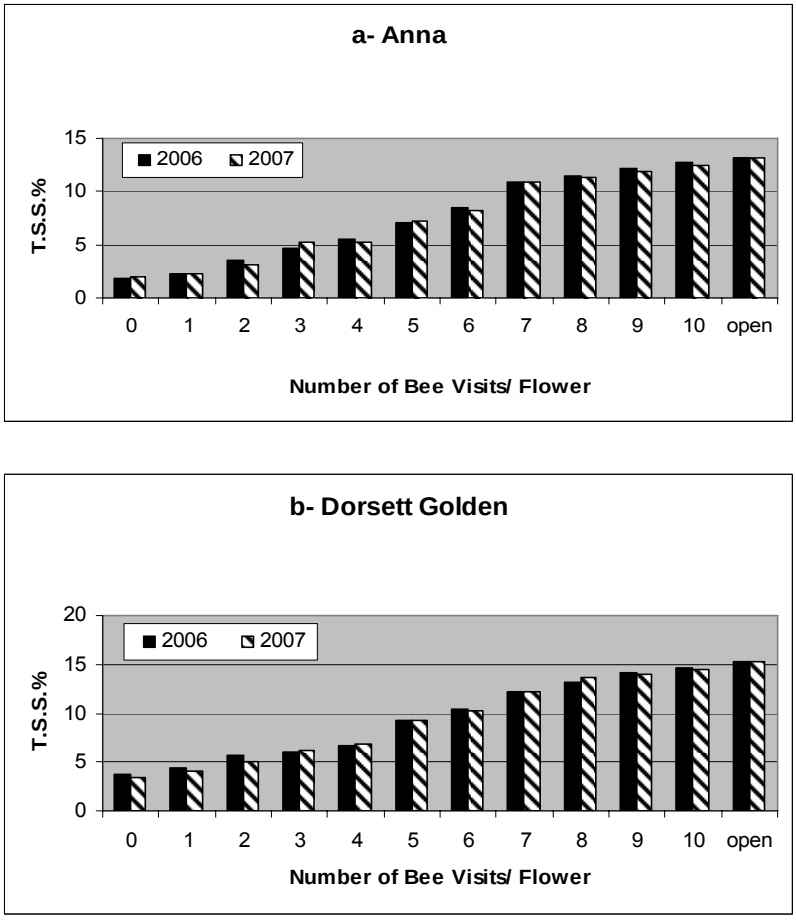

Figure 10: Effect of honeybee visits on apple fruit T.S.S.

The above mentioned results indicated that significant improvement on fruit characteristics of Anna and Dorsett Golden cultivars including fruit weight, volume, length, diameter and T.S.S. as a result of increased honeybee visits/flower However, fruit shape index was not significantly affected as both length and diameter increased proportionally due to activated honeybee visits. Whereas, fruit firmness decreased as a result of increased honeybee visits/ flower, the fruit quality and grade were improved with decreasing fruit firmness.

Consequently results of the present study are in line with previous findings of Brookfield *et al.,* (1996); Hegazy (1998) and Yehia *et al.,(*1999a); Vicens and Bosch, (2000) Thomson and Goodell, (2001) ; Stern *et al.,* (2001); Scheneider *et al.,(*2002) who concluded that increased bee activity had a positive correlation with fruit set and fruit characteristics.

Thus, in order to achieve highly satisfactory productivity in Anna and Dorset Golden apple orchards; supplying sufficient numbers of honeybee colonies prior to flowering are recommended.

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تأثير زيارات نحل العسل لأزهار التفاح على العقد و مواصفات الثمار

طاهر أحمد يحيى[1]- محمد عبدالوهاب يوسف[2]- سارة حسن الدرينى[2]

[1]- قسم بساتين الفاكهة- كلية الزراعة- جامعة القاهرة- الجيزة- جمهورية مصر العربية
[2]- قسم الحشرات الأقتصادية ونحل العسل- كلية الزراعة- جامعة القاهرة- الجيزة- جمهورية مصر العربية

أجريت الدراسة الحالية على أشجار تفاح عمر 4 سنوات لصنفى الأنا و الدورست جولدن نامية فى محطة بحوث البساتين بالقناطر الخيرية محافظة القليوبية خلال موسمى 2005 و2006. استهدفت الدراسة بحث تأثير عدد زيارات نحل العسل لأزهار التفاح على نسبة العقد ومواصفات الثمار الناتجة. أجريت العديد من المعاملات بتعريض أزهار الصنفين محل الدراسة إلى عدد من الزيارات تراوح من 1 إلى 10 زيارات للزهرة بجانب معاملة بدون زيارات نحل العسل وكذلك معاملة للتلقيح المفتوح. أوضحت النتائج تأثيرات مباشرة لزيادة عدد زيارات نحل العسل للأزهار على الزيادة المعنوية فى نسبة عقد الثمار و عدد البذور داخل الثمرة و كذلك متوسط وزن البذور. كما أوضحت الدراسة تأثير للمعاملات على تحسين معنوى فى وزن الثمار حيث كان متوسط وزن ثمرة التفاح الأنا الناتجة من التلقيح الذاتى 19.2 جم وأدت زيارة واحدة لنحل العسل للزهرة إلى زيادة معنوية فى متوسط وزن الثمرة حيث بلغ 37.45 جم و استمرت الزيادة المعنوية فى متوسط وزن الثمار لكل زيادة فى عدد زيارات نحل العسل للأزهار و التى بلغت 106.3 جم لعدد 10 زيارات نحل للزهرة خلال موسم 2005. نفس اتجاه النتائج فى الزيادة المعنوية لوزن الثمار تحقق فى الموسم التالى لصنف التفاح الأنا و كذلك لصنف الدورست جولدن خلال موسمي 2005 و2006.

أيضا أدت زيادة عدد زيارات نحل العسل للأزهار إلى زيادة معنوية فى حجم الثمار و طول و قطر الثمار و كذلك نسبة المواد الصلبة الذائبة مع انخفاض معنوي في الصلابة و ذلك لصنفى الأنا و الدورست جولدن خلال موسمى الدراسة.

وبناء على نتائج الدراسة الحالية يمكن التوصية بتوفير عدد مناسب من خلايا نحل العسل التى توفر على الأقل عدد 10 زيارات للزهرة الواحدة حيث يؤدى ذلك إلى زيادة نسبة العقد و تحسين معنوى فى مواصفات جودة الثمار مما يؤدى إلى زيادة الكفاءة الإنتاجية لبساتين التفاح.