The activity and performance of the colony of the honey bee are influenced by several factors such as: nectar and pollen floral resource (Helal et al., 2003; Taha et al., 2006; Taha and Bayoumi, 2009; Awad et al., 2017), time of the year (Taha, 2000; Shawer et al., 2003; Taha, 2015; Taha and Al-Kahtani, 2019), colony population size (Taha and Al-Kahtani, 2013; Kasangaki et al., 2018), and bee species/subspecies (Taha et al., 2016; Awad et al., 2017; Taha and Al-Kahtani, 2019). In addition, the productivity of honey bee colonies has been affected by feeding on proteinaceous diets (Pokhrel et al., 2006; Mahmood et al., 2013; Taha, 2015; Puškadija et al., 2017).

The aim of the present study is to investigate the activity of the honey bee (Apis mellifera L.) colonies in storing pollen, brood production, growth of the colony, and honey production in relation to the age of comb age.

2. Material and methods

The study was carried out at the apiary of the Training and Research Station, King Faisal University, Al-Ahsa oasis, in eastern Saudi Arabia during the summer and autumn seasons in 2017. Al-Ahsa lies at longitude 49° 37' 19” E, latitude 25° 25' 46” N and an altitude of 121 m above sea level. Twenty colonies of 14,000 bees (seven combs) of hybrid Carniolan (A. m. carnica Pollmann) honey bees were selected for this experiment. The colonies were equalized to be about the same strength (brood, bees, and food).
and were requeened by newly mated sister queens. The colonies were divided into 4 groups of 5 colonies. The combs in these colonies have been replaced by empty combs aged 1, 2, 3 and 4-years in groups 1, 2, 3 and 4, respectively. The number of returning workers into the colony within one minute was counted to determine the activity of foraging. The number of returning workers carrying pollen loads was recorded at the same time. These procedures were done periodically a day weekly at 0700–0800 hrs from July to September, and at 0900–1000 hrs from October to December. The flight activity reached the highest rates at the selected times (Taha, 2014).

A standard frame divided into square inches was used to measure the areas of worker sealed brood and stored pollen at 12 days intervals. The monthly number of combs covered with bees in each colony was counted for determination the colony population size according to bees Taha (2007). By the end of sidr (Ziziphus spp., Rhamnaceae) season flow (September and October), honey yield was determined by calculating the difference between the weight of combs before and after honey extraction. Data were analyzed by the one-way analysis of variance using SAS® software computer program (SAS Institute, 2003). A comparison between the means of treatments was done using the Duncan’s Multiple Range Test (Duncan, 1955).

3. Results

The obtained data showed that colony performance including foraging activity, storing pollen, brood production, colony growth, and honey production differed and significantly (p < 0.01) affected by comb age. Colonies with combs aged 1, 2 and 3-years were significantly (p < 0.01) more active in foraging rate in comparison to colonies with combs aged 4-years (66.40, 64.20 and 61.60 workers/min./colony vs. 59.20 workers/min./colony, respectively). The highest number of returning workers carrying pollen loads (19.85 workers/min./colony) was recorded in colonies with combs aged 1-year, followed by 18.94 workers/min./colony from colonies with combs aged 2-years, while the lowest number of returning workers with pollen loads (16.95 workers/min./colony) was recorded in colonies with combs aged 4-years (Fig. 1). The stored pollen area could be arranged in descending order: colonies with combs aged 1-year > colonies with combs aged 2-years > colonies with combs aged 3-years > colonies with combs aged 4-years (Fig. 2).

Data illustrated graphically in Fig. 3 showed that, colonies with combs aged 1, 2 and 3-years significantly (p < 0.01) exceeded colonies with combs aged 4-years in worker sealed brood area (2412.00, 2289.60 and 2092.80 sq. inches/colony vs. 1950.33 sq. inches/colony, respectively). The largest colony population size (20,000 bees/colony) was recorded in colonies with combs aged 1-year, followed by 19,200 bees/colony from colonies with combs aged 2-years, while the smallest population size (18,000 bees/colony) was recorded in colonies with combs aged 4-years (Fig. 4).

The largest amount of honey (5.25 kg/colony) was obtained from colonies with combs aged 1-year, followed by 4.90 kg/colony from colonies with combs aged 2-years, while the lowest honey yield (4.45 kg/colony) was obtained from colonies with combs aged 4-years (Fig. 5). The correlation between honey yield, number of returning workers, number of returning workers carrying pollen loads, stored pollen area, sealed brood area, and growth of the colony was significantly (p < 0.01) positive (Table 1).

4. Discussion

The performance of the colony of honey bee (Apis mellifera L.) was measured from the determination of foraging rate, gathering and storing pollen, brood production, colony population growth, and honey production. In comparison to the colonies with combs aged 4-years, colonies with combs aged 1, 2 and 3-years significantly (p < 0.01) exceeded in the number of returning workers, and number of returning workers carrying pollen loads by 12.16 & 17.10, 8.44 & 14.45, and 4.05 & 6.48%, respectively. The superiority of colonies with new combs may be due the large bee population resulted from the high rate of brood rearing. Significant (p < 0.01) positive correlation was found between size of the colony population with the number of returning workers (r = 0.94) and the number of returning workers with pollen loads (r = 0.78). These results are in harmony with the results obtained by Taha (2014).

Colonies with combs aged 1, 2 and 3-years stored significantly (p < 0.01) more pollen than colonies with combs aged 4-years by 19.70, 13.06 and 7.79%, respectively. The large stored pollen area may be due to the large number of workers collecting pollen which occurred from the high rate of brood production in new combs (Berry and Delaplane, 2001; Dizaji et al., 2008) which correlated with the stored pollen area. Strong positively correlation (p < 0.01) was found between stored pollen area with the number of returning workers with pollen loads (r = 0.93) and colony population size (r = 0.74). Our results confirmed by those obtained by
Taha (2015); Taha and Al-Kahtani (2019) who found a positively correlation between stored pollen area and size of the colony population.

In addition to the colony population size, brood production was affected by egg laying ability of the queens and food providing (DeGrandi-Hoffman et al., 1989; Taha, 2005; 2015). At the beginning of the experiment, the experimental colonies were headed by sister queens, adult populations and brood areas were relatively similar in all colonies, so any variations should due to the age of combs. Colonies had combs aged 1, 2 and 3-years reared worker
brood significantly \((p < 0.01)\) more than colonies had combs aged 4-years by 23.67, 17.39 and 7.30\%, respectively. These results endorsed the findings of Berry and Delaplane (2001) and Dizaji et al. (2008). The correlation between bee population size and the area of worker brood was strongly positive \((r = 0.93; p < 0.01)\). These results were in line with those of Jevtić et al. (2009); Taha (2015); Taha and Al-Kahtani (2019) who found a positive correlation between colony populations and the sealed brood area.

In comparison to colonies with combs aged 4-years, the colony population size of colonies with combs aged 1, 2 and 3-years significantly \((p < 0.01)\) increased by 23.98, 13.06 and 7.79\%, respectively. The large population size in colonies with new combs resulted from the higher brood production in new combs (Berry and Delaplane, 2001). In addition, workers reared in new combs were bigger than workers reared in old ones (Al-Kahtani, 2018). Bigger bees with larger wings can gather more nectar and pollen, and rear more brood, which resulted in a larger population size. Positive correlations between length and width of the forewing, the hindwing length and colony population size were found (Mostajeran et al., 2006).

The amount of harvested honey yield significantly \((p < 0.01)\) decreased in parallel with the increase of comb age; i.e. honey yield had an opposite relationship with the age of combs. In comparison to colonies with combs aged 4-years, the amount of honey harvested from colonies with combs aged 1, 2 and 3-years increased by 23.98, 13.06 and 7.79\%, respectively. Our results confirmed by Taha and El-Sanat (2007) and Dizaji et al. (2008) who obtained the largest honey yield from colonies had new combs, while the lowest honey yield was obtained from colonies had old combs. The superiority of colonies with new combs in honey production in comparison to colonies with old ones may be due to the higher brood production in new combs (Berry and Delaplane, 2001; Dizaji et al., 2008) resulted in large bee population size that gathered more nectar and produced high honey yield. The correlation between honey yield with worker sealed brood area \((r = 0.92; p < 0.01)\) and with colony population size \((r = 0.89; p < 0.01)\) were strong positive. Relatively similar results were obtained by Taha (2015) and Taha and Al-Kahtani (2019). In addition, old combs with smaller cells resulted in smaller workers. Body size was significantly positively correlated with most body characteristics (Al-Kahtani and Taha, 2014). The honey yield was significantly correlated with the wings and the leg characteristics (Mostajeran et al., 2006), and the area of corbicula (Kolmes and Sam, 1991).

5. Conclusion

The foraging rate, gathering and storing pollen, growth of the colony, and honey yield significantly depended on the age of combs. Beekeepers can replace old combs with new ones to increase brood and honey production.

### Table 1

| Items                                      | No. incoming workers | No. incoming workers with pollen loads | Stored pollen area | Worker sealed brood area | Colony population size |
|--------------------------------------------|----------------------|----------------------------------------|--------------------|--------------------------|------------------------|
| No. incoming workers                       |                      |                                        |                    |                          |                        |
| No. incoming workers with pollen loads     | 0.89**               |                                        |                    |                          |                        |
| Stored pollen area                         | 0.86**               | 0.93**                                 |                    |                          |                        |
| Worker sealed brood area                   | 0.88**               | 0.94**                                 | 0.93**             |                          |                        |
| Colony population size                     | 0.94**               | 0.78**                                 | 0.74**             | 0.93**                   |                        |
| Honey yield                                | 0.92**               | 0.84**                                 | 0.96**             | 0.92**                   | 0.89**                 |

** Indicate correlation is significant at the 0.01 level, respectively (2-tailed).
Acknowledgments

The researchers want to extend their sincere thanks and appreciation to the deanship of scientific research, King Faisal University for the financial funding and moral support for the project No. 150027.

References

Al-Kahtani, S.N., 2018. Morphometric characteristics of Carniolan honeybee workers in relation to age of comb. Sci. J. King Faisal Univ. (Basic App. Sci.) 19 (2), 47–54.

Al-Kahtani, S.N., Taha, E.A., 2014. Morphometric studies on dwarf honey bee Apis florea F. workers in Saudi Arabia. J. Apicultural Sci. 58 (1), 127–134.

Awad, A.M., Owayss, A.A., Alqarni, A.S., 2017. Performance of two honey bee subspecies during harsh weather and Acacia gerrardii nectar-rich flow. Scientia Agricola 74 (6), 474–480.

Berry, J.A., Delaplane, K.S., 2001. Effect of comb age on honey bee colony growth and brood survivorship. J. Apic. Res. 40, 3–8.

Coggshall, W.L., Morse, R.A., 1984. Beeswax. Production, Harvesting, Processing and Products. Wicwas Press, Ithaca, New York, p. 192.

Degrandi-Hoffman, G., Roth, S.A., Loper, G.L., Erickson, E.H., 1989. BEEP: A honeybee population dynamics Simulation model. Ecol. Model. 45, 133–150.

Dizaji, A.A., Alishah, M., Shaddel, A., Sis, N.M., 2008. Effects of comb wax age on the brood and honey product performance in honey bee. Asian J. Anim. Veterinary Adv. 3, 51–53.

Duncan, B.D., 1955. Multiple Range and Multiple F. Test. Biometrics 11, 1–42.

Free, J.B., Williams, I.H., 1974. Factors determining food storage and brood rearing in honey bee (Apis mellifera L.) comb. J. Entomol. Ser. A 49, 47–63.

Helal, R.M., El-Dakhakhni, T.N., Shawer, M.B., Taha, E.A., 2003. Effect of moving the apiaries on activity of honey bee colonies. 2- Flight activity, gathering of nectar and sugar concentration contents and honey. J. Agric. Res. Tanta Univ. 29, 268–282.

Hepburn, H.R., 1998. Reciprocal interactions between honey bees and combs in the integration of some colony functions in Apis mellifera L. Apidologie 29, 47–66.

Jay, C.S., 1963. The development of honey bees in their cells. J. Apic. Res. 2, 117–134.

Kasangaki, P., Nyamasyo, G., Ndegwa, P., Kajobe, R., 2018. Assessment of honey bee foraging activity and productivity of honey bee colonies. M. Sc. Thesis, Faculty Agriculture Tanta University, Egypt, 117p.

Taha, E.A., 2000. Effect of transferring the apiaries on activity of honey bee colonies. 2- Flight activity, gathering of nectar and wax secretion. J. Agric. Res. Tanta Univ. 29, 250–267.

Taha, E.A., 2005. Studies on honey bee (Apis mellifera L.). Unpublished Ph.D. Thesis, Faculty Agriculture Tanta University, Egypt, 151p.

Taha, E.A., 2007. Importance of banana Musa sp. (Musaceae) for honey bee (Apis mellifera L.). Hymenoptera: Apidae) in Egypt. Bull. Entomol. Soc. Egypt II, 125–133.

Taha, E.A., 2014. Seasonal variation of foraging activity, pollen collection and growth of honey bee colonies in Al-Ahsa, Saudi Arabia. Bull. Entomol. Soc. Egypt 91, 163–175.

Taha, E.A., 2015. The impact of feeding certain pollen substitutes on maintaining the strength and productivity of honey bee colonies (Apis mellifera L.). Bull. Entomol. Soc. Egypt, Econ. Ser. 41, 63–74.

Taha, E.A., El-Sanat, S.Y., 2007. Effect of combs age on honey production and its physical and chemical properties. Bull. Entomol. Soc. Egypt II, 9–18.

Taha, E.A., Bayoumi, Y.A., 2009. The value of honey bee (Apis mellifera L.) as pollinator of summer seed watermelon (Citrullus lanatus colocynthoides L.: Cucurbitaceae) in Egypt. Acta Biologica Szegedenis 53 (1), 33–37.

Taha, E.A., Al-Kahtani, S.N., 2013. Relationship between population size and productivity of honey bee colonies. J. Entomol. 10, 163–169.

Taha, E.A., Al-Kahtani, S.N., 2019. Comparison of the activity and productivity of Carniolan (Apis mellifera carnica Pollmann) and Yemeni (Apis mellifera jenmitica Rutrner) subspecies under environmental conditions of the Al-Ahsa oasis of eastern Saudi Arabia. Saudi J. Biol. Sci. 26 (4), 681–687.

Mostajeran, M.A., Edriss, M.A., Basiri, M.R., 2006. Analysis of colony and morphological characteristics in honeybees (Apis mellifera meda). Pak. J. Biol. Sci. 9 (14), 2685–2688.

Pokhrel, S., Thapa, R.B., Neupane, F.P., Hrestha, S.M., 2006. Absconding behavior and management of Apis cerana F. honey bee in Chitwan, Nepal. J. Inst. Agric. Anim. Sci. 27, 77–86.

Puškadija, Z., Spiljak, L., Kovacˇic´, M., 2017. Late winter feeding stimulates rapid spring development of Carniolan honey bee colonies (Apis mellifera carnica). Poljoprivreda 23 (2), 73–77.

SAS Institute, 2003. SAS/STAT User’s Guide release 9.1. SAS Institute Inc. Cary, NC 27513.

Shawer, M.B., El-Dakhakhni, N.M., Helal, R.M., Taha, E.A., 2003. Insect pollinators and foraging behavior of honey bees on alfalfa (Medicago sativa L.) as pollinator of summer seed watermelon (Citrullus lanatus colocynthoides L.: Cucurbitaceae); a source of nectar and pollen for honey bee (Apis mellifera L.). Bull. Entomol. Soc. Egypt, Econ. Ser. 41, 63–74.

Taha, E.A., 2014. The impact of feeding certain pollen substitutes on maintaining the strength and productivity of honey bee colonies (Apis mellifera L.). Bull. Entomol. Soc. Egypt, Econ. Ser. 41, 63–74.

Taha, E.A., 2019. Comparison of the activity and productivity of Carniolan (Apis mellifera carnica Pollmann) and Yemeni (Apis mellifera jenmitica Rutrner) subspecies under environmental conditions of the Al-Ahsa oasis of eastern Saudi Arabia. Saudi J. Biol. Sci. 26 (4), 681–687.

Taha, E.A., Nour, M.E., Shawer, M.B., 2010. The relationship between comb age and the amounts of mineral elements in honey and wax. J. Apicultural Res. Bee World 49 (2), 202–207.

Taha, E.A., Al-Abdulsalam, M., Al-Kahtani, S.N., 2016. Insect pollinators and foraging behavior of honey bees on alfalfa (Medicago sativa L.) in in Saudi Arabia. J. Kansas Entomol. Soc. 89 (1), 92–99.

Tulloch, A.P., 1980. Beeswax – composition and analysis. Bee World 61, 202–207.

Winston, M.L., 1987. The Biology of the Honey Bee. Harvard University Press, Cambridge, Massach.