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Relationship of population size and extraction frequency with honey production in *Apis mellifera* colonies

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Abstract
Present study is a part of PhD thesis of the first author, conducted at CCS Haryana Agricultural University, Hisar with thirty six colonies of varied strength (5, 10 and 15 frame). Each frame strength contains 12 colonies which were subjected to three types of honey extraction frequencies namely single, double and regular extraction. Total four honey extraction was carried out throughout the season under regular honey extraction regime. It is evident from the data that colonies with high work force (15 frame) remain superior with mean honey production of 27.61 kg under single honey where 10 frame colonies produce 24.3 kg/ colony and lowest was in weakest colonies. Similar trend was observed under two and regular extraction regimes where also weakest strength colony produce less honey 11.67 kg and 10.24 kg / colony which far less than high and medium strength colonies. Under two extractions it was observed that 10 frame colonies produce comparable honey, 18.33 kg /colony where strongest colony was seen with 22.38 kg/ colony. Even 15 frame colonies produce less honey but high from medium and low strength colonies that itself indicates that high strength colonies with single or maximum two extraction is best suitable under Indian condition.

Keywords: *Apis mellifera,* colonies, honey extraction, worker strength, extraction frequency

Introduction
There is always unanimity among beekeepers that colonies with high strength provide high returns in terms of honey production(Bhusal, 2011; Crane, 1990) [3, 9] but strangely there are no standards set for optimum colony strength for European honey bee (*A. mellifera*) beekeeping in India. In Indian conditions where agriculture is main occupation for peoples livelihood, role of honey bees (*A mellifera)* is limited to being mainly an agro-based subsidiary occupation (Chaudhary, 2014a) [8] solely for honey production. World over, about 56 million domesticated honey bee colonies produce around 1.5 million tones of honey (FAO, 2011) [12]. China is the largest honey producer (3,03,000 MT) and exporter governing 26 per cent of total world honey trade while India stands at dismal 8th position, producing 70,000 tons of which 38,177 MT is exported (54.5%) which earn Rs. 705.87 crores the country (Anonymous, 2016) [2]. India has about 1.3 million honey bee colonies engaged 2.42 lakh beekeepers with a productivity of 13.7 kg / colony for *A. mellifera* and 6.7 kg / colony for *A. cerana* (Chaudhary, 2014a) [8] and the situation has remained almost static even today.

In India, winter is the major honey flow season from mustard crop followed by few minor seasons up to early summer (December to May) followed by a long dearth from summer through rainy season till November (Chaudhary, 2003 a, b; [5, 6] Chaudhary, 2005 [7]; Kumar, 2013) [16]. On the technological front, the situation in India is worst with almost negligible addition of honey supers (only 0.17%) on colonies (Chaudhary, 2005) [7] as honey is extracted from brood chamber repeatedly at an interval of 7-10 days.Such constant honey extractions consume maximum labor in the beekeeping operation besides adversely affecting colony productivity, honey quality besides increasing the cost of production. Beekeeper's habit of extracting honey to the last drop at the end of honey flow season thus not leaving enough honey stores in the colony lead to colony debilitation and death during ensuing dearth period. Keeping in view of present scenario this study was planned as not much of work was done towards setting of standards for beekeepers to follow. There is scanty of literature available on how many honey extractions and when and how supering should be done by a beekeeper under Indian conditions.

Materials and Methods

Experiment was conducted for two years (2014-15 & 2015-16) continuously. An apiary was selected for present study containing 36 colonies of *A mellifera.* The colonies were further configured in the evening at farmers field into various colony strengths as per the envisaged treatments (5, 10 and 15 frames/colony, initially) taking care to equalize them in terms of young queen, food stores, brood area, etc. as per the protocol (Delaplane *et al.,* 2013) [11]. The colony entrance was closed to maintain constant strength and migrated to the experimental site at RDS Farm of CCS HAU, Hisar in December, 2014 on the mustard crop. Apiary was surrounded by abundant mustard that just started blooming and about 5-10% flowering was there in the field. Each colony with specified frame strength was labelled accordingly and placed in diamond orientation having a minimum of 10 feet row to row and 5 feet colony to colony distance.

On the initial colony strength of 5, 10 and 15 frames/colony, three treatments of honey extraction frequency were superimposed to evaluate their effect on honey productivity.

Honey extraction frequencies: Following three honey extraction frequencies were taken:

- **Single extraction:** Colonies under each colony strength were extracted only once in the season when 20-30 % crop were remain on flowering that will help colonies to collect nectar for survival.
- **Double / Two extractions:** Colonies were extracted two times in the honey flow season, first during mid honey flow season and second when single extracted colonies were extracted.
- **Regular/ Beekeeper's practice:** Colonies were extracted following beekeeper's practice at regular intervals during honey flow season.

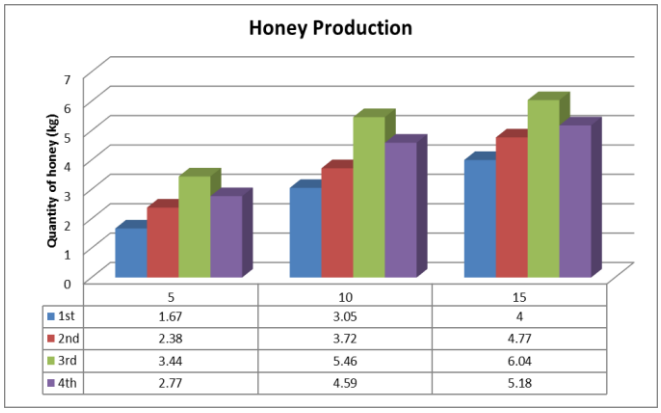
Each treatment consisted of 4 replications, one colony taken as a replicate.

Weight of honey extracted: To know the amount of honey extracted from each extraction frequency, initial weight of honey extractor and weight of extractor after extraction of honey from colonies under specific extraction frequency was recorded and colony weight was also taken before and after extraction. Statistical analysis was performed by two-way ANOVA using OPSTAT software (Sheoran, *et al.,* 1998) [22].

Results

Data presented in this manuscript is of major honey flow season only when extraction of honey was made and the data was pooled to make an easy conclusion of the outcome.

Honey production from regular / Beekeeper's practice: During both the years total four honey extractions were carried out in regular extraction and when data was pooled, almost similar trends were observed in both the years of observations (Fig 1). Honey production was comparatively lower in year 2015-16 than the previous year. Strong colonies at 15 frames produced more honey (19.99 kg/colony) followed by 10 frame colonies (16.82 kg) while the minimum honey was produced in the weakest 5 frame colonies (10.26 kg). Honey production was the lowest in first extraction (2.91 kg) improved in 2nd (4.77) to become maximum (4.98) in 3rd extraction. The 4th production was marginally lower at 4.18 kg/colony.



	5	10	15
1st	1.67	3.05	4
2nd	2.38	3.72	4.77
3rd	3.44	5.46	6.04
4th	2.77	4.59	5.18

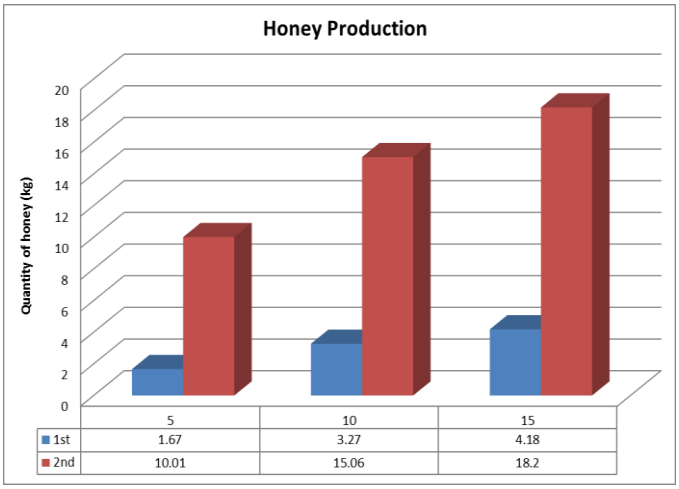
* Values are the mean of 4 replications

Fig 1: Mean honey extraction in different strength colonies under regular /Beekeeper's practice

Honey production under two honey extractions: Data revealed superiority of colony strength (Fig.2). Highest honey extraction (22.38 kg/ colony) was recorded in 15 frame colonies followed by 10 frames (18.33) and the lowest in 5 frame colonies (11.68 kg/colony). Similar trend was observed in both the extractions. Honey in the 1st extraction was low (3.04 kg) but increased significantly in 2nd extraction to 14.42 kg/colony.

Honey production under single honey extraction: Maximum honey production under single extraction regime was from the strongest colonies of 15 frames that yielded 27.61 kg honey/colony while in 10 frames, the yield was significantly lower (24.70 kg) and the lowest of only 12.46 kg/colony from weakest 5 frame colonies (Fig.3).

Mean honey production in different strength colonies under different honey extraction regimes: It was evident from the pooled data that if ample time is provided to colonies to store honey under single honey extraction regime, they produce more honey as compared with regular and two extractions in all colony strengths (Fig. 4). Highest honey was extracted in 15 frame colonies under single extraction (27.61 kg/colony) followed by 2 extractions (24.70 kg/colony) and 10 frames under single extraction (24.70 kg/colony). The least was observed in weakest 5 frame colonies under regular extraction (10.24 kg/ colony).



	5	10	15
1st	1.67	3.27	4.18
2nd	10.01	15.06	18.2

Fig 2: Mean honey extraction in different strength colonies under double/ two honey extractions

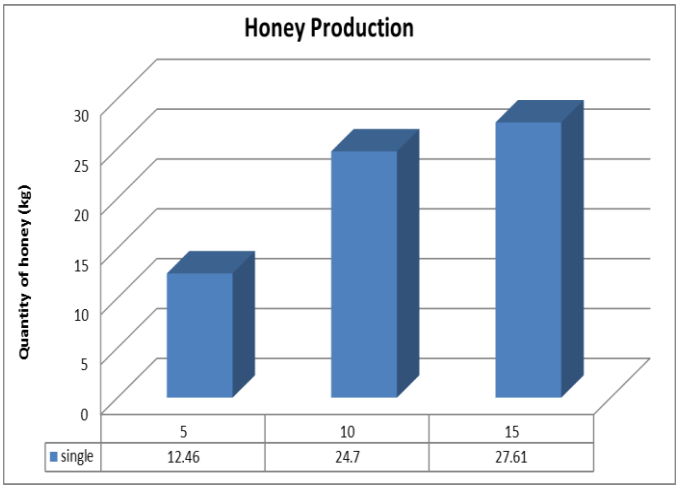


Fig 3: Mean honey extraction in different strength colonies under single honey extraction

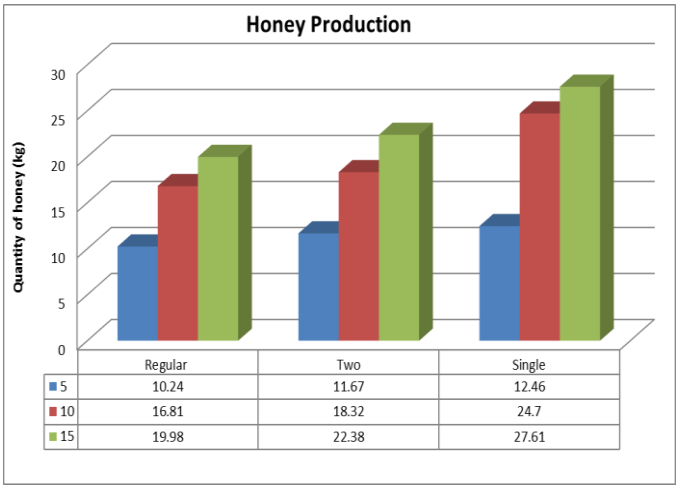


Fig 4: Mean honey extraction in different strength colonies under different honey extraction regimes

Discussion

Present studies clearly revealed that honey production is the direct product of colony strength during honey flow season. Larger forager force in stronger colonies gathers higher amounts of nectar compared to the relatively smaller forager force in weaker colonies. Results clearly point to the superiority of single honey extraction regime with maximum honey production of 23.12 kg/colony over the two extractions (18.66 kg/colony) while under regular extractions minimum honey was extracted (13.25 kg/colony). Similar results were also reported by Neupane *et al*., (2012) [17] that 5, 10 and 20 frame colonies produced mean honey at the rate of 30.1, 47.8 and 71.6 kg, respectively that was in the ratio of 1:1.6:2.4. Under regular honey extraction frequency, strong colonies at 15 frames produced maximum honey (19.99 kg/colony) followed by 10 frame colonies (16.82 kg) while the minimum honey was produced in the weakest 5 frame colonies (10.26 kg). When put under two extraction regime, still higher honey was extraction (22.38 kg) in 15 frame colonies followed by 10 frames (18.33) and the lowest in 5 frame colonies (11.68 kg). When colonies were least disturbed by putting under single honey extraction, the honey yields were maximum in 15 frame colonies (27.61 kg/colony), while in 10 frames, the yield was significantly lower (24.70 kg) and the lowest in 5 frame colonies (12.46 kg/colony). These findings are in line with the findings that honey production depends on the population of the bee colonies fromVerma (1992) [23]; Neupane *et al*. (2012) [17]; Bhusal*etal*. (2011) [4]. From Nepal, Neupane *et al.* (2012) [17] also reported the effect of honey production from three different original strengths of 5, 10 and 20 combs. The found honey production to be highly correlated to the number of worker brood cells in the colonies ($r = 0.96$, $p = 0.003$). Colonies of 5 comb initial strength (CIS), as farmers' practices, produced the lowest amount of honey (30.1 kg per annum). Bees in colonies of 10 CIS with a deep super, produced twice as much honey (62.2 kg), and colonies of 20 CIS with deep supers produced even significantly more honey (74.5 kg). Bhusal *et al*. (2011) [4] determined the effect of initial colony strength of *A. mellifera* on honey production in Nepal and reported an increase in honey production of 182%, 59% and 18% for the 10, 8 and 6 frame honeybee colonies, respectively, compared to the honey production of 2.82 kg/colony from 4-frame honeybee colonies. They further concluded that healthy colonies with a sufficient bee population will help to produce more honey. Strong bee colonies are also reported to produce more honey (Gabka, 2014) [14] as colonies with 8 combs in early April produced significantly more honey by the end of May (average 30.8 kg) than those covering 6 combs (22.1 kg). Verma, 1992 [23] also concluded that higher rate of honey production in larger and stronger colonies is due to the higher proportion of older bees as foragers producing one and half times more honey from one colony of *A. mellifera* with 60,000 worker bees than four colonies each with 15,000 worker bees. Size of colony has behavioural effect over honey bee foragers as foragers from high brood colony forage large pollen loads as compared to low brood colony. Same was observed in nectar foraging, high brood colonies making more trip and forage longer distances for nectar collection (Jevtic *et al.* 2009; Kumar & Singh 2000; Eckert *et al.*, 1994) [15, 16, 12].

Although honey yield was highest in 15 frame colonies under single extraction (27.16 kg/colony) but the present study also provides additional option to the beekeepers of two honey extractions in 15 frame colonies (24.11 kg) and single extraction in 10 frame colonies (22.98 kg/colony) that not only gave substantial honey yields but reduces the risks inclement weather poses during honey extraction. Our study also advocating lower honey extraction frequency of 1 or 2 in contrast to the present routine of honey extraction from brood frames at 7-10 days interval which is also found support from Szabo and Lefkovitch [21] (1990) who suggests reduction of harvesting operations from 4 or 6 to 2 or 3. They reported maximum honey with best quality from 2 extractions. Szabo *etal*., 1992 [19] further studied the effects of honey extraction frequency (4, 2 and 1 times), addition of various numbers of empty supers (5, 10 and 11-15) and queen age (1- and 2-yr-old) on the quantity and quality of honey of *A. mellifera* colonies. Colonies with two honey extractions, one at mid-flow and the second at the end of nectar flow, produced significantly more honey (142.1 kg) than colonies with one (106.0 kg) and 4 (116.2 kg) removals. The amount of comb space or number of empty supers did not influence the quantity of honey produced but extraction frequency and age of queen has remarkable effect over honey production. During a major honey flow in Canada, Szabo &Sparns (1994) [20] recommended use of less labour intensive technique of top supering with 1, 2 or 3 times honey extraction as the better method with honey yields as high as 76.8 to 102.4 kg than other labour intensive methods. Berry *et al.*, 2000 [3] also concurred with the superiority of top supering. Allsopp [1] (1994) in order to maximize honey production in *A.mellifera*capensis suggested deep supers with worker foundation as the most suited to increasing honey and wax

production.

Conclusion

From present study it can be concluded that higher work force in strong colonies collects more honey which leads to higher production. As supers were there in 15 and 10 frame (later stages) colonies quality of honey will also improve. Weak colonies (5 frame) not recommended on start of honey flow season that will leads to low production as colonies will spend more effort in expansion of colony (brood production). Medium strength colonies (10 frame) with single extraction and high strength colony (15 frame) with two extraction can give high and quality honey production.

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