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EFECTS OF SUPPLEMENTAL FEEDING FOR DIFFERENT PERIODS ON THE PRODUCTIVITY OF HONEY BEE DRONES

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Abstract: The investigation was carried out in apiary at Sohag region during the period from the first of January to the first of April, 2008. The effects of supplemental feeding for different periods on activity of colonies, and their relation to drones production were studied. Positive correlations were found between supplemental feeding and each of bee population size, workers and drones brood-rearing activity, stored pollen and weight of both drone body and mucus gland. Bee colonies fed on supplemental feeding at different periods produced significantly more bees, workers and drones brood and stored pollen than unfed control colonies. The maximum average of each of bee population size (11361 bee/ colony), workers brood area (605.2 $inch^2$/colony) and stored pollen (80.7 $inch^2$/ colony) resulted from bee colonies fed for 10-weeks period. Whereas the feeding period of 8-weeks gave the highest average of drones brood (34.6 $inch^2$/ colony), marking a 64.8% increment as compared with unfed control colonies. The feeding period of 10-weeks gave the highest average weight of both mature drone body (180.8 mg) and mucus gland (12.8 mg), inducing 12.3% and 19.6% increment in weight of drone body and mucus gland, respectively relative to the unfed control. Meanwhile, the highest increment in weight of newly emerged drones was 4.8% resulted from 10-weeks feeding period. The coefficient of determination was 0.21, indicating that the feeding periods, bee population, workers brood, and stored pollen accounted for 21% of drone production changes.

Key words: Honey bee, drones brood, supplemental feeding, body weight, mucus gland.

Introduction

Drones of honey bee do not forage or participate in colony maintenance or defence. Their only known function is in mating of virgin queens, which each mate with between 6 to 17 drones during mating flight (Adams *et al*., 1977). Each drone mates only once and then dies shortly thereafter (Witherell, 1965). Obtaining adequately mated bee queens in commercial mating apiaries is one of the important procedures required to produce bee queens with a long fertile life. This requires careful management by the beekeepers in providing sufficient numbers of drones of a suitable age in the same area at the same time that virgin queens are on their mating flights (Rhodes, 1999; 2002). Adult drones do not feed themselves because drones are characterized by a lower direct pollen consumption and lower digestive enzyme levels than in workers, although their need for nutrients is quite high. So, adult drones depend on an abundant supply of healthy nurse bees to feed them on pre-digested food, via proteinaceous glandular secretions, pollen and honey (Hrassnigg and Crailsheim, 2005). The ability of a colony to maintain a high population of adult drones depends on a continuous supply of pollen coming into the colony. Drone eviction occurs when a colony stops feeding its drones due to a lack of incoming pollen supplies (Rhodes, 2002). As known, the pollen is necessary for the growth, development and activity of honey bees. Shortage of pollen results in decreasing of brood rearing, developmental abnormalities, decreased length of workers life and poor honey production (Kleinschmidt and Kondos, 1978, Winston *et al*., 1983). Since pollen is often not present in adequate quantities in the field it is a limiting factor in colony development. So the beekeepers are concerned with providing an effective pollen supplements or substitutes, when natural pollen supplies are insufficient to promote colony development and health. The probability of proteinious feeding during autumn is essential to increase the ability of brood rearing and to prepare the bees for over wintering (Omar, 1989). More-over, obtaining high population of bees in the spring is of a particular interest to beekeepers.

The useful pollen substitute or supplements should stimulate colony growth and support aspects of worker quality, such as high brood survival and long adult life (Winston *et al*., 1983). Meanwhile, the pollen substitute should be acceptable and has the necessary stimulation for bees to consume their food (Doull, 1973). Haydak (1970) recommended beekeepers to feed their bee colonies with sugar syrup and pollen supplements or substitutes to maintain the brood rearing activity at times and in areas where the bees natural food sources are inadequate.

The aim of the present investigation was to evaluate the effect of supplemental feeding at different periods on colony status; brood rearing activity and bee population, and their relation to drones productivity. In addition to determine the ideal period of supplemental feeding for drones production at early and suitable time for appearance and mating of honey bee virgin queens.

Materials and Methods

The experiments were carried out in apiary at Sohag region, during the period from the first of January to the first of April, 2008.

Honey bee colonies:

Thirty honey bee colonies of the first hybrid of Carniolan honey bee, *Apis mellifera* L. nearly in equal strength and headed with sister queens were initiated. The colonies were randomly divided into five groups (six colonies for each) according to supplemental feeding period as follows:

-Group I, feeding period was 10 weeks, from January 20^{th} to April 3^{rd}.

-Group II, feeding period was 8 weeks, from February 5^{th} to April 3^{rd}.

-Group III, feeding period was 6 weeks, from February 20^{th} to April 3^{rd}.

-Group IV, feeding period was 4 weeks, from March 5^{th} to April 3^{rd}.

-Group V, control, the colonies were not fed with supplemental feeding, only receiving natural free feeding.

Diet preparing and administration:

The diet used in the present study was that described by Moustafa (2000). It consisted of 5 parts of powdered sugar, 3 parts defatted soybean meal, 1 brewer's dried yeast, 0.5 skimmed milk powder and 0.5 date palm pollen. The diet was offered in cake form at the rate of 150 g/colony.

It was offered and renewed continuously to each colony at different feeding periods, starting in January 20^{th} and ending in April 3^{rd}. The cakes were placed over the brood nest in perforated polyethylene bags to reduce the water evaporation.

Determination of food consumption:

Throughout the investigation, the food consumption was recorded by calculating the difference in the weight of diet before and after feeding (g/colony). This procedure was repeated several times at different periods of supplemental feeding.

Measurements of honey bee activities:

-Bee population size: the numbers of adult honey bees were determined every 12 days by a visual method of comparison with standard photographs of known numbers of honey bees on combs (Jeffree, 1951). Inspections were conducted as far as possible, when few bees were flying.

-Sealed brood and stored pollen: in all colonies, the total areas of worker sealed brood and stored pollen were measured. A graduated frame divided into square inches as used after the bees had been shaken from the combs (Jeffree, 1958). This procedure was carried out at 12-day intervals throughout the different feeding periods of the experiment. Drone areas were corrected by multiplying the brood areas by 12/14.

The increment of bee population size, sealed brood and stored pollen, which due to supplemental feeding was calculated from the following equations:

$$\text{\% Increase in bee population (BP)} = \frac{\text{BP of treatment} - \text{BP of control}}{\text{BP of control}} \times 100$$

$$\text{\% Increase in sealed brood (SB) (workers and drones)} = \frac{\text{SB of treatment} - \text{SB of control}}{\text{SB of control}} \times 100$$

$$\text{\% Increase in stored pollen (SP)} = \frac{\text{SP of treatment} - \text{SP of control}}{\text{SP of control}} \times 100$$

The body weight and the biometrical measurements:

To study the effect of supplemental feeding on drones quality, fresh and dry body weight of newly emerged drones were determined. Sixty adult drones one-day old for each treatment were obtained from six replicates (10 individuals for each), then individually weighed (in mg). After that the drones were dried in an oven at 60°C for one week according to Henderson (1992), then weighed. Finally the fresh and the dry body weight of adult drones were recorded. Also, the increment of body weight due to supplemental feeding was calculated using the following equation:

$$\text{\% Increase in body weight} = \frac{\text{W. fed drone} - \text{W. unfed drone}}{\text{W. unfed drone (control)}} \times 100$$

Other measurements were done on mature drones which were collected from the entrances of treated hive. Each treatment was represented by 30 mature drones from six replicates (5 individuals for each). The drones were individually weighed then the right fore-wing length and width for each drone was measured. Thereafter, the same drone was dissected in normal physiological solution using stereo-microscope of 40 times magnification force, in order to remove and determine the weight of mucus gland. Also, the increment of mucus gland due to supplemental feeding was calculated using the following equation:

$$\text{\% Increase in mucus gland} = \frac{\text{W. treated gland} - \text{W. untreated gland}}{\text{W. untreated gland (control)}} \times 100$$

Statistical analysis:

The statistical analysis was conducted by using the SAS general linear models procedure. Differences among means were determined by L.S.D. Significant differences were determined at P<0.05.Simple and multiple correlations between studied factors were calculated (SAS Institute, 1990).

Results and Discussions

Feeding periods and colony activities as related to drones production:

Consumption of supplemental feeding

The averages of total consumption of supplemental feeding at different periods are shown in Table (1) and Fig. (1). The total consumption was 586.7, 451.0, 382.0 and 112.0 g/colony for 10-week, 8-week, 6-week and 4-week feeding periods, respectively.

Table(1): Effect of supplemented feeding at different periods on some activities of honey bee colonies.

Feeding period (weeks)	Feeding consumption (g/colony)	Increment of bee activities (%)			
		Bee population	Worker brood	Drone brood	Stored pollen
I 10-week	586.7	38.7	61.3	17.6	83.4
II 8-week	451.0	37.4	50.1	64.8	31.8
III 6-week	382.0	21.4	17.3	42.9	8.2
IV 4-week	112.0	28.1	19.2	34.8	2.3

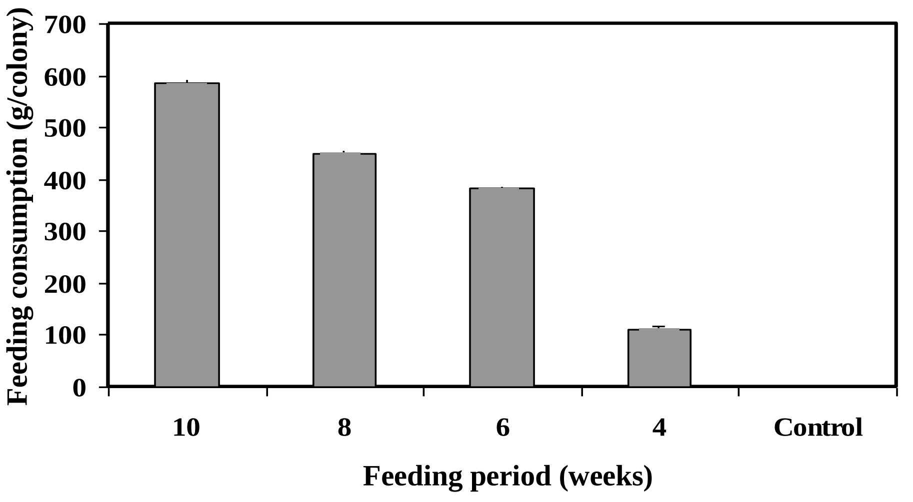

Fig.(1): Average of supplemental feeding consumption at different periods by honey bee colonies.

Feeding periods and bee population:

Table (1) and Fig. (2) show the total average of bee population size at different periods of supplemental feeding. In general, honey bee colonies fed with supplemental feeding at different periods produced significantly more bees than unfed control colonies. A high positive correlation was found between supplemental feeding and bee population sizes (r= 0.70). The feeding period of 10-weeks gave the highest average of bee population (11361.0 bee/colony), which induced 38.7% increment in bee population whereas the lowest average was recorded by 6-week feeding period (9944.3 bee/colony), marking a 21.4% increment over the unfed control.

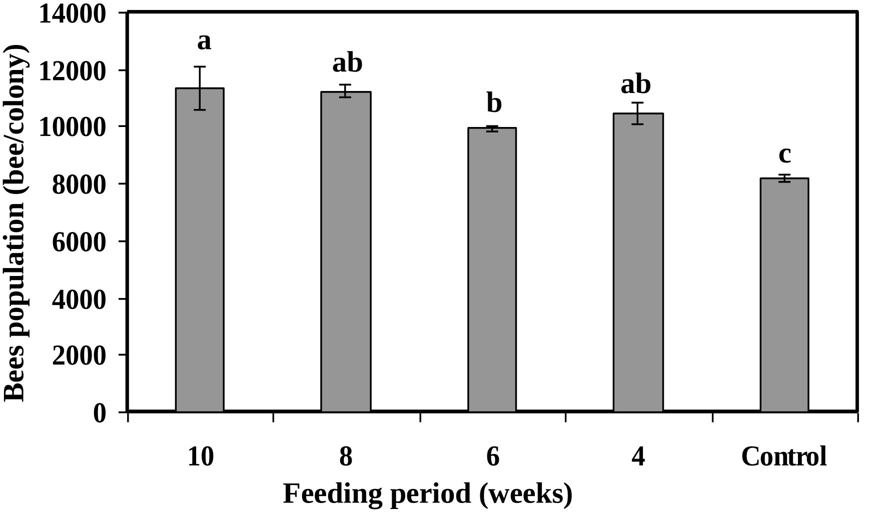

Fig.(2):The relationship between supplemental feeding at different periods and bee population size of honey bee colonies. Treatments followed by the same letters are not significantly different at 0.05 level of probability. Vertical lines denote standard errors.

Feeding periods and brood-rearing activity:

- Worker brood:

Honey bee colonies fed supplemental feeding at different periods raised significantly more worker brood than those unfed control colonies. Also, significant differences were found in produciton of worker brood among the colonies fed for different periods. A high positive correlation was found between supplemental feeding and workers brood area (r= 0.84). Also, a positive correlation was found between bee population size and workers brood area (r= 0.91). The maximum average area of workers brood (605.3 inch^2/ colony) was resulted by bee colonies fed for 10-weeks period, inducing 61.3% increment in workers brood area. Whereas bee colonies fed for 6-week or 4-weeks gave the minimum average of workers brood area (440.0, 447.7 inch^2/colony), with only 17.3, 19.2% increment in worker brood area as compared with unfed control colonies (Table 1 and Fig. 3).

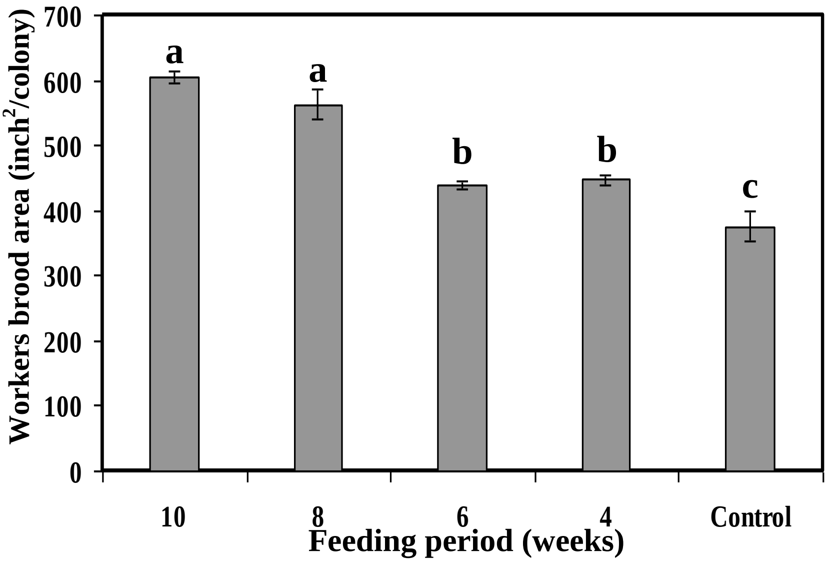

Fig.(3):The relationship between supplemental feeding at different periods and workers brood activity of honey bee colonies. Treatments followed by the same letters are not significantly different at 0.05 level of probability. Vertical lines denote standard errors.

- Drone brood:

Honey bee colonies fed supplemental feeding at different periods raised significantly more drones brood than those unfed control colonies. The maximum average area of drones brood (34.6 inch^2/colony) was resulted by 8-weeks feeding period, inducing 64.8% increment tin drones brood area compared with unfed control colonies. Followed by 6-weeks period (30.0inch^2/colony), inducing 42.9% increm-ent. Wher-eas bee colony fed for 4-weeks and 10-weeks gave 34.8 and 17.6% increment (Table 1 and Fig. 4).

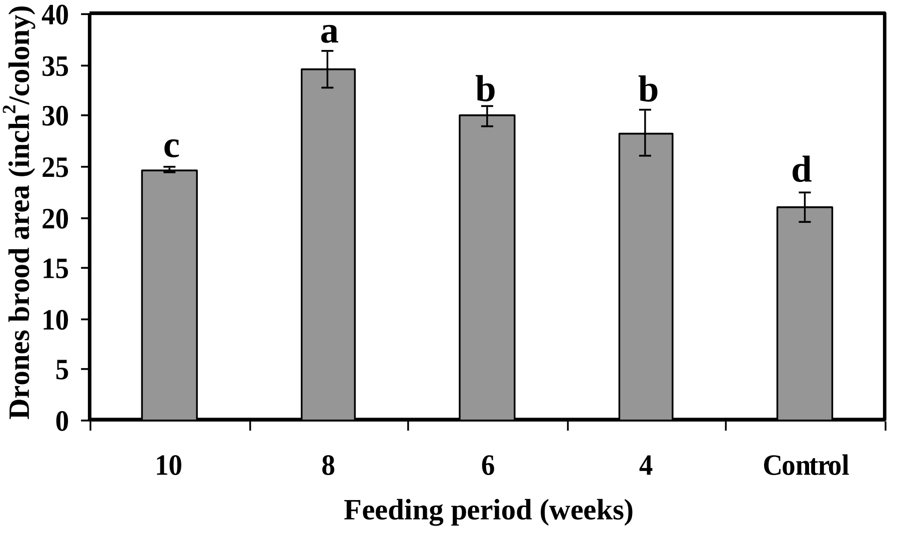

Fig.(4):The relationship between supplemental feeding at different periods and drones brood activity of honey bee colonies. Treatments followed by the same letters are not significantly different at 0.05 level of probability. Vertical lines denote standard errors.

Fluctuation of drones brood:

During the first three weeks of March, honey bee colonies fed with supplemental feeding at different periods produced more and earlier drones brood than unfed control colonies. The increments in early drones brood were 148.1, 113.7, 83.2 and 60.3% for colonies fed for 8-week, 6-week, 4-week and 10-week periods, respectively compared to unfed control colonies (Fig. 5).

Many correlations were found between production of drones brood and each of supplemental feeding at different periods and activities of honey bee colonies. Positive correlations were found between production of drones brood and each of bee population size (r= 0.59), workers brood (r= 0.40) and supplemental feeding (r= 0.31). Similar correlations were obtained by Free and Williams (1975), and Khodairy and Moustafa (2003). Whereas negative correlation was found between drones brood and stored pollen (r= -0.26), which may be due to consumption of more pollen by workers to produce more drone brood.

The present results are confirmed by Rhodes (2002), who reported that the strong colonies with large numbers of worker bees rear and maintain more brood and adult drones than weaker colonies. Low numbers of nurse bees in spring may contribute to problems with spring-reared drones. Adult

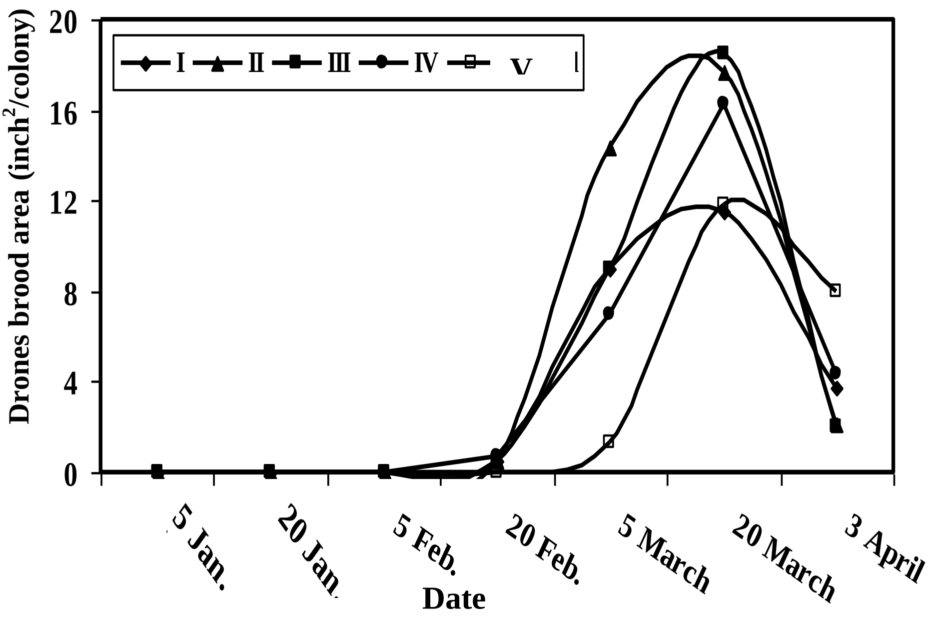

Fig.(5):Effect of supplemental feeding at different periods on the fluctuation of honey bee drones brood.

I, 10-week feeding period; II, 8-week feeding period; III, 6-week feeding period; IV, 4-week feeding period; V, control.

drones do not feed themselves but depend on an abundant supply of healthy nurse bees to feed them on pre-digested food, via proteinaceous glandular secretions, pollen and honey. Adult drones are physiologically characterized by a reduction in such functions as the ability to collect and digest nectar and pollen, and by a reduction of the glands that produce jelly and enzymes. This enhances the workers control over drones and facilitates additional support under flourishing colony conditions as well as rejection during dearth periods (Kraus *et al*., 2003; Hrassnigg and Crailsheim, 2005). A colony invests a lot of resources into the rearing and maintenance of a certain number of drones during the reproduction period (Seeley, 2002). Individual drones from the more successful colonies had a higher siring success, which was represented in a higher proportion of offspring (Kraus *et al*., 2003). Their body composition is specialized for containing and transferring large amounts of sperm and mucus.

In general, the amount of forage collected may have a direct effect on the attitude of workers towards drones, or it may be related to some other factor such as brood, because the amount of food collected influences on the amount of brood that is reared (Free, 1977).

The clearest indicator of adequate protein intake is that the colonies will be rearing drones. They will rear drones any time of the year (if the weather is warm enough) that there is ample pollen available. A shortage of pollen for the previous 7 days will result in the absence of drone brood stages but adult drones will be present. Whereas, a shortage for 14 days or more will result in no adult or brood stages of drones present in the hive (Rhodes, 2002). The ability of a colony to maintain a high popul-ation of adult drones depends on a continuous supply of pollen coming into the colony and not on stored pollen. Only pollen stored in close proximity to brood shows a positive influence on drone rearing. Colonies receiving a supplemental feeding for 4-10 weeks maintain drone populations higher than unfed control colonies.

Feeding periods and stored pollen:

The present results indicated that the supplemental feeding at different periods affected the stored pollen process. There were signi-ficant differences in the average of stored pollen between unfed control and all fed colonies, and also, among fed colonies at different periods. The feeding period of 10-week gave the highest average of stored pollen (80.7 inch^2/colony), inducing 83.4% increment in stored pollen. Whereas the lowest average was recorded by 4-week feeding period (45.0 inch^2/colony), resulting only 2.3% increment as compared to unfed control (Table 1 and Fig. 6). A high positive correlation was found between supplemental feeding and stored pollen (r= 0.710).

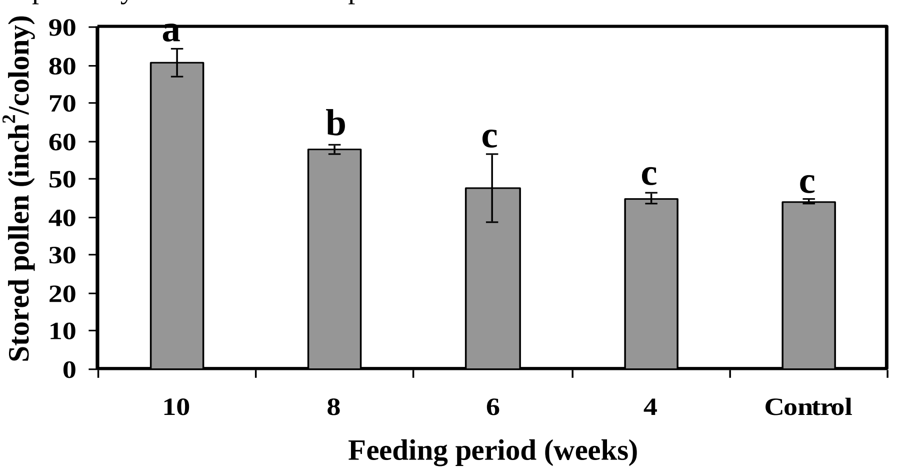

Fig.(6): The relationship between supplemental feeding at different periods and stored pollen. Treatments followed by the same letters are not significantly different at 0.05 level of probability. Vertical lines denote standard errors.

Fore-wing length and width:

The fore-wing length and width of mature drones of honey bee colonies fed with supplemental feeding at different periods and unfed control colonies were nearly similar with insignificant differe-nces (Table 2).

- Weight of mucus gland:

Honey bee colonies fed with supplemental feeding at different periods caused a significant incre-ment in mucus gland weight of mature drones as compared to unfed control colonies. The feeding period of 10-week gave the highest corres-pondding increment in mucus gland weight (19.6%). Whereas the lowest increment was recorded by 4-week feeding period (12.2%) as compared to unfed control colonies (Table 2 and Fig. 7). A positive correlation was found between supplemental feeding and weight of mucus gland (r= 0.473). As known, the mucus glands produce secretions (mucus) with a variety of functions. The secretory cells of mucus gland reach their maximum activity during the first days of adult life, which results in a maximally filled gland lumen by the age of 6 days (Moors *et al*., 2005). The mucus glands attain full maturity during the first 9 days after emergence and their secretion changes from a fluid to viscous, slightly alkaline mucus. The mucus glands increase in size as the drone matures (Dade, 1977). Mucus secre-tion plays variely roles, including contribution to the seminal fluid and activation of the spermatozoa (Chen, 1984; Davey, 1985). Also, the secretion plays a role in the formation of the mating sign after copulation and sperm transfer (Koeniger *et al*., 1989; Koeniger *et al*., 1996). The large amount of mucus is having important functions in the mating process and probably in the stimulation of oogenesis and ovipositon of honey bee queen (Seeley, 2002).

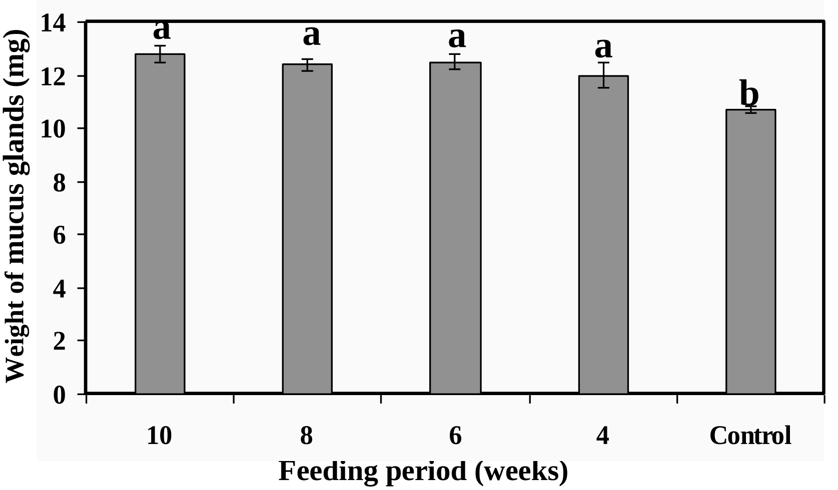

Fig.(7): The relationship between supplemental feeding at different periods and the weight of drone mucus glands Treatments followed by the same letters are not significantly different at 0.05 level of probability.Vertical lines denote standard errors.

- Fresh body weight:

The present results indicate that supplemental feeding at different periods caused a significant increment in both of the fresh body weight of mature drones and dry weight of newly emerged drones. The corresponding percentage increment in fresh body weight of newly emerged drones as compared to unfed control was 4.8, 4.2, 4.2 and 2.3% for 10-weeks, 8-weeks, 6-weeks and 4-weeks feeding periods, respectively. Whereas the corresponding increment in fresh body weight of mature drones as compared to control was 12.3, 12.0, 10.3 and 5.6% for 10-weeks, 8-weeks, 6-weeks and 4-weeks feeding periods, respectively (Table 2).

- Dry body weight:

Nearly similar patterns were observed in dry body weight of newly emerged drones. The corresponding increment in weight was 11.2, 8.7, 6.7 and 5.5% for 10-weeks, 8-weeks, 6-weeks and 4-weeks feeding periods (Table 2). Positive high correlations were found between supplemental feeding, and the fresh body weight of mature drones (r= 0.58) and dry weight of newly emerged drones (r= 0.51).

The increment in body weight of adult drones may be due to supplemental feeding, which increase in protein and other contents only be responsible for increased body weight growth. These aspects might have supported the evolution of big males which, probably for physiological reasons, produce more sperms than small males and which develop a higher kinetic energy at flight which could be advantageous to out compete other drones (Coelho, 1996; Hrassigg and Crailsheim, 2005). Also, the large body mass of drones increase their number of spermatozoa (Koeniger *et al*., 1990; Koeniger *et al*., 1996). Drones gain their high final body weight after a prolonged developmental period, during which spermatogenesis and organ formation occurs (Hrassnigg and Crailsheim, 2005).

Colony growth can be limited by either a lack of pollen or by the available pollen not containing the necessary nutrients. Thus, it is advantageous under some circumstances to feed pollen supplements or substitutes (Doull, 1980). This feeding is particularly useful to stimulate brood rearing, especially drone brood for exploitation of spring honey flows and pollination, and is also important for rearing and mating of honey bee queens (Winston *et al*., 1983).

The present results indicated that the honey bee colonies fed with supplemental feeding at different periods in winter produced significantly more bees and brood than unfed control colonies. These results are confirmed by Free and Racey (1968, and Abdalla *et al*. (2008). The present results showed positive high correlation between supplemental feeding, and each of bee population size, both of worker and drone brood activity, and stored pollen. These results agree with those of Akyol *et al*. (2006) and Abdalla *et al*. (2008). These correlations mean that worker and drone brood was increased by increasing bee population during the natural growth period of bee colony. Simulative feeding of bees is considered an important factor in preparing colonies for better spring development, early flows and for producing adult drones to mate queens (Skubida *et al*. 2008). In the present work, the 8-week feeding period gave the highest percentage of increment in drone brood (64.8%) as compared to unfed control. This means that the time and longitude of supplemental feeding periods are very important and must choose in carefully, these are confirmed by Szymas and Przybyl (1996).

Populations of workers and drones in spring months reflected the advantage of winter feeding. The present study showed that the colonies fed with supplemental feeding started rearing drone brood earlier than the non supplemented colonies, which confirmed by Mattila and Otis (2006).

As known, adult drones do not feed themselves but depend on an abundant supply of healthy nurse bees to feed them. Feeding of the colonies helps them to accept drone brood. Drone production and management could assist in the breeding of honey bees by efficiency and quality of mating (Hellmich and Waller, 1990). Bee population and brood depends on the protein of bee colony. Bees not only store pollen and honey in the hive, but also store feed reserves in their bodies, mainly in vitellogenin compound, which classed as a glycolipoprotein (Wheller and Kawooya, 2005). Vitellogenin is used by bees as an egg yolk protein precursor, as a food storage reservoir in their bodies, to synthesize royal jelly and more important in honey bee physiology and behaviour (Nelson *et al*., 2007). Statistical analysis indicated that the coefficient of determination was 0.21, indicating that the four mentioned variable factors, bee population, brood worker, bee bread and supplemental feeding were responsible for 21% of drones production changes during breeding period of drones. Supplemental feeding increase drone population and their protein and other contents, may be responsible for increasing body weight growth, probably for physiological reasons, produce more number of sperms and a lot of mucus and which develop a higher kinetic energy at mating flight.

The rearing of drone brood is also influenced by other factors such as: time of year (Allen, 1965), the colony's queen state (Woyke, 1977), the amount of forage collected and stored (Free and William, 1975) and the odours of individual drones (Holmes and Henniker, 1972), as well as by weather factors (Morse *et al*., 1967; Khodairy and Moustafa, 2003) and the genetic race (Free, 1977; Woyke, 1977).

Based on the present findings and previous studies, it can be concluded that the supplemental feeding at period of 4-8 weeks (optimum period, 8-week) plays an important role in building up colony populations for adequate rearing and maintenance of healthy drones which are essential for successful bee queen matings.

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تأثير التغذية الإضافية لفترات مختلفة على إنتاجية ذكور نحل العسل

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أجريت هذه الدراسة فى منحل بمنطقة سوهاج خلال الفترة ما بين الأول من يناير إلى الأول من أبريل 2008م . بغرض دراسة تأثير التغذية ا لصناعية لفترات مختلفة على نشاط طوائف نحل العسل وعلاقة ذلك بإنتاجية وجودة ذكور النحل . وكانت فترات التغذية تحت التجربة هى : 10 أسابيع ، 8 أسابيع ، 6 أسابيع ، 4 أسابيع وقورنت بالكنترول (تغذية طبيعية فقط) .

أوضحت النتائج وجود إرتباطات معنوية موجبة بين التغذية الصناعية وكل من تعداد النحل ونشاط تربية حضنة الشغالات والذكور وحبوب اللقاح المخزنة ووزن كل من جسم الذكور والغدد المخاطية . كما أوضحت النتائج أن طوائف نحل العسل التى تم تغذيتها صناعياً أعطت إنتاج أعلى معنوياً لكل من تعداد النحل ومساحة الحضنة لكل من الشغالات والذكور وكمية حبوب اللقاح المخزنة وذلك بالمقارنة بطوائف الكنترول . وسجل أعلى متوسط لكل من تعداد النحل (11361 نحلة / طائفة) ومساحة حضنة شغالات (605.3 بوصة مربعة / طائفة) وحبوب اللقاح المخزنة (80.7 بوصة مربعة / طائفة) للطوائف التى تم تغذيتها صناعياً لمدة 10 أسابيع . بينما سُجل أعلى متوسط من حضنة الذكور (64.6 بوصة مربعة / طائفة) للطوائف التى تم تغذيتها لمدة 8 أسابيع مُحققة 64.8% زيادة فى حضنة الذكور المنتجة بالمقارنة بطوائف الكنترول . وتغذية طوائف النحل لمدة 10 أسابيع أعطت أعلى متوسط فى الوزن لكل من جسم الذكور الناضجة (180.8 مجم) وكذلك الغدد المخاطية (12.8 مجم) مسجلة 12.3% و 19.6% زيادة فى متوسط وزن الجسم ووزن الغدة المخاطية على التوالى بالمقارنة بطوائف الكنترول . كانت أعلى نسبة زيادة فى وزن الجسم للذكور حديثة العمر وهى 4.8% للطوائف التى تم تغذيتها لمدة 10 أسابيع . كان مقدار معامل ا لتقدير 0.21 موضحاً أن عوامل "التغذية الصناعية وتعداد النحل وحضنة الشغالات وكمية حبوب اللقاح المخزنة " مجتمعة أثرت بنسبة 21% على التغيرات فى معدل إنتاجية الذكور .