Journal of Applied and Natural Science
Special Issue: 14 (SI), 220-226 (July, 2022)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Effect of supplementary sugar feeding on colony growth of Asiatic hive bee, *Apis cerana indica* F.

N Vijayakumari*
Department of Agricultural Entomology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore-641003 (Tamil Nadu), India
Saravanan P A
Department of Agricultural Entomology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore-641003 (Tamil Nadu), India
Chitra N
Department of Agricultural Entomology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore-641003 (Tamil Nadu), India
Rajendran L
Department of Plant Pathology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore-641003 (Tamil Nadu), India

*Corresponding author. Email: nviji216@gmail.com

Article Info
https://doi.org/10.31018/jans.v14iSI.3612
Received: March 10, 2022
Revised: May 9, 2022
Accepted: June 22, 2022

How to Cite
Vijayakumari, N. *et al.* (2022). Effect of supplementary sugar feeding on colony growth of Asiatic hive bee, *Apis cerana indica* F.. *Journal of Applied and Natural Science*, 14 (SI), 220 - 226. https://doi.org/10.31018/jans.v14iSI.3612

Abstract
Honey bees also known as "Angels of Agriculture" are arguably the most vital insects on the planet. Bee nutrition is an important aspect of colony management. Supplementary feeding is essential for maintaining the strength and health of honey bee colonies, especially during dearth periods. Experiments were conducted to evaluate a suitable, cheaper carbohydrate supplement and its effect on the colony growth of the Asiatic hive bee *Apis cerana indica*. Four different sugar syrup components, *viz.*, sugar, water, milk and glucose, were combined to form seven treatments : T_1-Sugar: water (1:1), T_2-Sugar: water (1:1) + Glucose (2%),T_3- Sugar: water (1:1) + Desi cow's milk (2%),T_4- Sugar + water (2:1), T_5- Sugar + water (2:1) + Glucose (2%) ,T_6- Sugar + water (2:1) + Desi cow's milk (2%) and T_7-Control and evaluated to select honey bee colonies . Among the different sugar syrup feeding treatments, the colonies fed with T_2 - Sugar: water (1:1) + Glucose (2%) had a profound effect within a month and the colonies recorded an increase in sealed brood area from 175.66 cm^2 to 425.00 cm^2, honey store area from 49.00 cm^2 to 130.33 cm^2, pollen store area from 47. 33 cm^2 to 125.33 cm^2, adult bee population from 4318.66 bees/colony to 4933.33 bees/colony. The work is new to *A. cerana indica*. Many of their bee colonies suffer from poor nutrition and absconding during the dearth period. The present study will help the beekeeping farmers maintain these Asiatic honey bee colonies during the starved period and will be useful in income generation.

Keywords: *Apis cerana indica*, Asiatic hive bee, Colony growth, Sugar feeding

INTRODUCTION

Honey bees are eusocial insects belonging to the *Apis* genus. Honey bees are considered one of the essential pollinators of angiosperms because of their foraging habits and special anatomical adaptations to collect their rewards from flowers. Honey bees are responsible for approximately 85 *% of t*he pollination activity required to feed approximately one-third of the world's food supply. India comprises seven *% of t*he world's vegetation, which can support 200 million bee colonies and provide direct employment to over 21.5 million individuals (Sharma *et al*., 2022). In addition to honey production, beekeeping provides a number of other advantages (Gupta *et al*., 2014). Honey bees are crucial for providing this vital ecosystem service that ensures fruit set in several cross-pollinated crops. Bee products are also an important source of nutrition and have a variety of healing properties (Musa ozcan and Al Juhaimi, 2015). Bee colonies require an ample supply of nectar and pollen from flowering plants to sustain their colony growth and reproduction. James *et al.*

This work is licensed under Attribution-Non Commercial 4.0 International (CC BY-NC 4.0). © : Author (s). Publishing rights @ ANSF.

(2008) revealed that the native bee flora begins to diminish in April, resulting in food shortages (pollen and nectar) and causing reduced egg laying and brood rearing. During dearth periods, bee colonies must be fed with supplementary feeding for their survival. Generally, when floral resources become scarce, supplementary feeding is a common management strategy for maintaining colony health. Sugar syrup feeding can boost colony growth and significantly affect colony weight, brood rearing, and pollen gathering (Paray *et al*., 2020). The major goal of this study was to evaluate appropriate supplementary sugar feeding and its effect on Asiatic honey bee, *Apis cerana indica* colony growth and development.

MATERIALS AND METHODS

The studies were carried out in selected Asian bee colonies, *A. cerana indica* placed on the Tamil Nadu Agricultural University Campus, Coimbatore. Asiatic hive bee colonies were given supplementary feeding to meet their energy requirements during the dearth period. Sugar and water were mixed in a 1:1 ratio, and glucose and Desi cow milk were added to six different treatments along with control conditions. The treatment include T_1-Sugar: water (1:1), T_2-Sugar: water (1:1) + Glucose (2%),T_3- Sugar: water (1:1) + Desi cow's milk (2%),T_4- Sugar + water (2:1), T_5- Sugar + water (2:1) + Glucose (2%) ,T_6- Sugar + water (2:1) + Desi cow's milk (2%) and T_7-Control. This sugar feeding was given to selected honey bee colonies and compared with control colonies. Three bee colonies with four frame strengths were selected for each treatment and given two supplementary feedings at 14-day intervals. The observations were recorded periodically at weekly intervals for a month (Kumar *et al*.,2013)

Frame strength, bee population, honey store, pollen store, bee strength, brood rearing, swarming tendency and pest and disease incidence are the important factors that contribute to colony growth. The brood rearing area and honey and pollen stores were measured with the help of a frame-sized wire grid (or) transparent polyethylene sheet in cm^2 and calculated after multiplying by 6.45. The colony's growth and success are reflected in the honey storage area. Sealed honey cells can be distinguished from sealed brood cells by their modest transparency and sunken appearance as opposed to the dull and slightly elevated appearance of sealed brood cells. Pollen gathered from flowers is generally stored in each comb's upper layer of cells for later use.

The colony's bee strength was measured in terms of the number of frames/combs covered with bees on both sides of the combs. The adult bee population was recorded by calculating the total number of frames entirely covered with honey bees, the *% area* partially covered and summed to obtain the total frame strength of the colony. The bee strength of the colonies was recorded in terms of the frame strength of bees at 14-day intervals. The number of worker bees going out and returning to the hive with and without pollen loads was counted using a stop watch to assess the foraging activities. Foraging activity was recorded in weekly intervals, and observations were taken three times a day at 1000 h, 1300 h and 1600 h for five minutes each, with the sum of the three intervals being used to calculate the total foragers of the hive per five minutes. The observations were statistically analysed with one-way ANOVA in a completely randomized design using SPSS software.

RESULTS AND DISCUSSION

Brood area

Over the course of a month, sugar syrup feeding significantly enhanced brood raising in Asian honey bee colonies, *A. cerana indica*. T_2 sugar syrup-fed colonies had the highest mean brood area development (295.25 cm^2) (Table 1), followed by T_3-fed colonies (271.41 cm^2), and the control colonies had slower brood area growth (205.41 cm^2). T_2 - Sugar: water (1:1) + glucose (2%) feeding resulted in a 53.37% increase in brood area compared to control colonies, and these colonies (T_2) produced more queen cells (Plate 1 a) and drone cells (Plate 1 b) with the maximum population resulting in colony division.

Guler *et al.* (2018) also found that providing sugar syrup in addition to glucose had a favourable impact in *Apis mellifera* colonies. The hive weights of colonies varied greatly based on the sugar types and syrup quantities. After being fed sugar syrup, honey bees were also motivated to improve their natural pollen collection and become capable of generating a brood. Sammataro and Weiss (2013) found that sugar syrup feeding has a stimulatory effect on the colonies, resulting in increased pollen-gathering and egg-laying activity and improved honeybee hygienic behaviour.

Honey store area

Sugar syrup + vitamin feeding increases colony formation and average honey yield per harvest much more than sugar feeding alone, according to Sahinler *et al*. (2005). In the present study, the colonies fed with T^2 - sugar: water (1:1) + glucose (2%) had a 47.67 % increase in honey storage area (90.08 cm^2) (Table 2). T^3 - Sugar: water (1:1) + Desi cow's milk (2%) performed well in the growth of honey store area (83.33 cm^2) (Plate 1 c). McGowan *et al*. (2016) found that sugar syrup increased the number of honey bee foragers visiting a variety of crops, resulting in a substantial impact on colony weight, brood rearing and pollen harvesting.

Table 1. Effect of sugar syrup feeding on brood development in *Apis cerana indica* colonies

Treatments	Brood area (cm^2)*					
	Week 1	Week 2	Week 3	Week 4	Mean	*% increase* in brood area over control
T_1 - Sugar: water (1:1)	173.33 (13.18)^{a}	230.00 (15.17)^{b}	275.00 (16.57)$_{ab}$	325.00 (17.74)^{bc}	250.33 (15.82)^{c}	30.20
T_2 -Sugar: water (1:1) + Glucose (2%)	175.66 (13.26)^{a}	265.00 (16.74)^{a}	315.66 (17.07)^{a}	425.00 (19.36)^{a}	295.25 (17.18)^{a}	53.37
T_3-Sugar: water (1:1) + Desi cow's milk (2%)	173.33 (13.18)^{a}	256.66 (15.71)^{b}	305.33 (16.68)^{ab}	350.66 (18.07) ^{b}	271.41 (16.47)^{b}	41.35
T_4- Sugar + water (2:1)	173.66 (13.19)^{a}	203.33 (14.27)^{c}	253.33 (15.91)^{b}	291.66 (17.07)^{c}	230.49 (15.18)^{d}	19.79
T_5-Sugar + water (2:1) + Glucose (2%)	174.33 (13.22)^{a}	225.00 (15.01)^{b}	266.66 (16.32)^{ab}	320.00 (17.88)^{bc}	246.50 (15.70)^{cd}	28.64
T_6- Sugar + water (2:1)+ Desi cow's milk (2%)	175.00 (13.24)^{a}	233.33 (15.49)^{b}	256.66 (16.22)^{b}	306.66 (17.74)^{bc}	242.90 (15.58)^{d}	26.56
T_7-Control	170.66 (13.05)^{a}	188.33 (13.74)^{c}	210.00 (14.48)^{c}	256.66 (16.01)^{d}	205.41 (14.33)^{f}	
SED	0.10	0.33	0.35	0.39	0.11	
CD (0.05)	0.33	0.73	0.78	0.86	0.23	

*Mean of three replications; In the column, means followed by a common alphabet are not significantly different by LSD (p= 0.5). Figures in parenthesis are square root transformed values.

Table 2. Effect of sugar syrup feeding on honey store area in *Apis cerana indica* colonies

Treatments	Honey store area (cm^2)*					
	Week 1	Week 2	Week 3	Week 4	Mean	*% increase* in honey store area over control
T_1 - Sugar: water (1:1)	47.00 (6.92)^{a}	72.00 (8.02)^{bc}	80.02 (8.75)^{b}	102.6 (10.12)^{bc}	75.45 (8.68)^{cd}	23.68
T_2 -Sugar: water (1:1) + Glucose (2%)	49.00 (7.07)^{a}	80.66 (8.55)^{a}	100.00 (9.79)^{a}	130.33 (10.87)^{a}	90.08 (9.49)^{a}	47.67
T_3-Sugar: water (1:1) + Desi cow's milk (2%)	50.00 (7.14)^{a}	75.00 (8.27)^{ab}	83.33 (9.12)^{b}	125.00 (10.48)^{ab}	83.33 (9.12)^{b}	36.61
T_4- Sugar + water (2:1)	48.00 (6.99)^{a}	67.66 (8.25)^{ab}	76.00 (8.71)^{b}	95.00 (9.74)^{cde}	71.41 (8.45)^{e}	17.06
T_5-Sugar + water (2:1) + Glucose (2%)	49.32 (7.08)^{a}	70.00 (8.19)^{abc}	79.66 (8.87)^{b}	98.00 (9.61)^{de}	74.25 (8.61)^{cd}	21.71
T_6- Sugar + water (2:1) + Desi cow's milk (2%)	50.00 (7.14)^{a}	66.66 (8.19)^{abc}	77.66 (8.81)^{b}	97.66 (9.88)^{cd}	72.75 (8.52)^{de}	19.26
T_7-Control	47.00 (6.92)^{a}	60.66 (7.82)^{c}	68.33 (8.26)^{c}	88.33 (9.39)^{e}	66.83 (8.17)^{f}	
SED	0.15	0.17	0.19	0.21	0.06	
CD (0.05)	0.33	0.38	0.42	0.48	0.13	

*Mean of three replications; In the column, means followed by a common alphabet are not significantly different by LSD (p= 0.5). Figures in parenthesis are square root transformed values.

Pollen store area

Sugar syrup feeding significantly impacted the pollen storage area (cm^2) of all the treated colonies. T_2 - Sugar: water (1:1) + glucose had the highest mean pollen storage area of all the treatments (2 *%), an*d T_3-Sugar: water (1:1) + Desi cow's milk (2%) had the largest pollen storage area (85.41 cm^2), with a 52.5 *% incr*ease over the control (Table 3). T_3-Sugar: water (1:1) + Desi cow's milk (2%) had the smallest pollen store area (78.91 cm^2) (Plate 1 c). Compared to the other treatments, the control colonies had a minimum pollen storage area of 56.66 cm^2. Goodwin (1986) also recorded that giving sugar syrup to honey bee colonies doubled their pollen production during the flowering season.

Adult population

Sugar syrup feeding greatly helped the adult honey bee population. Table 4 summarizes the outcomes of

Table 3. Effect of sugar syrup feeding on honey store area in *Apis cerana indica* colonies

Treatments	Pollen store area (cm^2)*					
	Week 1	Week 2	Week 3	Week 4	Mean	*% increase* in pollen store area over control
T_1 - Sugar: water (1:1)	47.00 (6.92)^{a}	65.33 (7.76)^{ab}	80.00 (8.65)^{ab}	95.00 (9.21)^{bc}	73.83 (8.59)^{b}	34.23
T_2 -Sugar: water (1:1) + Glucose (2%)	47.33 (6.95)^{a}	70.00 (8.12)	99.00 (8.99)^{a}	125.33 (9.71)^{a}	85.41 (9.24)^{a}	52.52
T_3-Sugar: water (1:1) + Desi cow's milk (2%)	48.33 (7.02)^{a}	63.00 (7.93)^{ab}	88.33 (8.62)^{abc}	116.33 (9.29)^{ab}	78.91 (8.88)^{b}	43.48
T_4- Sugar + water (2:1)	45.33 (6.89)^{a}	63.33 (7.80)^{ab}	73.66 (8.39)^{bcd}	85.33 (8.96)^{bc}	66.82 (8.17)^{c}	21.49
T_5-Sugar + water (2:1) + Glucose (2%)	48.33 (7.02)^{a}	64.33 (7.80)^{b}	78.66 (8.22)^{cd}	87.66 (8.81)^{c}	69.66 (8.34)^{bc}	26.65
T_6- Sugar + water (2:1) + Desi cow's milk (2%)	46.00 (6.85)^{a}	63.33 (7.70)^{b}	70.00 (8.06)^{de}	88.33 (8.85)^{c}	66.91 (8.17)^{c}	21.65
T_7-Control	44.66 (6.75)^{a}	52.00 (7.21)^{c}	60.00 (7.74)^{e}	70.00 (8.36)^{d}	56.66 (5.37)^{d}	
SED	0.14	0.16	0.18	0.19	0.88	
CD (0.05)	0.33	0.37	0.40	0.43	0.85	

*Mean of three replications; In a column, means followed by a common alphabet are not significantly different by LSD (p= 0.5). Figures in parenthesis are square root transformed values.

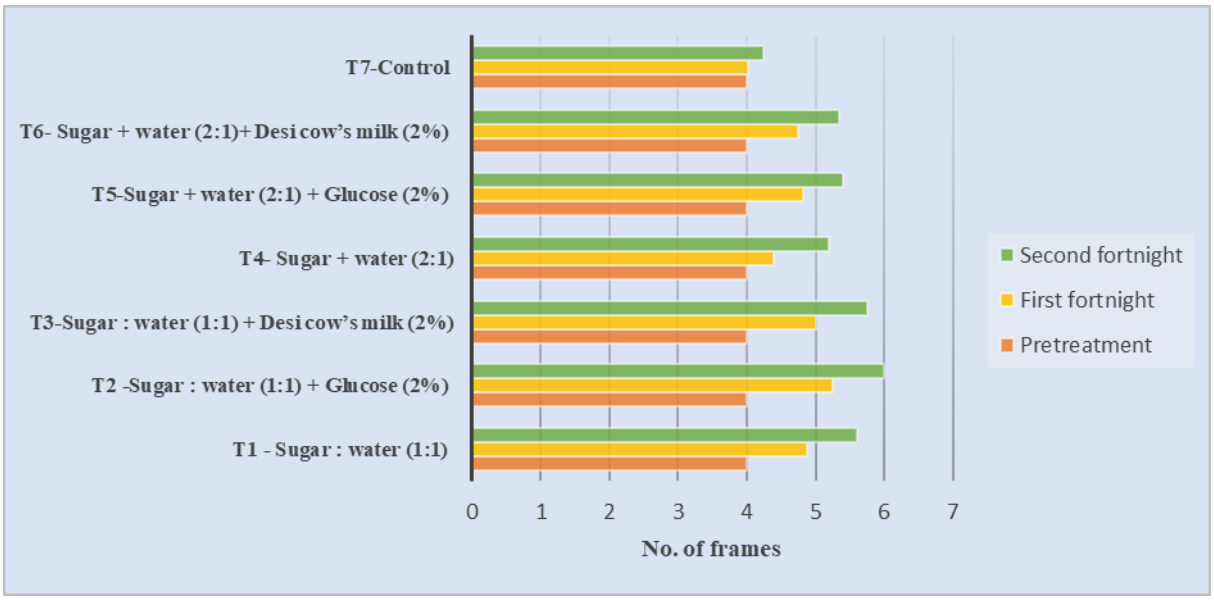

Fig. 1. *Effect of sugar syrup feeding on frame strength in Apis cerana indica colonies*

several treatments. T_2 - Sugar: water (1:1) + glucose (2%) had the greatest adult bee population (Plate 1 d) of the treatments, with 4451.00 bees per colony, followed by T_3 - sugar: water (1:1) + Desi cow's milk (2%) with 4453.48 bees per colony. The adult bee population in the control colonies was minimal, with just 4122.33 bees per colony. The adult bee population rose up to 66.08 *% in* T_2 colonies a month after sugar feeding compared to control colonies. Sammataro and Weiss (2013) reported comparable findings to the current study: sucrose-fed hives boosted brood rearing and adult bee populations in Italian honey bees, *A. mellifera*.

Frame strength

The results on the effect of sugar syrup feeding on frame strength are given in Fig. 1. After a month of sugar syrup feeding, the honey bee colonies attained maximum frame strength. In comparison to the other treatments, the colonies given T_2 - sugar:water (1:1) + glu-

cose (2%) grew significantly, with a mean frame of 5.62 frames. T_3-Sugar: water (1:1) + Desi cow's milk (2%) produced 5.37 frames per colony, but the control colonies with no sugar syrup feeding produced 4.13 frames per colony. According to Neupane and Thapa (2005), sugar syrup feeding to Asian bee colonies increased the number of brood cells by 43.5 *%* and the number of brood frames by 37.1 *%*. From the observations, the number of brood cells increased by 54 *%*, much higher than the previous studies.

Foraging activity

Sugar syrup feeding boosted foraging activity in Indian honey bee colonies. The average outgoing foragers from the colony entrance differed considerably between sugar syrup feeding and nonfeeding colonies (Fig. 2). The colonies fed with T_2 - sugar: water (1:1) + glucose (2%) had the most outgoing foragers (50.25 bees/5 min), followed by T_3-sugar:water (1:1) + Desi cow's milk (2%) (46.69 bees/5 min) and control colonies (30.87 bees/5 min).

Table 4. Effect of sugar syrup feeding on adult population in *Apis cerana indica* colonies

Treatments	Adult population*					
	Week 1	Week 2	Week 3	Week 4	Mean	% increase in adult population over control
T_1 - Sugar: water (1:1)	4300 (65.30)^{a}	4493.33 (67.01)^{ab}	4650.00 (68.18)^{ab}	4750.00 (68.91)^{b}	4396.66 (66.30)^{abc}	41.37
T_2 -Sugar: water (1:1) + Glucose (2%)	4318.66 (65.71)^{a}	4683.33 (68.43)^{a}	4833.33 (69.52)^{a}	4933.33 (70.23)^{a}	4501.00 (67.08)^{a}	66.08
T_3-Sugar: water (1:1) + Desi cow's milk (2%)	4150.00 (64.41)^{a}	4380.66 (65.77)^{bc}	4533.33 (67.32)^{bc}	4750.00 (68.62)^{b}	4453.48 (66.73)^{ab}	54.71
T_4- Sugar + water (2:1)	4266.66 (65.30)^{a}	4353.33 (65.97)^{bc}	4501.66 (67.09)^{bc}	4650.00 (68.19)^{bc}	4310.00 (65.65)^{c}	20.84
T_5-Sugar + water (2:1) + Glucose (2%)	4345.00 (65.91)^{a}	4410.00 (66.40)^{bc}	4543.33 (67.40)^{bc}	4666.66 (68.31)^{bc}	4377.50 (66.16)^{bc}	36.83
T_6- Sugar + water (2:1) + Desi cow's milk (2%)	4273.33 (66.22)^{a}	4416.66 (66.45)^{bc}	4550.00 (67.44)^{bc}	4633.33 (68.05)^{bc}	4345.00 (65.91)^{bc}	29.13
T_7-Control	4200.00 (64.80)^{a}	4244.66 (66.45)^{bc}	4350.00 (66.70)^{c}	4450.00 (67.45)^{c}	4122.33 (64.20)^{d}	
SED	0.36	1.64	0.66	0.19	0.41	
CD (0.05)	1.01	1.62	1.45	0.43	0.89	

*Mean of three replications; In the column, means followed by a common alphabet are not significantly different by LSD (p= 0.5). Figures in parenthesis are square root transformed values.

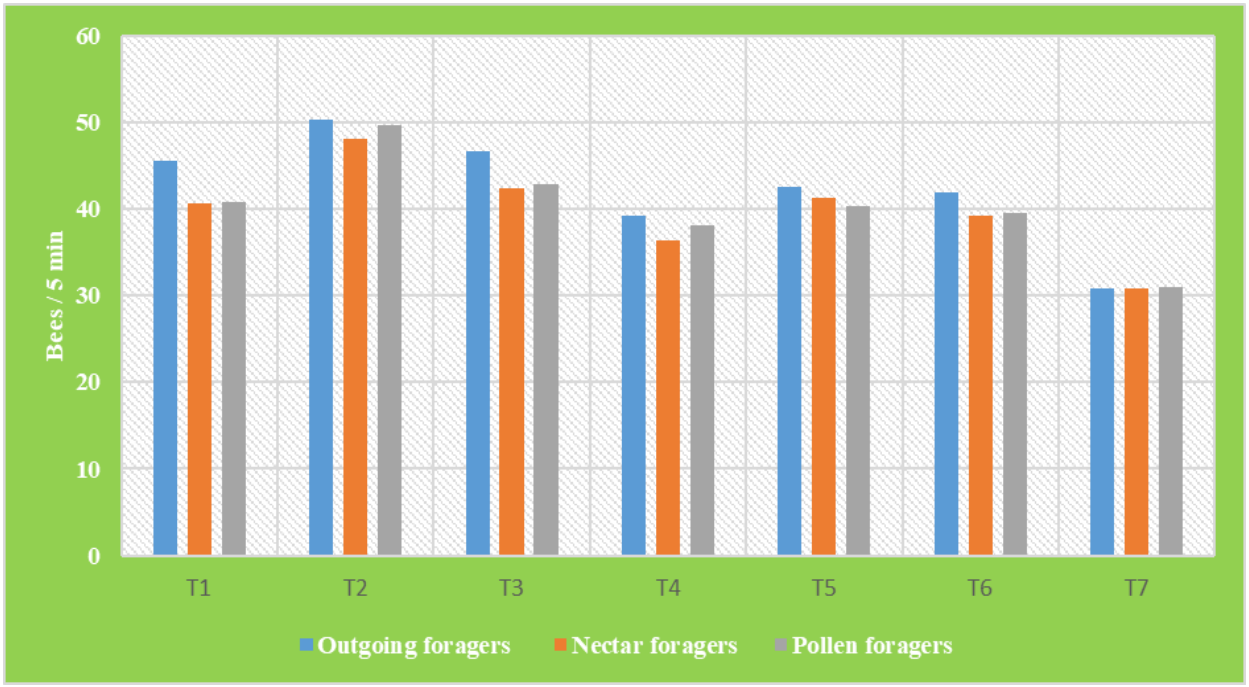

Fig. 2 . *Effect of sugar syrup feeding on foraging activity in Apis cerana indica colonies*

Plate 1. A. *Showing Queen cell production in sugar syrup feeding colonies*

Plate 1. B. *Showing Drone cell production in sugar syrup feeding colonies*

Plate 1. c. *Showing Improvement in pollen store and honey store area*

Plate 1. d. *Showing maximum adult population in T_2 sugar syrup feeding colonies*

T_2 - Sugar: water (1:1) + glucose (2%) had the most nectar foragers (48.13 bees/5 min) with 56.77% higher foraging activity than control colonies, followed by T_3 - sugar: water (1:1) + Desi cow's milk (2%) with a mean nectar foraging activity of 42.34 bees/5 min and control colonies with the least nectar foragers (30.79 bees/5 min).

Similarly, T_2 - Sugar: water (1:1) + Glucose (2%) colonies had the most pollen foragers (49.62 bees/5 min), followed by T_3-Sugar: water (1:1) + Desi cow's milk (2%) colonies (42.86 bees/5 min). The T_2-fed colonies had 61.29 *% more* pollen foragers than the control colonies. On the other hand, pollen foragers increased in all sugar-fed hives compared to control colonies. According to Gemeda *et al*. (2018), supplemental feeding improves the pollination services provided by bees in crops by increasing foraging activity. The foraging efficiency of colonies was determined by the number of bees with pollen load entering the hive. Most of the work is done on Italian bees, *A. mellifera*, while only a few experiments with *A. cerana indica* have been done with the specified concentration.

Conclusion

Sugar syrup feeding improved the vital colony growth parameters of Asian honey bee, *A. cerana indica* colonies. Supplementary feeding with sugar + water (1:1) + glucose (2%) significantly increased the brood area (203.3 cm^2), honey store area (70.95 cm^2), pollen store area (67.8 cm^2) and colony frame strength (4.76). Sugar syrup feeding during the dearth period will help the colonies to develop faster and perform better than the control colonies. Sugar syrup feeding is one of the most suitable options for keeping the colony healthy throughout the dearth period. Sugar syrup feeding along with glucose (1:1) significantly improved the colony growth parameters, particularly in egg-laying and foraging activity.

ACKNOWLEDGEMENTS

The authors are grateful to the Department of Agricultural Entomology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, for providing Asian bee colonies for research work and the support provided by the technical staff and assistants of the Department.

Conflicts of interest

The authors declare that they have no competing interests.

REFERENCES

1. Sharma, Anurag, Daroch, R. K. , Kapoor R. & Kasi, I. K. (2022). Status of bee keeping in Himachal Pradesh, India: A review. *The Pharma Innovation Journal* , SP-11 (3) 257-265.doi.org/ 10.22271/tpi.2022.v11.i3Sd.11234.

2. Paray Bilal Ahamad., Indu Kumari , Younis Ahmad Hajam , Bharti Sharma , Rajesh Kumar, Mohammed Fahad Albeshr , Mohammad Abul Farah & Javed Masood Khan (2020). Honeybee nutrition and pollen substitutes: A review. *Saudi Journal of Biological Sciences.* doi. org/10.1016/j.sjbs.2020.11.053

3. Gemeda, T.K., J. Li, S. Luo, H. Yang, T. Jin, J. Huang & J. Wu. (2018). Pollen trapping and sugar syrup feeding of honey bee (Hymenoptera: Apidae) enhance pollen collection of less preferred flowers. *PloS one* 13 (9), e0203648.doi.org/10.1371/journal.pone 0203648.
4. Goodwin, R. (1986). Increased kiwifruit pollen collection after feeding sugar syrup to honey bees within their hive. *New Zealand Journal of Experimental Agriculture* 14 (1), 57-61.doi.org/ 10.1080/03015521.1986.10426125
5. Guler, A., D. Ekinci, S. Biyik, A.V. Garipoglu, H. Onder & H. Kocaokutgen. (2018). Effects of feeding honey bees (Hymenoptera: Apidae) with industrial sugars produced by plants using different photosynthetic cycles (carbon C3 and C4) on the colony wintering ability, lifespan, and forage behaviour. *Journal of Economic Entomology* 111 (5):2003-2010.
6. Gupta, R.K., M. Khan, R. Srivastava & V. Goswami. (2014). History of beekeeping in developing world. *In Beekeeping for poverty alleviation and livelihood security*, 3-62. Springer, Dordrecht. doi.org/10.1007/978-94-017-9199-11
7. James, R., R.R. James & T.L. Pitts-Singer. (2008). *Bee pollination in agricultural ecosystems*: 10-25, Oxford University Press on Demand.
8. McGowan, J., A. De la Mora, P.H. Goodwin, M. Habash, M.M. Hamiduzzaman, P.G. Kelly & E. Guzman-Novoa. (2016). Viability and infectivity of fresh and cryopreserved Nosema ceranae spores. *Journal of Microbiological Methods* 131:16-22.doi.org/10.1016/j.mimet.2016.09.021.
9. Musa Özcan, M. & F. Al Juhaimi (2015). Honey as source of natural antioxidants. *Journal of Apicultural Research.* 54 (3):145-154. doi.org/10.1080/00218839.2016.114 497 6
10. Neupane, K. & R. Thapa. (2005). Alternative to off-season sugar supplement feeding of honeybees. *Journal of the Institute of Agriculture and Animal Science* 26:77-81. doi.org/10.3126/jiaas.v26i0.615
11. Kumar, Rajesh, R.C. Mishra & O.P. Agrawal.(2013). Effect of feeding artificial diets to honey bees during dearth period under Panchkula (Haryana) conditions. *Journal of Entomological Research* 37 (1) : 41-45.
12. Sahinler, N., A. Gül & A. Şahin.(2005). Vitamin E supplement in honey bee colonies to increase cell acceptance rate and royal jelly production. *Journal of Apicultural Research* 44 (2):58-60. doi.org/10.1080/00218839.2005.11101149.
13. Sammataro, D. & M. Weiss. (2013). Comparison of productivity of colonies of honey bees, *Apis mellifera,* supplemented with sucrose or high fructose corn syrup. *Journal of Insect Science* 13 (1):47-55. doi.org/10.1673/031.013.1901.