

Selection of honey bee (*Apis mellifera* L.) colonies for desirable traits

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Summary

The experiment on selecting honey bee *Apis mellifera* L. colonies for desirable traits was conducted at the Apiary of the Department of Entomology, CCS Haryana Agricultural University, Hisar, Haryana (India) during 2020-21. The significant variations were observed in various colony parameters viz. colony strength (7.2 to 13.0 no. of bee frames), brood area (1029.42 to 3917.73 cm²), honey store (1196.48 to 2568.71 g), pollen area (314.76 to 692.73 cm²), brood survival rate (76.56 to 91.61.39 %) and paper potness (8.82 to 24.73 %). Ranking of honey bee colonies was developed on the basis of a five-point scoring system for each desirable trait. Colonies were rated based on 1 to 5 point scale. The average score ranged from 1.2 to 4.9. On the basis of top score, 9 colonies (C-6, C-8, C-2, C-20, C-12, C-11, C-5, C-19 and C-16) were selected for further evaluation and mass queen rearing, having average scores ranged from 3.5 to 4.9.

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Introduction

The performance and productivity of a honey bee colony depend on certain positive traits/attributes. Most beekeepers do not go for the selection of colonies to raise queen bees & their mating with the drones of desirable traits. Therefore, the existing stock of honey bee colonies has bees that are usually inbred individuals. Hence, the apiaries are inhabited with genetically more or less the same kind of queens, leading to a lack of genetic diversity within the honey bee populations, limiting the workers response to a health challenge or a change in the environment or climate. This lack of genetic diversity may lead to diseases having a greater impact on bee colonies. The diversity among honey bees represents a highly valuable biological capital that is worth preserving as a basis for future selection and development in response to new ecological and production challenges. The highly complex reproductive biology of honey bees, including multiple mating of queens, long distance mating flights, male haploidy, excess drone production and drone congregation areas, have evolved as an effective toolbox for the selection of genetically diverse honey bee populations. However, modern beekeeping and breeding techniques may limit or extinguish these natural selection effects (Bouga et al. 2011; Haldhar et al. 2021a&b), which risks lowering the vitality of bee populations. Colony strength and its honey production potential depend primarily on the age and qualities of its queen (Ruttner, 1988 and Snelgrove, 1966). World over, the European honey bee (*Apis mellifera* L.) is the basis for the flourishing bee industry. Since its introduction in India, a lot of need-based research has been done on

various aspects of bee behaviour, bee pathology, bee flora, seasonal management, etc. but bee breeding and stock improvement has remained neglected in India (Singh et al. 2007; Haldhar et al. 2022). A highly productive colony must be headed by a queen that can lay 1,500 eggs daily (Farrar 1980). Brood solidness is also an important trait of a colony. The brooding pattern/solidness of a colony could be erratic or solid. The

brood solidness of a comb is expressed by the percentage of empty worker cells in a brood patch of a given area. An acceptable level of empty cells in a comb should usually be less than 10% (Delaplane et al. 2013). In light of the above facts regarding the importance of selecting better-performing colonies, those colonies with all these important traits could be selected in the breeding yard for further breeding programmed for the improvement of the stock. Therefore, the present study was undertaken on selecting honey bee (*Apis mellifera* L.) colonies for desirable traits.

Materials and Methods

The present investigation on 'Selection of honey bee (*Apis mellifera* L.) colonies for desirable traits' was carried out at the Apiary of Department of Entomology, CCS, Haryana Agricultural University, Hisar, Haryana (India) from July 2020 to June 2021. The selection of *A. mellifera* L. colonies was based on desirable traits like colony strength, brood area, prolificness, honey stores, pollen store area, brood survival rate, etc. Twenty *A. mellifera* L. colonies were taken randomly from the existing stock and the performance of these 20 *A. mellifera* L. colonies were recorded at 21 days intervals on the following parameters (Al-Tikrity et al. 1971).

Colony strength

The strength of each honey bee colony was estimated by counting the number of frames covered with brood and bees as per the method of Chaudhary (2003 a, b).

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Brood area

The capped brood area in the *A. mellifera* L. colonies was recorded with the help of one inch wire grid fixed on a brood frame which was later expressed in square centimetres by multiplying the square inches with 6.45 (Chhuneja et al. 1992).

Pollen stores

The pollen stores of the colonies were recorded by using the measuring frame with wire-grid squares covered by pollen. Its value expressed in square centimetres.

Honey stores

Ripe honey was measured with the help of the measuring frame with wire-grid squares. The total area of the ripe honey measured in square inches was multiplied with 6.45 (to convert the area into cm²) x 1.25 (as 1.25 cm² honey = 1 g) to record the honey quantity in grams.

Pepper potness

Per cent of empty cells in honey bee colonies was recorded.

Cleanliness

Debris (mg) lying on the bottom board in the *A. mellifera* L. colonies was recorded.

Bee activity

Activity of *A. mellifera* L. was observed by counting the number of bees leaving the hive (outgoing) and those landing at the entrance (incoming) per minute during different day hours (0900 to 1000 h, 1300 to 1400 h and 1700 to 1800 h). The proportion of pollen foragers was recorded in the case of incoming bees.

Temperament of bees

No. of stings/min on a swinging rubber ball covered with black cloth on which 1-2 drops of amyl acetate was applied before swinging in front of the hive.

Hygienic behavior

25 pupae in the sealed stage were killed by piercing the caps with an entomological needle. The pierced area was observed after 24 hours for the removal of pin-killed brood. Per cent removal of killed brood was worked out by using following formula:

$$\text{Percent removal} = \frac{\text{Number of pin killed pupae removed}}{25} \times 100$$

Rating of various performance characters

The overall performance of experimental colonies of *A. mellifera* L. was rated on the basis of 1-5 point scale. The ranking was done for the eleven different parameters i.e. bee strength, sealed worker brood area, honey store, pollen area, brood survival rate, pepper potness, pollen loads/bee (mg), hygienic behavior, nest cleaning, mean incoming bees and mean outgoing bees. The ranking of the least performing colony was given 1 point, whereas the best-performing colony was ranked the highest rank 5.

Results and Discussion

Overall performance of *Apis Mellifera* L. colonies

The data on performance of 20 *A. mellifera* L. colonies revealed that the maximum bee strength (13.0) was recorded in colony number C-8 (Table 1), whereas the minimum was in colony number C-13 (7.2 bee strength). The maximum sealed brood area was found in colony number C-20 (3917.73 cm²), which was statistically at par with colony number C-19 (3115.35 cm²), C-8 (3326.91 cm²), C-6 (3048.27 cm²) and C-2 (3890.64 cm²) and it was significantly superior over rest of the colonies. Minimum sealed brood area recorded in colony number C-13 (1029.42 cm²). The highest average honey store was recorded in colony number C-8 (2568.71 g), followed by C-11 (2496.15 g), whereas the minimum honey store was found in colony number C-9 (1196.48 g).

Table 1. Performance of 20 *Apis mellifera* L. colonies from existing stock at CCSHAU, Hisar during 2020-21

Colonies No.	Bee strength	Sealed worker Brood area (cm ²)	Honey store (g)	Pollen area (cm ²)	Brood survival rate (%)	Pepper potness (%)	Nest cleaning/ Debris (mg)	Pollen loads/bee (mg)	Hygienic behavior	Mean incoming bees/min	Mean outgoing bees/min
C-1	8.5	1722.15 (3.19)*	1472.21 (3.12)*	387.00 (2.58)*	80.65 (65.15)**	21.29 (27.47)**	6.32	6.37	86.67 (68.89)**	27.5	28.2
C-2	12.8	3890.64 (3.59)	2410.69 (3.36)	663.06 (2.82)	89.03 (71.09)	9.03 (17.23)	4.38	6.73	98.67 (86.14)	38.5	32.6
C-3	9.0	1869.21 (3.34)	1588.31 (3.17)	474.72 (2.62)	81.51 (64.53)	21.72 (27.73)	5.74	6.53	81.33 (64.41)	25.2	29.0
C-4	9.3	1924.68 (3.27)	1544.78 (3.17)	468.27 (2.66)	84.52 (66.84)	19.57 (26.23)	6.01	6.33	86.67 (68.89)	30.0	31.5
C-5	11.0	2232.99 (3.33)	2113.99 (3.29)	566.31 (2.75)	88.39 (70.39)	12.26 (20.47)	4.60	6.57	92.00 (73.89)	34.8	33.4
C-6	12.7	3048.27 (3.48)	2476.80 (3.37)	617.91 (2.78)	89.89 (71.81)	9.46 (17.82)	3.68	6.80	100.00 (90.00)	42.6	35.9
C-7	8.4	1568.64 (3.19)	1468.99 (3.11)	376.68 (2.57)	81.51 (64.61)	18.49 (25.41)	7.84	6.40	85.33 (67.50)	22.5	26.4
C-8	13.0	3326.91 (3.52)	2568.71 (3.39)	681.12 (2.80)	91.61 (73.31)	8.82 (17.18)	3.96	6.67	100.00 (90.00)	40.8	38.9
C-9	7.8	1504.14 (3.15)	1196.48 (3.39)	314.76 (2.48)	77.20 (61.54)	24.73 (29.80)	5.74	6.07	80.00 (63.61)	23.4	20.4
C-10	8.2	1857.60 (3.24)	1517.36 (3.13)	367.65 (2.56)	81.29 (64.46)	21.08 (27.23)	6.40	6.20	81.33 (64.41)	30.5	24.3
C-11	10.1	2866.38 (3.45)	2496.15 (3.37)	594.69 (2.76)	86.67 (68.65)	12.26 (20.34)	3.88	6.50	96.00 (83.24)	33.6	29.8
C-12	11.0	2690.94 (3.42)	1802.78 (3.23)	566.31 (2.74)	87.74 (69.99)	9.68 (17.90)	3.48	6.53	97.33 (82.29)	35.6	39.4
C-13	7.2	1029.42	1269.04	394.74	76.56	22.15	5.86	6.03	81.33	22.7	22.3

		(3.01)	(3.05)	(2.58)	(61.04)	(27.97)			(64.71)		
C-14	9.8	2774.79 (3.43)	1993.05 (3.28)	530.19 (2.72)	85.59 (68.79)	18.92 (25.68)	4.76	6.52	92.00 (73.89)	28.6	23.8
C-15	8.0	1747.95 (3.20)	1462.54 (3.13)	390.87 (2.58)	80.00 (63.48)	20.43 (26.76)	6.36	6.23	84.00 (66.79)	26.2	21.6
C-16	10.6	2939.91 (3.44)	1925.33 (2.76)	579.21 (2.76)	88.39 (70.59)	14.84 (22.56)	5.50	6.57	94.67 (79.38)	36.4	29.4
C-17	8.6	2485.83 (3.38)	1533.49 (3.14)	479.88 (2.67)	78.92 (62.73)	20.43 (26.66)	7.14	6.40	82.67 (65.40)	27.0	27.2
C-18	9.0	2467.77 (3.39)	1585.09 (3.20)	509.55 (2.70)	81.72 (64.71)	17.85 (24.89)	6.12	6.27	93.33 (77.75)	24.7	28.7
C-19	10.2	3115.35 (3.48)	1685.06 (3.20)	595.98 (2.77)	86.24 (68.19)	15.27 (22.90)	4.88	6.30	98.67 (86.14)	31.2	36.0
C-20	12.1	3917.73 (3.59)	1820.51 (3.22)	692.73 (2.83)	88.60 (70.31)	9.25 (17.64)	4.36	6.93	98.67 (86.14)	39.4	36.4
CD_(0.05)	2.04	(0.12)	(0.12)	(0.13)	(5.01)	(3.17)	1.31	0.48	(9.95)	4.68	6.11

All values are mean of 10 observations; *Figure in parenthesis are $\log(x+1)$ transformed values; ** Figure in parenthesis are angular transformed values

The maximum pollen area was recorded in colony C-20 (692.73 cm²), followed by C-8 (681.12 cm²) and C-2 (663.06 cm²). The colony number C-9 (314.76 cm²) was recorded with minimum pollen area and it was significantly lower than the rest of the colonies except colony number C-10 (367.65), C-7 (376.68), C-15 (390.87) and C-13 (394.74). Statistically similar brood survival rate (per cent) was recorded in colony number C-8 (91.61 %), followed by colony number C-6 (89.89 %), C-2 (89.03 %), C-20 (88.60 %), C-5 (88.39 %), C-16 (88.39 %), C-12 (87.74), C-11 (86.67) and C-14 (85.59) whereas minimum brood survival rate was observed in colony number C-13 (76.56 %).

The paper potness (per cent of empty cells) in selected 20 *A. mellifera* L. colonies varied from 8.82 (C-8) to 24.73. The maximum paper potness was recorded in colony number C-9 (24.73 %), which was statistically at par with colony number C-13 (22.15 %), C-3 (21.72 %), C-1 (21.29 %), C-10 (21.08 %) and C-15 & C-17 (20.43 %). At the university apiary, variations have been found in the selected 20 *A. mellifera* colonies' performance parameters like pollen loads/bee (mg) (ranged from 6.03 to 6.93 mg), nest cleaning/ debris (mg) (varied from 3.48 to 7.84 mg), average incoming bees/min (22.5 to 42.6 bees/min) and average outgoing bees/min (20.4 to 39.4 bees/min).

The present findings confirm with those of Thakur (1994), who selected better honey-producing breeder colonies based on desirable traits (biological and economical characters). The variations in different colony performance parameters like bee strength, sealed worker brood area (cm²), honey store (g), pollen area (cm²), brood survival rate (%), pollen loads/bee (mg) were also reported by Singh et al. (2007); Sharma (2010); Jat et al. (2016); Monika (2017); Kumar and Mall (2018) and Sharma et al. (2020). Burgett et al. (1985) reported about the quantification of the number of adult workers of *Apis mellifera*, found on combs of standard sizes at full holding capacity and this holding capacity of combs can assist in evaluating honey bee colonies for honey-production potentials.

Table 2. Ranking of characters listed for selection of *A. mellifera* L.

Parameters	SCORES				
	1	2	3	4	5
Bee strength	7.2-8.4	8.4-9.5	9.5-10.7	10.7-11.8	>11.8

Out of 20 colonies selected, eleven colonies (>50%) removed more than 90 per cent of dead brood, thus exhibited very good hygienic behavior by removing the dead or damaged broods from the combs of all the *Apis mellifera* colonies. Colony number C-6 and C-8 removed 100 per cent dead brood. Hygienic behavior is a much-desired trait for the survival of a bee colony; therefore, it is considered an important factor for selecting honey bee colonies. Present findings are in confirmation with those of Seeley et al. (2007); Sharma et al. (2020), who reported that the first-stage bees remove the capping of the brood cell, and then remove the dead larvae or pupae, and this characteristic has been found to be regulated by two pairs of recessive genes and according to the Rothenbuhler (1964) who recorded that disease resistance is known to correlate with the 'hygienic behaviour' of worker bees.

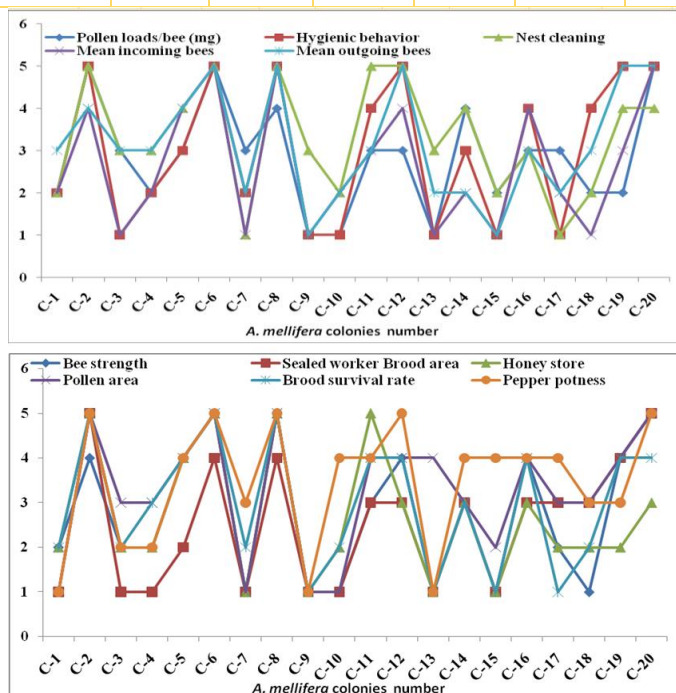
Ranking of 20 *A. mellifera* colonies on 5 point scale for various performance characteristics

The performance of experimental colonies of *A. mellifera* L. was rated based on 1-5 point scale in Table 2, 3 and Fig 1. The overall performance of a colony was measured by the average ranking value of the bee strength, sealed worker brood area, honey stores, pollen stores, brood survival, paper potness, nest cleanliness, pollen loads, hygienic behavior, mean incoming bees/ and mean outgoing honey bees. The score ranged from 1.2 to 4.9. Based on top score, 9 colonies (C-6, C-8, C-2, C-20, C-12, C-11, C-5, C-19 and C-16) and) were selected for further evaluation and mass queen rearing, having average score ranging from 3.5 to 4.9. In the present investigation, the ranking of honey bee colonies have been developed based on five point scoring system for each of the desirable traits. (Sharma et al. 2017), honey bee colonies were ranked on five-point scale and selected for further studies. Similarly, Singh et al. (2007); Sharma et al. (2020) also used a five-point scale for scoring of various performance characters to select better-performing *A. mellifera* colonies for stock improvement programmed.

Sealed worker Brood area (cm ²)	1504.1-1986.9	1986.9-2469.6	2469.6-2952.3	2952.3-3435.0	>3435.0
Honey store (g)	1196.5-1470.9	1470.9-1745.4	1745.4-2019.8	2019.8-2294.3	>2294.3
Pollen area (cm ²)	314.8-390.4	390.4-466.0	466.0-541.5	541.5-617.1	>617.1
Brood survival rate (% workers emerged)	77.2-80.1	80.1-83.0	83.0-85.8	85.8-88.7	>88.7
Pepper potness (% empty cells)	21.5-24.7	18.3-21.5	15.2-18.3	12.0-15.2	<12.0
Nest cleaning (Debris mg)	6.97-7.84	6.10-6.97	5.22-6.10	4.35-5.22	<4.35
Pollen loads/bee (mg)	6.03-6.21	6.21-6.39	6.39-6.57	6.57-6.75	>6.75
Hygienic behavior	80.0-84.0	84.0-88.0	88.0-92.0	92.0-96.0	>96.0
Mean incoming bees/min	22.50-26.60	26.60-30.60	30.60-34.60	34.60-38.60	>38.60
Mean outgoing bees/min	20.40-24.20	24.20-28.00	28.00-31.80	31.80-35.60	>35.60

Table 3: Ranking of 20 *A. mellifera* colonies on 5 point scale for various performance characteristics

Colonies No.	Bee strength	Sealed worker Brood area	Honey store	Pollen area	Brood survival rate	Pepper potness	Pollen loads/bee (mg)	Hygienic behavior	Nest cleaning	Mean incoming bees	Mean outgoing bees	Overall mean
C-1	2	1	2	1	2	1	2	2	2	2	3	1.8
C-2	4	5	5	5	5	5	5	5	5	4	4	4.7
C-3	2	1	2	3	2	2	3	1	3	1	3	2.1
C-4	2	1	2	3	3	2	2	2	3	2	3	2.3
C-5	4	2	4	4	4	4	3	3	4	4	4	3.6
C-6	5	4	5	5	5	5	5	5	5	5	5	4.9
C-7	1	1	1	1	2	3	3	2	1	1	2	1.6
C-8	5	4	5	5	5	5	4	5	5	5	5	4.8
C-9	1	1	1	1	1	1	1	1	3	1	1	1.2
C-10	1	1	2	1	2	4	1	1	2	2	2	1.7
C-11	3	3	5	4	4	4	3	4	5	3	3	3.7
C-12	4	3	3	4	4	5	3	5	5	4	5	4.1
C-13	1	1	1	4	1	1	1	1	3	1	2	1.5
C-14	3	3	3	3	3	4	4	3	4	2	2	3.0
C-15	1	1	1	2	1	4	2	1	2	1	1	1.5
C-16	4	3	3	4	4	4	3	4	3	4	3	3.5
C-17	2	3	2	3	1	4	3	1	1	2	2	2.2
C-18	1	3	2	3	2	3	2	4	2	1	3	2.4
C-19	4	4	2	4	4	3	2	5	4	3	5	3.6
C-20	5	5	3	5	4	5	5	5	4	5	5	4.6

**Figure 1. Raking of 20 *A. mellifera* colonies on 5 point scale****Acknowledgement**

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Declarations of interests

All authors of this manuscript declare that they have no conflict of interest.

Data sharing

All relevant data are within the manuscript.

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