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Feeding substitutes -A Management Tool for Enhancing the Pollen and Honey area during Dearth Period in *Apis cerana* Fabricius in Kashmir

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ABSTRACT: The experiment was conducted at an apiary maintained at the Division of Entomology, SKUAST-K, Shalimar from July to September during the year, 2020 to develop efficient and cheap nectar substitute for dearth period management of *Apis cerana* honeybee colonies. The syrup containing apple juice, sugar and mixture of both was evaluated as a diet supplement to develop an efficient feeding substitute. Bees were provided with the four nectar feeding substitutes viz., T_1, apple juice and sugar in the ratio of 1:1; T_2, apple juice and sugar in the ratio of 1.5:1; T_3 apple juice alone and T_4, sugar syrup in the ratio of 1:1 and compared with T_5 natural feeding to determine their impact on desirable attributes of colonies. The feeding substitutes supplemented resulted in the gradual increase in the pollen and honey area (sq cm). The pollen area (347.78 sq cm) and honey area (854.76sq cm) was maximum in T_2, apple juice and sugar in the ratio of 1.5:1, followed by T_1; apple juice and sugar in the ratio of 1:1 (pollen area; 328.57 sq cm, honey area; 818.76 sq cm) and T_4; sugar syrup in the ratio of 1:1(pollen area; 316.16 sq cm, honey area; 768.16 sq cm). All the desirable parameters were found to be least in T_5 natural feeding. So, among the evaluated feeding supplement treatments; apple juice and sugar in the ratio of 1.5:1 (T_2) was the best nectar feeding substitute during dearth period followed by apple juice and sugar in the ratio of 1:1 (T_1). The nectar feeding substitutes are better for colony health than a complete lack of proteins and carbohydrates which otherwise cause starvation. They are most useful during the times of floral dearth period that stimulate colony growth. The efforts put into the nectar feeding substitutes would assist beekeepers to use this knowledge in order to improve colony management and thereby, colony health.

Keywords: *Apis cerana*, apple juice, dearth period, feeding substitutes, honey, pollen.

INTRODUCTION

In natural ecosystem, honeybees collect three vital substances; water, nectar and pollen to overcome and satisfy their nutritional requirements (Javaheri *et al*., 2000). Both nectar and pollen provide essential nutrients for honeybees. Nectar serves as a source of carbohydrates (primarily monosaccharide,s and oligosaccharides) and trace amounts of vitamins, minerals, and amino acids (Ball, 2007). Most vitally, honeybee colony,s protein source is pollen, which has varying amounts of amino acids, lipids, vitamins, and minerals. These nutrients obtained from pollen are essential for larval development of honeybees (Stanley and Linskens, 1974). Pollen largely contributes to the growth of fat bodies in larvae and egg development in the colony queen (Pernal and Currie 2000; 2001). The nurse bees consume pollen so that hypo-pharyngeal glands can biosynthesize proteinaceous secretions that are progressively fed to the larvae (Winston, 1987; Knecht and Kaatz 1990; Crailsheim *et al*., 1992).

Seasonal and climatic fluctuations (precipitation, hail, etc.) produce considerable losses in floral resources throughout the year (Sahin *et al*., 2015). Meanwhile, flowers are essential for honeybee brood production, immunological function, and overwintering survival (De Pasquale *et al*., 2016; Meikle *et al*., 2017). While nectar is a source of carbohydrates, pollen supplies proteins, lipids, and micronutrients (Stoner *et al*., 2022). When the natural flora is insufficient, the queen bee,s egg-laying level decreases, resulting in a fall in the colonys population level (Topal *et al*., 2022). Malnutrition reduces individual survival rates, causes larval life to cease, renders the colony prone to disease, and drives individuals to leave the colony (Topal *et al*., 2019; De-Grandi-Hoffman *et al*., 2016). Usually, a honey bee colony obtains 10-26 kg of pollen each year from flowers (Brodschneider and Crailsheim 2010) as a rudimentary source of protein content and amino acid composition for the well-being of their colony (Taha *et al*., 2019). Furthermore, appropriate protein and carbohydrate stores in the colony are suggested to aid

honey bees in fighting or tolerating different stressors associated with modern apiculture (Brodschneider and Crailsheim 2010). Although pollen remains the most desirable and appealing protein source for honey bees, pollen replacements have advantages. Pollen introduced to the colonies from the outside is costly to get in large quantities, and it also entails the danger of introducing infections (Pereira *et al*., 2019; Schittny *et al*., 2020) or pesticides (Ostiguy *et al*., 2019) into the colonies.

Thus, human intervention is needed to overcome these problems, particularly for disease management and additional feeding. To compensate for the lack of nutritive forage in the environment, hives are routinely given artificial "feeding substitute" diets (Ricigliano *et al*., 2022). As a result, better colony health for honey production and pollination can be maintained (Di Pasquale *et al*., 2013; Hoover *et al*., 2022). To compensate for insufficient forage resources and boost colony vigour prior to pollination services, beekeepers provide different feeding substitute diets (Mortensen *et al*., 2019; Noordyke and Ellis 2021). Supplemental foods are fed to the honeybees to supply the nutritive requirements of colonies in areas and at times when natural food sources (pollen, nectar or honey) are inadequate. The brood rearing activity and nutritional status of the colony, the quantity and quality of incoming pollen and nectar, and the food reserves in the hive will determine whether the bees need supplemental food or not. Colonies need supplemental food for subsistence and continued brood rearing until nectar and pollen collection again becomes adequate. A sudden curtailment of nectar and pollen income when brood rearing activities are in progress often causes the adult bee population in colonies to decline (Standifer *et al*., 1978).

MATERIALS AND METHODS

The study was undertaken at an apiary maintained at the Division of Entomology, Faculty of Horticulture, SKUAST-K, Shalimar from July to September during the year, 2020-21. Twenty honeybee colonies of *A. cerana* each of10 bee frame strength were evaluated to study the effect of nectar feeding substitutes for various colony developmental parameters at the apiary. The beehives were made of homogenous material and were of same dimensions. The treatment details are as under

Treatment	Nectar Substitute	Concentration
T_1	Apple juice + Sugar	1:1
T_2	Apple juice + Sugar	1.5:1
T_3	Apple Juice alone	-
T_4	Sugar syrup	1:1
T_5 (Control)	Natural feeding	-

The experiment was conducted in Randomized Complete Block Design and each treatment was replicated four times. Different treatments of nectar feeding substitutes (@ 200 ml/hive were provided to honeybees at an interval of 21 days by placing them inside the hive after filling the syrups in plastic feeders of dimension 14×12 inches with floating dry leaf twigs so that the bees may not get drowned in the syrup. Observations were recorded on pollen and honey area (sq cm) before the application of nectar feeding substitutes and on 3rd, 5th, 7th, 9th, 15th and 21st day after feeding nectar supplements. The space (sq cm) covered by the pollen and honey in the combs was measured with the help of wire grid device (8 cm × 8 cm).

RESULTS AND DISCUSSION

During first feeding, the maximum pollen area of 295.70 sq cm in bee colonies was recorded with nectar feeding substitute, T_2(Apple Juice and sugar in the ratio of 1.5:1) followed by pollen area of 285.95sq cm by supplementing Apple Juice and sugar in the ratio of 1:1 (T_1); 280.16 sq cm by supplementing sugar syrup in the ratio of 1:1 (T_4) and 269.58 sq cm by supplementing Apple Juice alone (T_3). The pollen area was statistically higher and maximized in all the feeding supplements in comparison to the Control treatmentT_5; natural feeding (237.87sq cm). On 3rd day after treatment (DAT) of second feeding, the maximum pollen area recorded was 362.75 sq cm (T_2) followed by 340.25 sq cm (T_1), 325.75 sq cm (T_4) and 302.00sq cm (T_3) while the minimum pollen area was recorded in natural feeding treatment 232.75 sq cm (T_5). Similar trend was observed with second feeding supplements on 5th, 7th, 9th, 15th and 21st days of treatment (DAT). However, at the end of second feeding (21st DAT), the maximum pollen area recorded was 452.75 sq cm (T_2) followed by 418.50 sq cm (T_1) while the minimum pollen area recorded was 249.00 sq cm (T_5) followed by 347.25 sq cm (T_3) and 392.50 sqcm (T_4) (Table 1 and Fig. 1).During first feeding, significant increase in honey store was observed in T_2; Apple Juice and sugar in the ratio of 1.5:1 (702.45 sq cm), followed by T_1; Apple Juice and sugar in the ratio of 1:1 (684.12sq cm), T_4; Sugar syrup in the ratio of 1:1 (661.04sq cm) and T_3; Apple Juice alone (626.41 sq cm) while, a sharp reduction was observed in T_5;natural feeding (547.41 sq cm). After the completion of second feeding (21st DAT), the maximum honey area recorded was 1168.50 sq cm (T_2) followed by 1104.75 sq cm (T_1) while the minimum honey area recorded was 552.25 sq cm (T_5) followed by 836.50 sq cm (T_3) and 995.50 sq cm(T_4) (Table 2 and Fig. 2). The per cent increase in pollen area over control after feeding 1st in the colonies treated with nectar feeding substitutes T_1, T_2, T_3 and T_4 was calculated to be 47.30, 56.98, 31.35 and 41.91 per cent, respectively after 21 days after treatment. Similarly, for 2nd feeding, incremental pollen area after 21 DAT was computed to be 68.07, 81.83, 39.46 and 57.63 per cent more in comparison to control treatment for the colonies treated with nectar feeding substitutes T_1, T_2, T_3 and T_4, respectively. The increase in honey area after 1st feeding was computed as 56.61, 62.27, 31.23 and 46.32 per cent more in the colonies fed with nectar feeding substitutes T_1, T_2, T_3 and T_4, respectively as compared to control colonies. Similarly, the per cent increase in honey area overcontrol for feeding 2nd was 100.00, 111.59, 51.47 and 80.26 per cent higher in the colonies fed with nectar feeding substitutes T_1, T_2, T_3 and T_4, respectively after 21 days after treatment (Table 3). The results were corroborated by the findings of

Pande and Karnatak (2013) who reported increase in pollen and honey area when juices of different temperate fruits were supplemented for off-season dietary management of honeybees. Similarly, Pande *et al*. (2014) too reported moderate increment in pollen and honey area when colonies were supplemented with germinated pulses as a pollen substitute during the dearth floral period. The findings are further in consonance with Pande *et al.* (2015); the authors opined substantial increase in pollen and honey area when bees were supplemented with different fruit syrups. However, Somerville (2005) were of the view that the ample available nectar acts as a stimulus to the colony and encouraging colony for pollen collection.

Table 1: Effect of different nectar feeding substitutes on pollen area (sq cm) of *Apis cerana* before and after feeding during July, 2020 to September, 2020.

Treatments	Feeding Ist Pollen area (cm^2)								Feeding 2nd Pollen area (cm^2)								Pooled mean
	Before treatment	3rd DAT	5th DAT	7th DAT	9th DAT	15th DAT	21st DAT	Mean	Before treatment	3rd DAT	5th DAT	7th DAT	9th DAT	15th DAT	21st DAT	Mean	
T_1 (Apple juice + sugar, 1:1)	250.33	254.00	263.00	273.00	285.00	306.00	334.75	285.95	334.75	340.25	348.00	357.75	371.50	391.25	418.50	371.20	328.57
T_2 (Apple juice + sugar, 1.5:1)	251.33	256.75	267.25	278.00	294.50	321.00	356.75	295.70	356.75	362.75	373.00	384.75	399.25	426.75	452.75	399.87	347.78
T_3 (Apple juice alone)	250.33	251.50	258.00	263.00	267.50	279.00	298.50	269.58	298.50	302.00	307.00	311.25	316.25	327.25	347.25	318.50	294.04
T_4 (Sugar syrup)	250.33	253.00	259.75	269.00	279.25	297.50	322.50	280.16	322.50	325.75	332.75	342.00	351.00	369.00	392.50	352.16	316.16
T_5 (natural feeding) Control	251.33	247.00	243.25	240.25	237.50	232.00	227.25	237.87	227.25	232.75	233.50	235.50	237.50	243.25	249.00	238.58	238.22
		CD (p≤ 0.05)								CD (p≤ 0.05)							
Treatment		0.536								0.453							
Time interval		0.587								0.497							

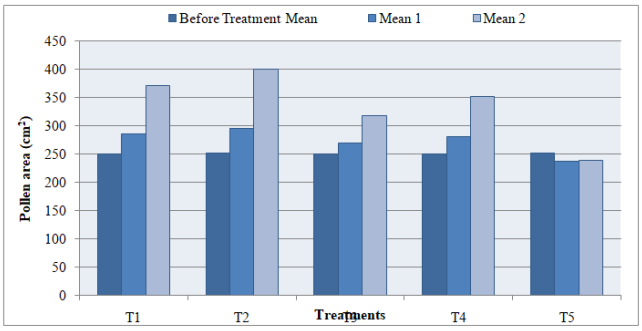

Fig. 1. Effect of different nectar feeding substitutes on pollen area (cm^2) of *Apis cerana* before and after feeding.

Table 2: Effect of different nectar feeding substitutes on honey area (sq cm) of *Apis cerana* before and after feeding during July, 2020 to September, 2020.

Treatments	Feeding Ist Honey area (cm^2)								Feeding 2nd Honey area (cm^2)								Pooled mean
	Before treatment	3rd DAT	5th DAT	7th DAT	9th DAT	15th DAT	21st DAT	Mean	Before treatment	3rd DAT	5th DAT	7th DAT	9th DAT	15th DAT	21st DAT	Mean	
T_1 (Apple juice + sugar, 1:1)	566.65	581.75	605.75	642.00	686.00	751.75	837.50	684.12	837.50	851.00	876.25	911.50	956.00	1021.00	1104.75	953.41	818.76
T_2 (Apple juice + sugar, 1.5:1)	567.50	587.75	618.00	657.25	706.00	778.00	867.75	702.45	867.75	887.00	918.00	957.00	1033.50	1078.50	1168.50	1007.08	854.76
T_3 (Apple juice alone)	566.50	571.25	586.25	606.25	631.00	662.00	701.75	626.41	701.75	707.00	721.50	741.25	766.75	796.50	836.50	761.58	693.86
T_4 (Sugar syrup)	566.65	577.25	596.75	626.75	666.50	716.50	782.50	661.04	782.50	791.75	811.00	841.00	881.50	931.00	995.50	875.29	768.16
T_5 (natural feeding) Control	567.45	561.00	556.50	548.50	544.50	539.25	534.75	547.41	534.75	535.75	536.75	538.00	540.50	547.25	552.25	541.75	544.58
		CD (p≤ 0.05)								CD (p≤ 0.05)							
Treatment		0.529								5.340							
Time interval		0.579								5.850							

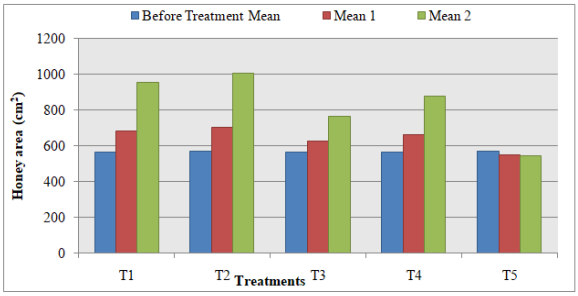

Fig. 2. Effect of different nectar feeding substitutes on honey area (cm^2) of *Apis cerana* before and after feeding. In each figure, mean 1 represents mean value for feeding i^{st} and mean 2 represents mean value for feeding $2^{nd.}$

Table 3: Impact of nectar feeding substitutes in enhancement of pollen and honey area over control colonies.

Treatment	Per cent increase in Pollen area after 21 DAT		Per cent increase in Honey area after 21 DAT	
	Feeding 1st	Feeding 2nd	Feeding 1st	Feeding 2nd
T_1 (Apple juice + sugar, 1:1)	47.30	68.07	56.61	100.00
T_2 (Apple juice + sugar, 1.5:1)	56.98	81.83	62.27	111.59
T_3 (Apple juice alone)	31.35	39.46	31.23	51.47
T_4 (Sugar syrup)	41.91	57.63	46.32	80.26

CONCLUSIONS

The practice of beekeeping is a year round process. Management applied during dearth floral period will positively affect the colony performance sooner or later. The primary objective of this study was to develop an economical and efficient nectar substitute for dearth period management of honeybees. The results so obtained have great significance for beekeepers for efficient colony management during lean floral period. From the present findings, it can be safely concluded that bees have accepted all the nectar feeding substitutes and have shown a positive impact on incremental pollen and honey area. Thus, beekeepers can use nectar substitutes to improve the nutrition of honeybees especially when there are less floral rewards.

FUTURE SCOPE

More studies are needed to determine the nutritional components of different nectar feeding substitutes and to use these substitutes in colony nutrition in order to support the healthy development of the colony. Especially knowing the nutritional structure of nectar substitutes will contribute to the formation of the price policy according to the quality of these products produced as an economic gain.

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Conflict of Interest. None.

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