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Apis mellifera colony productivity and growth influenced by initial frame strength: Farmer's perspective

SUMIT SAINI[1], O P CHAUDHARY[2] and VADDE ANOOSHA[3]

CCS Haryana Agricultural University, Hisar, Haryana 125 044

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ABSTRACT

Beekeeping is a very good source of extra income to farmer and a very productive enterprise for landless farmers. Under Haryana condition there is unanimity among farmers and beekeepers regarding no. of frames to be kept while the season of honey production is about to start. Keeping this problem of farmers' in view present study was designed and implemented during 2014-15 and 2015-16 under semi-arid conditions of Haryana. Thirty six colonies with initially three (5, 10 and 15 frames) frame strength, twelve colonies in each were equalized (in terms of brood and food reserves) and transferred to experimental site. Strong colonies (15 frames) were observed superior in honey production (885.9 inches^2), brood rearing (488.6 inches^2) and pollen (129.2 inches^2) reserves followed by medium strengths colonies having honey area 544.0 inches^2 and lowest brood rearing and honey reserves (257.1 and 247.1 inches^2 respectively) was observed in weakest colonies. Surviving with low strength weak colonies was observed with high egg area proportionate with strong and medium colonies. Observations were recorded throughout the major honey flow season for all growth parameters, average sealed honey area was recorded maximum in February (520.4 inches^2) and a dip was observed in March (41.2 inches^2) that is due to honey extraction and also due to end of honey flow season. Up and downs were observed in case of average total brood area but it keeps on decreasing after April and minimum on 31 May observation (286.8 inches^2). Strong colonies with 15 frames was recorded with high brood area as compared to 5 and 10 frame colonies throughout the season which clearly indicates superiority of keeping good strength colonies at the start of honey flow season.

Key word: *Apis mellifera,* Brood, Colony growth, Frame strength, Honey

There is unanimity among the stakeholders that strong colonies result in higher productivity (Bhusal 2011, Retneiks 1986, Matheson 1984, Crane 1990). Time of year and colony size may interact to affect the value of pollen or nectar, and hence foraging behaviour. If a colony has attained a large size by mid-summer, then colony-level and individual foraging behaviour should aim to build the nectar stores needed to ensure over-winter survival. Nectar resources are therefore assigned a high value. For a small colony in mid-summer seeking to over-winter successfully, the primary goal should be to increase its population rather than nectar stores (Eckert *et al.* 1994). It has been observed that colonies with low amounts of stored pollen or nectar show increased rates of foraging as compared to colonies with high quantities of these stored resources (Free 1967, Seeley 1989). Beauchamp (1992) presented a detailed model investigating the question of how much effort individual workers should devote to foraging. He assumed that honey bee foraging behaviour is selected to achieve maximum colony population by the end of the season, subject to the constraint that enough honey has been collected for overwintering. Kumar *et al.* (1995) reported that in India, colonies covering 4, 6, 8 and 10 combs produced 9-12, and 18 kg of honey, respectively. According to Bhusal and Thapa (2006), and Chaand *et al.* (2017) in a significant research found that the extent of honey production and pollination depends upon the foraging pattern of the colony. The foraging pattern in turn is influenced by the colony strength, viz. number of workers, presence of brood, pollen and honey stores and also of artificial feeding. Also concluded that population of the colony has a greater impact on the colony productivity and efficiency.

In spite of various evidences of initial colony strength having effect over colony productivity strangely there are no standards set for optimum colony strength for *A. mellifera* L. in India to keep beekeepers safe from losses, caused due to lack of knowledge. Contemporary Indian beekeeping is facing four major problems, viz. low colony productivity, colony debilitation/mortality, extremely poor honey quality and ever increasing high cost of production (labor and migration) resulting in non-stability of the beekeeping

[1]Research Associate (e mail: sumit87saini@gmail.com), CIB and RC, Directorate of Plant Protection Quarantine and Storage, Faridabad. [2]Professor, (e mail: chaudharyop@gmail.com), [3]Ph D Scholar (Entomology) (e mail: anooshareddysaini@gmail.com), Department of Entomology, CCS Haryana Agricultural University, Hisar 125 044.

Table 1 Comparison of total honey area under different colony strengths on different dates of observations

Colony strengths (No. of frames/ colony)	Area (inches^2/colony) on dates of observations of year 2014-16											Mean
	Dec-15	Jan-15	Jan-31	Feb-15	Feb-28	Mar-15	Mar-31	Apr-15	Apr-30	May-15	May-31	
5	109.6	329.4	410.4	437.1	503.5	280.4	187.1	260.1	233.0	159.3	133.7	276.7
10	343.2	606.9	496.1	804.0	813.3	584.3	471.3	500.2	366.4	435.0	336.7	523.4
15	610.5	964.5	1031.8	1272.4	1433.5	1058.3	581.9	761.8	906.5	628.1	495.7	885.9
Mean	354.4	633.6	646.1	837.8	916.8	641.0	413.4	507.4	501.9	407.4	322.0	
CD (P≤0.05)	*Dates of observations*					*No. of frames*			*Interaction frame strength × Dates*			
	56.1					29.3			97.2			

enterprise (Chaudhary 2014 a, b). Keeping in view present study was planned to evaluate effect of number of initial frame strength on honey, pollen and brood production under Haryana condition during 2014-15 and 2015-16.

MATERIALS AND METHODS

A farmer's apiary of 36 colonies of *Apis mellifera* L. was selected for the study. The colonies were further configured in the evening into various colony strengths as per the envisaged treatments (5, 10 and 15 frames/colony) taking care to equalize them in terms of young queen, food stores, brood area, etc. as per the protocol (Delaplane *et al.* 2013). 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 placed near water pond and was surrounded by abundant mustard that just started blooming. 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.

Frame strength of experimental colonies		
5 Frame	10 Frame	15 Frame
No. of colonies to be examined in each frame strength = 36 colonies (12 each in 5, 10 and 15 frame strength)		

After transferring colonies to the experimental site, initial state of each colony across various treatments was recorded that included a standard set of 16 parameters (Sealed honey (square inches): Unsealed honey/nectar: Pollen: Eggs: Larvae/unsealed brood: Pupae/sealed brood: Drone brood: Queen quality: Queen cells) (Dietemann *et al.* 2013).

The amount of brood and honey was determined on the basis of brood measuring frame containing squares of area 1 cm^2 each but later on area of resources and different stages of the honey bee in a colony was measured using new brood measuring frame that included a double-rimmed metal casing joined with a hinge, resting on a metal stand to make operations "hands free" (Saini *et al.* 2018). Commonly used beekeeping tools like bee veils were utilized while working with honey colonies using hive tool for opening the boxes and shifting of frames while taking observations and ten frame honey extractor (centrifuge) was used for extraction of honey at different time intervals. Observations were recorded at fortnightly intervals for all colony growth parameters. Statistical analysis were performed by two-way ANOVA using OPSTAT software (Sheoran *et al.* 1998).

RESULTS AND DISCUSSION

Honey flow periods during 2014-15 was shorter and confined to end March only while during 2015-16 it prolonged beyond mustard season to end of May due to availability of nectar and pollen from minor bee flora.

Variations in honey reserves under different colony strengths (inches^2)

Total honey area in a colony (sum of sealed honey and unsealed honey/nectar) was found be directly correlated to the colony strength (Table 1), being minimum in the weakest 5 frame colonies (276.7 inches^2) that increased 1.9 folds in medium strength 10 frame colonies to 523.4 and was the maximum in strongest 15 frame colonies (885.9), an increase of 3.2 fold over the weakest colonies and even 1.7 times than the 10 frame colonies. Total honey stores were relatively higher in the colonies throughout the honey flow season from 354.4 at the beginning (15 December) to 322.0 inches at the end of season on 31 May. A sudden spurt was recorded in January (15 and 31, 633.6 and 646.1 inches^2) but maximum was on 28 February (916.8) and 15 January (837.8 inches) and on 15 March also it was significantly higher (641.0) and at par with January values. A sudden dip in honey value is due to extraction of honey.The superiority of these improved practices is further elevated by the proportion of sealed and unsealed honey (Fig 1). The 10 and 15 frame colonies recorded higher proportion of sealed honey (47.2 and 45.5%) than the five frame colonies (39.2%).

Sealed honey area (inches^2): Significant variations in sealed honey area in a colony were observed and found to be influenced by the colony strength (Table 2). Maximum sealed honey in colonies with 15 frames (402.9 inches^2), a 3.7 fold increase over 5 frame colonies and even 1.6 times over 10 frame colonies. The mean sealed honey area was very low at the beginning of experiment on 15 December (96.7 inches^2) and increased steadily later to become maximum on 28 February (520.4). Similar trend was recorded in all colony strengths but the growth was lowest in the weakest colonies and they had lowest reserves post 31 March period compared to medium and high strength colonies.

Table 2 Comparison of sealed honey area in different colony strengths on different dates of observations

Colony strengths (No. of frames/ colony)	Area (inches^2/colony) on dates of observations of year 2014-16											Mean
	Dec-15	Jan-15	Jan-31	Feb-15	Feb-28	Mar-15	Mar-31	Apr-15	Apr-30	May-15	May-31	
5	9.3	83.6	143.2	144.5	254.1	136.0	16.3	155.2	120.3	52.6	77.8	108.5
10	121.3	315.8	193.2	397.4	460.0	288.1	32.8	281.2	176.0	239.5	210.1	246.9
15	159.4	327.8	416.3	549.0	847.2	591.2	74.4	332.5	502.8	342.3	288.4	402.9
Mean	96.7	242.4	250.9	363.6	520.4	338.4	41.2	256.3	266.4	211.5	192.1	
CD (P≤0.05)	*Dates of observations*					*No. of frames*			*Interaction frame strength × Dates*			
	47.0					24.5			81.4			

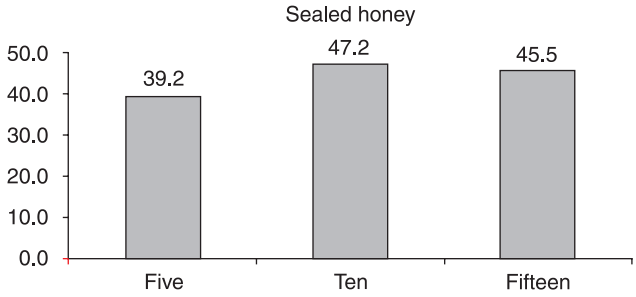

Fig 1 Sealed honey in different frame strength

Unsealed honey area (inches^2): The amount of nectar stored in a colony was proportional to the colony strength (Table 3), minimum being in the weakest five frame colonies (168.2 inches^2), increasing significantly in 10 frame colonies to 278.1 and to the maximum (483.1) in the strongest colonies of 15 frames. In the strongest colonies, the increase in nectar area was 2.9 folds over the weakest colonies and 1.7 times over 10 frame colonies. The pattern of nectar stores was altogether different from sealed honey in way that from moderate levels on 15 December (257.8) it increased greatly on 15 and 31 January (391.2 and 401.1) to become maximum on 15 February (474.2), maintaining significant levels later that dwindled only in May. The honey area was also reported to be influenced by the colony strength by Neupane *et al.* (2012). Bhusal *et al*. (2011) and Bhusal and Thapa (2006) also correlated initial colony strength with honey production and Verma (1992) also concluded that larger and stronger colonies result in 1.5 fold increase in honey area from *A. mellifera* with 60000 worker bees. Anonymous (2005) also reported extensive increase in sealed honey and brood area in mustard in Punjab where colonies grew by 190%. Chaand *et al.* 2017, also have similar kind of findings of colony strength over colony build up.

Variations in brood area under different frame strength (inches^2)

Colony strength was found to have significant impact on total brood area (Table 4). The weakest five frame colonies possessed minimum brood area (310.9 inches^2) that increased significantly with increase in colony strength to 10 frames (436.2) and became maximum (488.6) in the strongest colonies on 15 frames. It was interesting to record significant amount of brood area in colonies throughout the honey flow season, indicating higher utility to the beekeeping operation in the regions. The brood area was quite higher even at the beginning of the season (468.8) and became maximum quite earlier on 15 January (573.1 inches^2), maintained high levels up to 28 February (407.1) and declined in March (308.5) but again registered growth up to 15 May (356.3) to become minimum on 31 May (286.8 inches^2). By no means, the values were lower to sustain optimum growth of colonies during whole of the honey flow season.

Unsealed brood: Highly significant variations were observed in area of unsealed brood/larvae as strength of colony increases from five frames (88.4) to 15 frame (155.8). Over the season observations depict that 15 frame colonies have highest larval population followed by 10 and lowest in 5 frames. High brood production was observed on 15 January in all frame strengths and lowest in 31 May here 10 and 15 frame colonies were observed at par with each other (Table 5).

Sealed brood: Significant variation in sealed brood

Table 3 Comparison of unsealed honey in different colony strengths on different dates of observations

Colony strengths (No. of frames/ colony)	Area (inches^2/colony) on dates of observations of year 2014-16											Mean
	Dec-15	Jan-15	Jan-31	Feb-15	Feb-28	Mar-15	Mar-31	Apr-15	Apr-30	May-15	May-31	
5	100.3	245.8	267.2	292.6	249.3	144.4	170.8	104.9	112.6	106.7	55.9	168.2
10	222.0	291.0	319.6	406.7	353.4	296.2	438.5	219.0	190.3	195.4	126.6	278.1
15	451.0	636.7	616.4	723.4	586.3	467.2	507.5	429.4	403.7	285.7	207.3	483.1
Mean	257.8	391.2	401.1	474.2	396.4	302.6	372.3	251.1	235.6	196.0	129.9	
CD (P≤0.05)	*Dates of observations*					*No. of frames*			*Interaction Frame strength × Dates*			
	38.4					20.1			66.5			

Table 4 Comparison of total (sealed + unsealed + egg) brood in different colony strengths on different dates of observations

Colony strengths (No. of frames/ colony)	Area (inches^2/colony) on dates of observations of year 2014-16											Mean
	Dec-15	Jan-15	Jan-31	Feb-15	Feb-28	Mar-15	Mar-31	Apr-15	Apr-30	May-15	May-31	
5	290.0	480.6	420.4	433.1	346.6	258.9	241.9	268.9	212.3	243.8	223.8	310.9
10	484.7	584.9	494.8	461.4	376.2	360.6	326.4	501.6	441.2	439.7	327.3	436.2
15	631.8	653.7	522.0	549.2	498.5	455.2	357.2	514.4	498.3	385.4	309.3	488.6
Mean	468.8	573.1	479.0	481.2	407.1	358.3	308.5	428.3	383.9	356.3	286.8	
CD (P≤0.05)	*Dates of observations*					*No. of frames*			*Interaction Frame strength × Dates*			
	40.1					20.9			69.4			

Table 5 Comparison of unsealed brood in different colony strengths on different dates of observations

Colony strengths (No. of frames/ colony)	Area (inches^2/colony) on dates of observations of year 2014-16											Mean
	Dec-15	Jan-15	Jan-31	Feb-15	Feb-28	Mar-15	Mar-31	Apr-15	Apr-30	May-15	May-31	
5	103.1	134.4	124.2	126.0	92.5	73.1	64.8	74.3	64.7	56.1	59.1	88.4
10	101.7	193.3	147.6	116.3	120.6	104.2	90.4	136.4	152.2	113.8	96.0	124.8
15	177.9	206.3	175.2	165.4	202.2	149.4	108.5	160.2	146.0	125.5	97.8	155.8
Mean	127.6	178.0	149.0	135.9	138.4	108.9	87.9	123.6	121.0	98.5	84.3	
CD (P≤0.05)	*Dates of observations*					*No. of frames*			*Interaction Frame strength × Dates*			
	19.3					10.1			33.4			

was observed in different frame strengths which range from 201.6 to 128.8. When observed over the honey flow period maximum brood area was recorded during 15 January (258.3) which decrease significantly on 31 January (165.2), sealed brood area keeps on decreasing and increasing but a steady decrease was observed after April (Table 6).

Egg area: Colonies with lowest frame strength keeps on producing low eggs throughout the honey flow season and varies significantly (Table 7). Egg area 94.0 cm^2 was observed in five frames which were significantly lower than 10 frames 123.3 cm^2. As per the observations recorded over the season it was revealed that even egg area was significantly low in weak colonies but proportion of egg produced was higher as compared to the medium and high frame colonies is more. Bhusal *et al*. (2011) determined the effect of initial colony strength of *A.mellifera* on honey production in Nepal. Neupane *et al.* (2012) found honey production to be highly correlated to the number of worker brood cells in the colonies (r = 0.96, p = 0.003). They found initial colony strength of 5,10 and 20 combs (ratio 1:2:4) resulted in overall mean number of brood cells at the rate of 1.0:1.4:1.8, thus, in proportion to the strength of colonies, the lowest increase of the brood amount occurred in strong colonies.Studies of Neupane *et al.* (2012), Szabo (1992), Anonymous (2005) and Bhusa *et al*. (2011) are in line with our findings who reported that the bee colony strength depends upon the amount of brood produced. These findings find further support from those of Gabka (2014) who reported that the colonies covering 8 combs had significantly more brood (20.8 dm^2 on the average) than colonies covering 6 combs (15.5 dm^2). Bhusal *et al*. (2011) further determined the effect of initial colony strength on mean number of brood cells constructed, number of combs developed, to be significantly affected by the honeybee population.

Pollen stores in different frame strength

Pollen area in a colony was found to be directly influenced by colony strength (Table 8) as the area increase

Table 6 Comparison of sealed brood in different colony strengths on different dates of observations

Colony strengths (No. of frames/ colony)	Area (inches^2/colony) on dates of observations of year 2014-16											Mean
	Dec-15	Jan-15	Jan-31	Feb-15	Feb-28	Mar-15	Mar-31	Apr-15	Apr-30	May-15	May-31	
5	90.3	201.5	144.3	202.1	163.7	97.0	124.7	128.4	69.6	90.0	105.2	128.8
10	246.1	257.0	172.7	235.8	137.2	116.8	181.1	253.5	124.3	187.9	157.9	188.2
15	264.1	316.2	178.6	228.9	133.9	193.7	146.9	234.6	254.3	141.4	124.7	201.6
Mean	200.1	258.3	165.2	222.3	144.9	135.8	150.9	205.5	149.4	139.8	129.3	
CD (P≤0.05)	*Dates of observations*					*No. of frames*			*Interaction Frame strength × Dates*			
	23.5					12.3			40.8			

Table 7 Comparison of egg area in different colony strengths on different dates of observations

Colony strengths (No. of frames/ colony)	Area (inches^2/colony) on dates of observations of year 2014-16											Mean
	Dec-15	Jan-15	Jan-31	Feb-15	Feb-28	Mar-15	Mar-31	Apr-15	Apr-30	May-15	May-31	
5	96.5	144.7	151.9	105.1	90.4	88.8	52.5	68.5	78.0	97.7	59.6	94.0
10	137.0	134.5	174.5	109.4	118.4	139.6	55.0	111.6	164.7	138.0	73.4	123.3
15	189.9	131.3	168.2	155.0	162.5	112.1	101.8	119.6	98.0	118.5	86.8	131.2
Mean	141.1	136.8	164.9	123.2	123.8	113.5	69.7	99.9	113.6	118.1	73.2	
CD (P≤0.05)	*Dates of observations*					*No. of frames*			*Interaction Frame strength × Dates*			
	19.7					10.3			34.2			

Table 8 Comparison of Pollen area in different colony strengths on different dates of observations

Colony strengths (No. of frames/ colony)	Area (inches^2/colony) on dates of observations of year 2014-16											Mean
	Dec-15	Jan-15	Jan-31	Feb-15	Feb-28	Mar-15	Mar-31	Apr-15	Apr-30	Mar-15	Mar-31	
5	18.2	66.9	82.0	91.9	62.4	69.8	67.5	46.6	51.3	52.6	53.8	60.3
10	80.0	114.3	112.5	88.0	88.2	94.0	92.1	77.1	85.1	87.3	72.1	90.1
15	98.1	145.0	158.0	147.8	135.4	138.6	125.3	92.2	132.0	139.1	109.8	129.2
Mean	65.4	108.7	117.5	109.2	95.3	100.8	95.0	72.0	89.5	93.0	78.6	
CD (P≤0.05)	*Dates of observations*					*No. of frames*			*Interaction Frame strength × Dates*			
	16.5					8.6			NS			

significantly with increase in strength from five frames (60.3 inches^2) to 10 (90.1) and further to 15 frames where it was maximum (129.2). The 10 frame colonies hoarded 1.5 times more pollen than 5 frames while 15 frames had twice the amount of 5 frame colonies. Pollen stores in colonies were relatively higher during the entire honey flow season (65.4-117.5 inches). Highest pollen area was recorded during 15 and 31 January (108.7 and 117.5) while on other periods, they were moderate to high except on 15 April when they were the lowest (72.0). The five frame colonies had initial lowest pollen reserves (18.2) but that increased substantially in January and followed the general pattern of pollen hoarding. The significant observations were relatively higher pollen reserves in weak five frame colonies (12.0 inches^2/frame) compared to 10 (9.1) and 15 frame colonies (8.6). The findings are supported by those of Bhusal *et al*. (2011) who reported initial colony strength of *A. mellifera* correlated with mean number combs developed and pollen/bee brood collection and Verma (1992) found populous colonies with 60000 worker bees forage for large pollen loads as compared to low brood colony. High brood colonies were also reported to make making more trip and forage longer distances for nectar collection (Jevtic *et al.* 2009, Kumar and Singh 2000, Eckert *et al.* 1994).

Drone brood area in different colony strength

Drones (males) brood was present throughout the honey flow season but their highest frequency was up to 28 February (16.6-18.2 inches^2/colony) from an initial low of 5.1 on 15 December (Table 9). The drone area decreased significantly in April and May when it was lowest (2.6-2.7 inches). The drone brood area lowest (5.4) in the weakest colonies and almost doubled in 10 and 15 frame colonies (10.1 and 12.9 inches, respectively). Drones area is also an important parameter of colony growth as it is an indicator of colony multiplication/swarming warning. Scanty literature is available on effect of drone over colony growth.

The role of colony strength in improving honey quality,

Table 9 Comparison of drone area in different colony strengths on different dates of observations

Colony strengths (No. of frames/ colony)	Area (inches^2/colony) on dates of observations of year 2014-16											Mean
	Dec-15	Jan-15	Jan-31	Feb-15	Feb-28	Mar-15	Mar-31	Apr-15	Apr-30	Mar-15	Mar-31	
5	2.1	8.1	6.4	7.3	13.2	7.2	5.1	4.3	2.9	1.0	2.1	5.4
10	3.2	23.9	15.4	19.6	16.3	9.5	9.4	6.6	2.1	2.9	2.3	10.1
15	10.1	17.7	19.0	20.3	25.2	16.0	10.0	6.2	9.3	4.1	3.7	12.9
Mean	5.1	16.6	13.6	15.7	18.2	10.9	8.2	5.7	4.8	2.6	2.7	
CD (P≤0.05)	*Dates of observations*					*No. of frames*			*Interaction Frame strength × Dates*			
	3.5					1.8			6.0			

quantity and in good brood production is amply clear.The mega importance lies in the present status of beekeeping in India by changing the present practice of Indian beekeepers. Keeping honey bee colony on high worker strength at the beginning of the honey flow season could increase production from 2.8-4.0 folds and also improves colony strength that can survive better during dearth.

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