Impact of some pollen substitute diet on colony performance of *Apis cerana indica* Fab. in Odisha

A Thesis submitted to the

Odisha University of Agriculture and Technology

In Partial fulfillment of the Requirement for the degree of

Master of Science in Agriculture

(Entomology)

By

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BHUBANESWAR-751003, ODISHA

2021

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CERTIFICATE - I

This is to certify that the thesis entitled **"Impact of some pollen substitute diet on colony performance of *Apis cerana indica* Fab. in Odisha"** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (ENTOMOLOGY)** of the Odisha University of Agriculture and Technology, Bhubaneswar is a faithful record of *bona fide* research work carried out by **Sanjeeb Behera, Adm No. 191221611** under my guidance and supervision. No part of the thesis has been submitted for the award of any other degree or diploma.

It is further certified that the assistance and help availed by her from various sources during the course of investigation has been duly acknowledged.

(Dr. R. N. Mohapatra)
CHAIRMAN
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CERTIFICATE-II

This is to certify that the thesis entitled **"Impact of some pollen substitute diet on colony performance of *Apis cerana indica* Fab. in Odisha"** submitted by **Sanjeeb Behera, Adm No. 191221611** to the Odisha University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE IN AGRICULTURE (ENTOMOLOGY)** has been approved by the students' advisory committee and external examiner.

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ACKNOWLEDGEMENT

Since the beginning of time, teachers have been regarded as the second living god after parents. It's impossible to imagine repaying a teacher's obligation. The only emotion that can be felt is thankfulness. Few words will ever be enough to express my gratitude to those whose support was critical to the accomplishment of this research. The task that was entrusted to me was completed successfully, and success is nothing more than the result of concerted efforts.

First and foremost, I thank Lord JAGANNATH for providing me with the energy, patience, wishdom, and chances to carry out this research and successfully accomplish it.

I would want to take this opportunity to thank the chairperson of my advisory committee, Dr. (Mr.) Dr. R.N Mohapatra, Professor & PI, AICRP on Honeybees and Pollinators, Department of Entomology CA, OUAT, Bhubaneswar, for putting out the study criteria and teaching me how to think rationally and methodically. Despite his busy and hectic schedule, his honest, disciplinary attitude and excitement for his job have inspired us to strive in the correct direction and with a clear vision toward our objective. Throughout my time with him, I have admired and respected his intense attention, academic and prudent advice, wholehearted, always accessible and eager assistance, laborious efforts, and, above all, his sense of compassion. Working under his guidance throughout the duration of these research, from the beginning to the current form of thesis, was a truly wonderful experience. My time working with him will always be one of the most memorable experiences of my life.

I am particularly grateful and obliged to Dr. L.K. Rath, Professor and Head, Department of Entomology, OUAT, Bhubaneswar, for his helpful ideas, encouragement, profound excitement for the topic, and vigilance throughout the study.

Dr. (Mrs.) Pravsini Behera, Assistant Entomologist, AICRP on Honeybees & Pollinators (ICAR) has been a constant supporter of my study, and I am grateful for her patience, inspiration, and enthusiasm. Furthermore, she is constantly available and eager to assist her pupils in their academic pursuits.

I would also want to thank Dr. Pradyumna Tripathy, Professor, Department of Vegetable Science, CA, OUAT, Bhubaneswar, for providing facilities for the experiment and assisting in various instances for the current work.

I would like to convey my heartfelt gratitude particularly to Dr. C. R. Satapathy, Retd Professor, entomology & Principal Investigator, AICRP on Honeybees & Pollinators (ICAR) and ICAR - Emeritus Scientist OUAT, Bhubaneswar, for his helpful ideas and support during my research.

Dr. J. Padhi, Dr. P.R. Mishra, Dr. P. Sarangi, Dr. A. Kar, Dr. A. Sasmal, Dr. T. Samal, Dr. S.K. Mukherjee, and Dr. M.K. Tripathy are among my instructors who were always willing to assist me during my studies.

I would want to express my gratitude to Pitabasha Bhaina , Judhistir bhaina and Karthika bhaina, field staff members and non-teaching staff specially Aparna, for their assistance throughout my research work.

Despite the fact that I am as bright as a star in the sky, I would like to take this opportunity to express my deepest gratitude and immense love to my most loving parents, Mr. S.C. Behera and Mrs. Kumudini Behera, for their selfless sacrifice, lovable inspiration, encouragement, and eternal beauty in evaluating this tiny personality. My deepest thanks goes to my older sisters for her unwavering love, inspiration, and dedication.

It gives me great pleasure to recognise my friends Abhisek, Revanth, Sathvik, Deeptismita and Subhashree for their love, affection, inspiration, encouragement, unselfish aid, and happy companionship. From the bottom of my heart, I thank you all.

I appreciate Ranjit Bhaina, the man behind the desk, for the manuscript's precise alignment and binding. I owe him a great debt of gratitude.

I would want to express my gratitude to everyone who assisted me in my study, whether directly or indirectly.

Bhubaneswar **(Sanjeeb Behera)**

Date:

ABBREVIATIONS AND SYMBOLS

%	:	per cent
&	:	and
°C :		Degree centigrade
a.m.	:	Anti Meridiem
p.m.	:	Post Meridiem
AICRP	:	All India Coordinated Research Project
cm	:	Centimetre
et al.	:	and others
Fig.	:	Figure
hr	:	Hour
i.e.	:	that is
cm2	:	centimetre square
min	:	minute
Viz.	:	Namely
PS	:	Pollen substitute
CPF	:	Corbicular Pollen Feeding
S. E (m)	:	Standard error of mean
CD	:	Crirtical difference
N/A	:	Non- significant

ABSTRACT

The field experiments were conducted to study the impact of pollen substitute diet on colony performance, foraging activity and economics of pollen substitute diet of the Indian hive bee *Apis cerana indica* Fab in Odisha. The study was under taken during September, 2020 to December, 2020 at apiary of AICRP on honeybees and pollinators, OUAT, Bhubaneswar. Twenty four colonies were selected and was laid out in RBD with six treatments and four replications. Four different pollen substitute diets viz; PAU Ludhiana diet, YSPUHF diet, GBPAUT diet and OUAT diet were prepared as per specified compositions and the natural corbicular pollen was collected. Besides one control treatment was added where only 50% sugar solution was provided. The colony performance was observed at 21 day interval while the foraging activities were observed at weekly interval after each feeding. It was clearly observed that the overall increase of brood area (403.44 cm^2), nectar area (142.19 cm^2), pollen area (16.50 cm2) and bee strength (5.75) was significantly high in corbicular pollen fed colonies in compare to other treatments. The PAU pollen substitute diet fed colonies were close to these treatments. With regards to foraging activity it was recorded the overall nectar forager (7-09) and pollen forager (5-46) was maximum in corbicular pollen substitute diet. Also when the consumption of different pollen substitute diet was tested it was observed that maximum (31.4%) diet was consumed in corbicular pollen diet followed by PAU substitute (26.6%), GBPUAT diet (25.1%), OUAT diet (25.0%) and YSPUHF diet (24.2%). As regards the study of economics it was observed that feeding with different pollen substitute diet enhanced all the yield attributing traits for higher honey production thereby giving a return of Rs 600 to 800/- per colony. Though the corbicular pollen diet provided highest return (Rs800 per colony) but from the cost point of view PAU diet was more remunerative followed by OUAT diet which may be recommended for use by beekeepers.

INTRODUCTION

Honeybees are social insects that spend their entire lives with their colony mates, with generations overlapping. Because they coevolved with angiosperms, nectar and pollen are their primary sources of nutrition. According to the National Bee Board, which is part of the Ministry of Agriculture, India produced 1.05 lakh metric tonnes (MT) of honey in 2017-18, up from 35,000 MT in 2005-06. In 2005-06, India had 8 lakh bee colonies, however now it has 35 lakh bee colonies. The number of beekeeping firms and associations has also expanded, with 9091 recognised bodies in the apiary business as of January 2019.

Honeybees are the most important pollinators of many crops. Currently, seven *Apis* species have been identified, with India hosting four of them: two domesticated species, *Apis cerana indica* Fab. and *A. Mellifera* L., and two wild species, *Apis dorsata* and *A. florea*. The Indian honeybee (*Apis cerana indica* Fab.) is the foundation of Indian beekeeping and is found all over the country. It can grow up to 2500 metres above sea level and has a variety of biological and economic characteristics. *Apis cerana* can be found in climatic zones ranging from tropical, moist rainforests to dry grasslands and taiga on around 30 million km2 of Asian landscape (Koetz, 2013; Radloffet al., 2010). Swarming, absconding, robbing, production of laying workers, low honey yield, and vulnerability to the Thai sacbrood virus are all disadvantages of this species. Pollen grains are the male germs of flowers that are high in protein and are used by honey bee colonies as a building ingredient for growth and tissue repair (Somerville, 2000; Alghamdi, 2002; Mishima et al., 2005). Carbohydrates make up the majority of the colony's diet. Both larvae and adults require this for appropriate growth and development. Nectar and honey are the primary sources of carbohydrates. As a result, the carbohydrate supplement may aid to maintain brood rearing and colony development in the face of adversity. Pollen is particularly important for brood raising and colony formation under adverse conditions. Pollen is especially important for brood raising because nectar is used as a food source for both brood and adults. They gather nectar from a variety of natural sources. When bee foraging plants do not blossom, they may continue to grow vegetatively. There isn't enough nectar for the bees. The wet season is also unfavourable for bees, since they confront a severe food deficit, which leads to absconding. Food supplementation is unavoidable for the bees in such situations. Honeybees collect pollen and nectar when foraging, pollen being a protein source and nectar being a carbohydrate supply, both of which meet their nutritional needs (Seeley,1985 and Winston, 1987). Because honeybees have a division of labour, only the forager bees will be responsible for foraging (Von Frisch, 1967; Suwannapong, 2000). During the monsoon and winter seasons, it is critical to have adequate food supplies of honey and pollen. Supplementary pollen feeding reduced absconding in *Apis cerana indica* Fab, according to Woyke (1976) and Raj and Basavanna (1980).

Program sugar is the most effective supplementary feeding for bees since it encourages them to mate, forage for pollen, and eventually produce honey during the honey flow season. Sugar can encourage bees to work harder. Supplemental food allows the colony to reach its full capacity as a production unit, allowing it to produce more honey and pollinate more effectively. Sugar syrup can encourage colonies to produce more brood.

This has an impact on how much pollen a colony accumulates. Pollen substitute and sugar syrup feeding increases the number of bees and frames covered by bees, brood area, and colony weight significantly more than sugar syrup or pollen alone (Sahinler et al., 2003).

Bee management necessitates three forms of feeding: dearth feeding (during the rainy season), supplementary feeding (during the summer season), and stimulant feeding (during the winter season) (winter season). Because of this scarcity, beekeepers must feed their hives, with additional and stimulant food provided as needed. The extracted honey appears to be natural honey, but it lacks nutritional and therapeutic properties (El-Banby et al., 1989). As a result, artificial food supplementation is required for fruitful honey production and the survival of *A.cerana indica* Fab. during times of scarcity. Sugar syrup (1:1) is one of the most popular nectar substitutes, whereas pollen alternatives for honey bees during the dearth period include soybean flour, mung bean flour, cornflour, mixed flour, and others. It is vital to assess the efficacy of such nectar and pollen alternatives in the preservation of honeybee colonies. However, no research has been done to determine the impact of a pollen substitute diet on *Apis cerana indica* Fab's growth and development, as well as foraging activity. Odisha, in particular, is a state in India. Artificial feeding of honeybee colonies during a drought has long been acknowledged as a necessary practise for long-term survival, reproduction, and brood raising, particularly in stationery beekeeping. During the dearth period, strong colonies have an early build up and more foraging bees during the succeeding floral period, resulting in increased honey production and improved pollination services. Pollen substitute diets are being developed in the interest of beekeepers to tackle the problem of floral dearth (Abdullah et al 1971). Using honeybee colonies for pollen collecting during the flow season is costly and has a negative impact on their productivity. As a result, developing a pollen substitute diet is critical for feeding honey bee colonies during periods of scarcity. The effect of pollen substitute diet for Indian hive bee, *Apis cerana indica* F. under odisha was studied with the following goals in mind:

1. Effect of pollen substitute diet on colony performance attributes.

2. Effect of pollen substitute diet on the foraging activity.

3. Assessment of economics of pollen substitute diet.

REVIEW OF LITERATURE

Honeybees play a crucial role in crop pollination. They pollinate a vast number of flowers in exchange for pollen and nectar, which they use to feed themselves. Various colony characteristics, including as colony population/strength, brood condition, queen prolificacy, availability of bee flora, and meteorological circumstances, influence honey output. There are a lot of references on crop pollination and evaluating the quantity and quality of bee flora, but there isn't much information on the influence of regular sugar feeding on bee colony performance. However few related references about present investigations entitled "Impact of some pollen substitute diet on colony performance of *Apis cerana indica* Fab. in Odisha" has been reviewed under the following subheadings:

2.1 Effect of pollen substitute diet on colony performance attributes (brood area, honey area, pollen area, brood, and bee strength)

2.2 Effect of pollen substitute diet on the foraging activity of *Apis cerana indica* F

2.3 Assessment of economics of pollen substitute diet.

2.1 Effect of pollen substitute diet on colony performance attributes (brood area, honey area, pollen area, brood, and bee strength) of *Apis cerana indica* F.

Bailey (1966) discovered that semi-refined cane sugar is harmless for bees, while semi-refined beat sugar shortens their lives.

Artificial feeding in *Apis mellifera*, according to Standifer et al. (1970), only had a favourable influence on brood rearing in a bad year. Pollen containing fructose-glucose syrup was more appealing than pollen containing simply water, which was, in turn, more appealing than dry pollen. Similarly, when mixed with fructose-glucose syrup, pollen supplement plus the attractant portion was more appealing than when mixed with water alone.

Pollen supplements containing the attractant fraction and sucrose were equally appealing as those containing sucrose, fructose, and glucose in equal weights, but more bees fed on the three-sugar supplement than on one containing only fructose and glucose. There were no significant differences in the number of bees counted on pollen supplements containing equal amounts of honey, sucrose, fructose, and glucose (Doull 1974).

According to Ewies and Ali (1976), the honey bee favours sucrose above glucose, inverted sugar, molasses sugar, and other sugars.

Villumstad (1977) discovered that as the number of bees in the colony increased, so did the overall brood area.

Honey bees' foraging rates are directly proportional to their strength (Neukrish 1982). Husseien (1979) found that feeding bee colonies 1:1 sugar syrup blended with 0.75 to 1.0 percent ascorbic acid increased honey production significantly.

Colonies that only offered pollen substitute acquired enough natural pollen to rear and brood as well as colonies that offered pollen replacements, according to Herbert et al (1979).

Colonies fed invert sugars had significantly smaller brood areas (12 and 13dm2) than those fed sucrose, according to Vanden and Smeekens (1982). (20dm2).

When pollen substitute was supplied to colonies for 21 days, Imdorf et al. (1983) discovered that brood area increased briefly but adult numbers fell.

In California, Peng et al. (1984) conducted research on additional feeding honey bees and found that colonies fed sugar syrup had much higher populations than unfed control colonies. The brood levels in the unfed control colonies were likewise marginally lower than those in the colonies that received feeding treatments.

Silva et al. (1985) discovered that giving the colonies sugar syrup and a protein supplement (soy flour + 25% pollen) yields more honey than only sugar syrup and protein supplements. Brood and honey production increased in sugar-fed colonies, according to Musa et al. (1988). According to Brar et al. (1989), brood rearing was at its best from February to April due to good weather conditions and the availability of abundant bee flora.

Foraging efficiency was found to have significant positive connections with pollen storage, brood area with foraging efficiency, and egg-laying pollen stores. *A. mellifera*, on the other hand, produced 22% more brood than *A. cerana* (Shah and Shah 1989).

Honey production increases as the population grows, according to Szabo and Lefkovitch (1989) in Alberta, Canada. Honey production is substantially connected with the number of worker brood cells, worker population, and multiple drone brood cells and population of drones.

In Punjab, India, Chhuneja (1991) discovered that colony size and pollen had independent effects on honey bee rearing.

According to Pesante et al. (1992), European honey bee (*A. mellifera*) colonies fed 1 litre or 3 litres of 50 percent protein and pollen substitute twice a week gained significantly more weight than African colonies. However, it went unnoticed at another apiary where the nectar flow was smaller. Colonies that were fed one litre of syrup weighted more than those that were fed three litres.

Bees absorbed more api-invert solution at concentrations of 50 percent and 60 percent sugar and api-invert solution, according to Kammerer (1994), but sucrose at 20 percent, 30 percent, and 40 percent. When bees were given three sugar solutions, each containing a single sugar, their overall sugar consumption was roughly 30% fructose, 27% glucose, and 43% sucrose, but the sugar solution stored by the bees had a smaller proportion of fructose and more glucose. The sucrose ratio was virtually same.

While the colonies had an average brood area of 220cm2, brood frames gradually rose until December (330cm2), but declined sharply in January in *A. cerana indica* (160cm2). Kumar and Wakode (1997, Kumar and Wakode).

According to Chaudhary (2000), the brood area of *A. mellifera* increased rapidly from 2.5 to 7.3 frames per colony from February to March, then remained stable at 6 frames until May and June, after which it began to fall until early September.

According to Karacaoglu et al. (2003), increased pollen and sugar feeding with varied diets had no significant effect on honey yield or brood growth in experimental colonies.

When bees were fed pollen substitute, the number of brood cells increased by 53.5 percent, brood frames increased by 37.1 percent, and frames inhabited by bees increased by 32.0 percent, according to Neupane and Thapa (2005). When fed banana and pumpkin syrup, honeybee colonies grew brood cells by 16.3 percent and 2.8 percent, brood frames by 17.1 percent and 8.6 percent, and bees covered frames by

12.0% and 3.2 percent, respectively. The number of brood cells, brood frames, and bee-covered frames remained nearly constant when honeybees were given pumpkin syrup.

Pramod and Suresh (2010) investigated the impact of bee strength and artificial feeding on the fecundity of *Apis mellifera* L. queens in Pantnagar's Tarai environment. During the dearth period, all treated colonies except control were fed a 50% pollen substitute, and it was discovered that the amount of frames in colonies had no effect on egg laying, but it was continued regardless of the months or number of frames from May to July, including control. After July, the egg-laying slowed to a halt, and from August through October, no eggs were found. This suggests that the honey/pollen accumulated in the control between June and July played a role in egg laying. Weekly results were significantly superior in all treatments (T1 to T4), and aggregated data suggest that none of the treatments were significant among themselves.

The influence of several simulative feeds on the spring growth of *Apis mellifera* was studied by Andelkovic et al. (2011). They discovered that the spring simulative feed is a critical determinant in the formation of honey bee colonies.

Ram C. Sihag and Manisha Gupta (2013) observed that strength of a colony was directly proportional to the brood rearing since strong colonies always reared more broods in the colony.

Kumar et al. (2013) found that formulated meals (defatted soy four, brewer's yeast, and soy protein hydrolysate power) were the most successful, with 723.4 cm2 sealed brood area, 5.8 total bee covered frames, and 9138.6 bee population. The performance of all experimental colonies was shown to be superior than that of control colonies.

The honey gathered from the T1 (soybean diet), T2 (gramme diet), T3 (Maize diet), and T4 (sugar alone) diets was 21.3 kg 0.22, 24.4 kg 0.29, 19.3 kg 0.11, and 16 kg 0.11, according to Mahmood et al. (2013). Honey produced after pollen was treated with gramme diet (T2) was much superior than honey generated by bees fed on other pollen supplemental diets.

Andi and Ahmadi (2014) did a 60-day trial feeding colonies in May and June (the first 45 days of feeding every second day and the other 15 days without feeding). Treatment 2 (2000 mg/L vitamin C) had the largest average brood area (9049 cm2), while treatment 1 (control) had the smallest (4848 cm2) (p0.05). At treatment 4, the mean colony population was larger than the control (10.41 vs. 8.38 comb, respectively) (p0.05). Treatment 2 had the lowest percentage (17.5%). In treatment 4, worker bees had a higher mean body weight than the other group (p0.05). Brood area, colony population, and worker body weight and protein rose when vitamin C was added to spring nutrition (1:1 sugar syrup) in the colonies.

According to Pradeepa et al. (2014), the CPI in sugar-fed colonies jumped from 4.6 to 11.4. After one week of rescue, the wax moth infested colony's CPI (7.4 to 3.0) showed a considerable fall and then a large recovery (3.0 to 8.5). In colonies kept in the hot sun, the CPI dropped dramatically from 8.2 to 1.8, recovered significantly from 1.8 to 9.4 in the post-rescue period, and showed no significant change in the case of 50 percent brood elimination. Sugar syrup and pollen aid in the formation of CPI and other appropriate rescue measures to prevent colonies from fleeing.

The bee, *Apis mellifera* colonies were given 500g of sugar solution (1:1 sugar and water) during the season of dearth (May to July), which was shown to be extremely effective and helpful for colonies of bees. After passing through the dearth phase, the bee strength was found to be 7.8, 6.2, 4.4, and 3.3, respectively, if these were fed at 1,2,3, and 4-week intervals. The colonies did not eat artificially in a timely manner, but they were able to live until the last week of June, when they began to dwindle in the first week of July (Tomar and Singh 2014).

Pande and colleagues (2015) For the observation, provide four varieties of syrups: T1 Banana, T2 Papaya, T3 Grapes, and T4 Guava in comparison to T5 Sugar. Brood area (sq cm), honey store (sq cm), pollen store (sq cm), and forage (forager/minute) activities increased steadily, with banana (brood area 768.00, 774.00; honey stores 836.33, 856.00; pollen store 329.00, 335.33 with 18.33, 20.33 respectively) being the most active (brood area 768.00, 774.00; honey stores 836.33, 856.00; pollen store 32 (brood area 733.00, 741.67; honey store 822.33, 845.00; pollen store 313.00, 318.67 with 16.66, 18.67 respectively), Sugar (brood area 680.00, 683.00; honey store 799.00, 804.67; pollen store 298.67, 304.33 with 16.66, 17.33 respectively) and grapes (brood area 612.00, 615.67; honey store 734.67, 746.67; pollen store 282.67, 290.00 with 11.66, 11.67 foragers per minute respectively) All needed criteria were determined to be the least in guava. So, among the studied banana fruits, the best nectar supplement was banana, followed by papaya, both of which cut feeding expenses by more than 35% and 50%, respectively.

According to Kishan and Srinivasan (2016), 4 and 8 g/FS (Frame Strength) were superior than 0, 1 and 2 g/FS (Frame Strength) in the dearth season (October to December 2014), showing that larger amounts of PS (Pollen Substitute) may be given in the dearth period compared to the honey flow period. Providing high levels of PS during times of scarcity aids in the growth of a large colony of honey bees, who then labour to collect pollen and nectar during times of abundance. As a result, colony growth parameters did not significantly rise above 4g / FS. In the dearth period, 4g/FS of PRGF-based PS was shown to be optimal, while in the honey flow season, 2g/FS of PRGF-based PS was found to be optimal. PS showed a positive influence on colony development metrics like as honey production, pollen storage, sealed brood production, and adult population.

According to El-sherif et al. (2017), treatment (C) (Brewer yeast – chickpea cake supplemented with 4.2 percent pollen as a protein supplement + sugar syrup) was the best diet (2:1). When compared to the equivalent average in the colonies before feeding, it came first in order and produced a higher brood-rearing rate of 968.84 worker brood/day with increasing percentages of 127.28 percent. When compared to the weight before feeding, the average weight of stored honey was 3502.92 grams/colony, an increase of 433.78%. The weight of stored pollen did not differ significantly between the diets, however treatment (C) generated a greater weight of stored pollen of 249.03 grams/colony with an increase of 315.45 percent when compared to before feeding, and the average lifespan of caged freshly emerging workers was 26.17 days.

According to Fathy et al. (2018), the average total number of square inches of store pollen per colony for those treated with Glucose, Fructose, Molasses, Moringa, and Control was 3116, 3132, 2825, 3552, and 2566 sq. in. The greatest rates of pollen collection were recorded in July and May, with 740 and 685 square feet per colony, respectively. Moringa produced the most stored pollen (3552 sq. in/colony) over the course of a year, whereas Threatened colonies with Molasses produced the least (285 sq. in/colony). In addition, the smallest quantities resulted in the smallest quantity of pollen stored (285 sq. in/colony).

After 15 and 30 days of testing, Rashid et al. (2018) found that the PS-1 colonies had the largest growth in brood cells, with brood cells increasing 385.0 percent and 351.6 percent, respectively, compared to 94.2 percent and 58.9 percent in control colonies. The colonies that were given PS-1 produced the most honey, whereas the control colonies produced the least. Syrup-2 had the most pollen collection (2.61g), whereas syrup-3 had the least.

The colonies were fed (chickpea flour + wheat germ + dried brewer's yeast) and produced the highest average biological activity of 105,54 g 363,75 inch2, 134,83 inch2, and 404,08 inch2 / colony for diet consumption, sealed workers brood area, stored pollen area, and stored honey area, respectively, according to Younis (2019). The colonies fed (pea flour + defatted soybean flour + dried brewer's yeast) had the lowest average biological activity, averaging 77.0 g, 235.1 inch2, 75.43 inch2, and 258.39 inch2/colony for food intake, sealed workers brood, and stored pollen, respectively.

2.2 Effect of pollen substitute on foraging activity

Feeding honey bee colonies with pollen substitute enhances their pollen gathering performance, according to Free and Spencer-booth (1961). When dilute (40 percent sugar) and intense (62 percent sugar) sugars were given, the results were similar.

Pollen collection activity is influenced by the availability of pollen-producing flowers as well as environmental factors like as dawn, sunset, and day temperature, according to Bisht and Pant (1968). They also discovered that the time the bees began collecting pollen journeys and the maximum daily temperature had a negative relationship. The relative humidity of the day and the periods when the bees began gathering pollen had a substantial correlation.

Ibrahim (1973) found that when *A.mellifera* colonies were fed pollen substitute containing 4% pollen, they gathered 28.6% more pollen than identical colonies fed honey solution containing the same amount of pollen.

According to Reddy (1980), the Indian honey bee Apis cerana's foraging activity peaked in July and peaked again in January in Bangalore. Pollen plus nectar collectors were found in larger quantities than pollen or nectar collectors, he discovered.

Thakur et al. (1982) found that foraging activity was higher in the afternoon in Himachal Pradesh (300 bees returned in 5 minutes), and that they saw more pollen foragers in the morning than in the afternoon.

In Himachal Pradesh, honey bees began foraging around 9.00 a.m. and were most active from 11.00 a.m. to 4 p.m. (Bhalla et al., 1983)

Foraging behaviour for pollen and nectar is strongly influenced by daytime temperature and humidity. Foraging A.cerana indica's threshold temperature was assessed to be approximately 14^0 C, whereas Apis florea and Apis dorsata's threshold temperatures were estimated to be around 17^0 C. During the winter months, the ideal feed temperature for the former was 20^0 C and 24^0 C for the latter two species (Brisht et al., 1983).

Summer (06.00, 08.00, 10.00, and 16.00 hours); rainy (09.00 and 10.00 hours); autumn (09.00, 10.00, and 12.00 hours); early winter (09.00 and 14.00 hours); late winter (11.00 hours); and spring (06.00, 08.00, 10.00, and 16.00 hours), according to Mattu and Verma (1985). (08.00 and 11.00 hours). Overall, nectar collection was higher than pollen, pollen + nectar, and water collection in all seasons of the year. During various seasons, there were more changes in the percentage of nectar collectors compared to pollen, pollen + nectar, and water collectors.

Bee flying was impacted by temperature and blocked above 32^0 C, according to On and Choi (1986).

Foraging began at 5.00 a.m. in July-August, peaked between 8.00-9.00 a.m., and ended around 20.00 a.m. Around 12.00-15.00 h, there was the least amount of activity. Pidek (1986) discovered that feeding the A. mellifera colony bigger pollen substitute meals reduced the total time taken but had no effect on the amount of food consumed.

Foragers in Quebec, Canada, were able to collect more pollen in smaller colonies due to greater brood, resulting in reduced honey output, according to Marceau et al. (1990).

Syrup feeding increased the quantity of kiwi fruit pollen collected by up to 7.9 times during the whole flowering season, according to Goodwin et al. (1991).

In fall, Raj et al. (1993) found that pure pollen attracted more foragers thanpollen substitute.

Honey bee preference was evaluated against refined and unprocessed PS by Khorvash et al (1994), and unrefined PS produced excellent findings.

Augustjin (1994) found that flight activity in honey bee (*A. mellifera*) colonies dropped to practically nothing in October from a peak of 28,000 bees per day in early August. The activity is momentarily enhanced with sugar feeding.

According to Jyothi (1994), the number of *Apis cerana indica* bees visiting the mango panicle grew gradually from 6:00 a.m. to 12:00 p.m., with a peak (16-20 bees/panicle) between 9:00 a.m. and 11:00 p.m.

Thapa and Pokhrel (2005) found that feeding sugar syrup to bee foragers increased outbound and inbound flying by 908-987 percent and 578-704 percent, respectively. In comparison to control colonies, a modified diet (low dosage of sugar syrup mixed with pollen substitute) was excellent for treating honeybee colonies off-season, resulting in high flight activity levels of 3.3 times out-going and 2.8 times in-coming.

Pollen collection was highest in the early morning, and lowest in the afternoon, according to Reyes-Carrillo et al. (2007).

Colonies led by virgin queens had more foraging activity but less pollen collection than colonies led by mated queens, whereas queen-less colonies had lower foraging activity and pollen collection than colonies led by mated queens (Free et al., 1985). Foraging behaviour is also influenced by colony strength and brood-rearing activities (Amdam et al., 2009, About-Shaara et al., 2013).

Between black and yellow strains of Indian honey bee *Apis cerana indica*, Shruti et al. (2009) examined behavioural characteristics such as pollen carrying capability, pollen and honey storage, and colony population. Pollen foragers carry relatively little fluid during the warmest periods, and pollen foraging decreases at high ambient temperatures, according to the findings.

The sucrose response thresholds of resin foragers were lower than pollen foragers, according to Simone-Finstrom et al. (2010). Workers with low sucrose response thresholds begin foraging for water and pollen sooner and at a younger age than workers with high sucrose response thresholds who forage for nectar (Pankiw 2005).

Honey bee workers' foraging efficiency can be harmed by diesel exhaust because worker bees' capacity to detect floral scents is harmed (Girling et al., 2013).

According to Chaand et al. (2017), a substantial rise in foragers collecting pollen only and nectar exclusively was linked to increased pollen and nectar availability, which was mostly attributable to the blooming of more plant species that provide both pollen and nectar.

Sweet cherry pollen collection increased 2.16-fold, field bean pollen collection rose 3.27-fold, red clover pollen collection increased 5.2-fold, and kiwifruit pollen collection increased 7.9-fold after sugar syrup feeding (Gemeda et al., 2018).

According to Hemalatha et al. (2018), the highest temperature has a positive connection with the foraging activity of arriving and outgoing bees with honey and pollen (r=0.117, r=0.188, and r=0.120, respectively). During the winter season, the highest foraging activity was 10.30 percent, 9.91 percent, and 9.26 percent during the third, fourth, and fifth standard weeks, respectively. The departing bee population outnumbered the nectar gatherers from the first (47.69 percent) to fifth (48.61 percent) standard weeks. The population of nectar gatherers achieved the pollen gatherers contribution of just 16 percent in the sixth standard week. Pollen gatherers were never more numerous than nectar gatherers or emigrating bees.

2.3 Assessment of economics of pollen substitute diet

Tsibulski (1975) found that having unsealed brood in the colony reduces honey output because it is utilised for brood raising.

With the use of contemporary methods, one may generate 15 kg of honey each colony, bringing in Rs.3,000 per year. 'Maskey' (1989).

According to Khadka (1999), the cost-benefit ratio of exotic bees (*Apis mellifera*) ranges from 0.66 to 1.06, and the average B/C ratio of exotic and native bees is 0.66 and 0.48, respectively, in seven VDCs in the sub-urban area of Nepal's Lalitpur district. The typical B/C ratio is less than one, as seen by this graph. Lack of bee food supplies, poor management, a lack of technical and medical services, high fixed input costs, and insufficient training were the primary causes of low production. To make apiculture more profitable, these factors must be improved.

In the Dadeldhura area of Nepal, Gurung (2005) stated that one beekeeper was able to sell NRs.40,000 (US$563) worth of honey in one season with very little monetary input. The average yearly cash revenue from Apiscerena beekeeping was around NRs 4,152 (US$56) among beekeepers in Alital, Dadeldhura, accounting for more than one-third of the entire annual cash income from agriculture operations. Mountain women from all across the nation do traditional beekeeping and generate around 2 to 3 kg of honey per colony each year.

Bhusal (2006) found that the exponential increase in honey production Y=4,22 – 0,7325 X + 0,09625 X2 (4 x 10 comb covered by bees per colony) and Y = 4.22 – 0.000299 x + 0,000000016 X2 (9,800 x 24,500 honeybees per colony), n = 4 produced 2.32, 1.59, and 1.18 times more honey from the initial 10,8, and 6 – frame colonies, Colony strength, brood raising, comb construction, foraging behaviour, and honey output all have a substantial positive linear relationship. Kumar (2012) discovered that as the number of colonies grows, so does the profit from beekeeping. Between November 2008 and April 2009, there were substantial differences in adult bee populations, with an overall average of 10.0 1.3 frames of bees given sucrose syrup compared to 7.51.6 frames of bees fed entirely on HFCS.

According to Sammataro and Weiss (2013), colonies given SS developed a honeycomb of 7916.7 cm2 (1015.25 cm2) on average, while colonies given HFCS created 4571.63 cm2 (786.45 cm2). Bees fed HFCS had a mean mass of 4.65 kg (0.97 kg), while those fed sugar had a mean mass of 8.27 kg (1.26). In the second trial, colonies treated with PS throughout the winter months at a remote field site produced more spring brood than colonies fed with HFCS.

Patruica and Hutu (2013) used 110 bee colonies in their study, which were fed pollen substitute 1.4 L/weekly colonies) on a controlled schedule between March 25 and April 15. On April 20, the bees were moved to a rapeseed field for foraging, and honey output was assessed for each experiment at each foraging period. When compared to the control group, colonies given PS with prebiotic and probiotic supplements produced more honey and had greater earnings (varying from 14.67 percent to 45.49 percent).

MATERIALS AND METHODS

The present studies were carried out to find the effect of pollen substitute diet on colony performance (brood area, honey area, pollen area, bee strength), extent of pollen substitute diet consumption and foraging activities (incoming nectar foragers, incoming pollen foragers) of Indian hive bee *Apis cerana indica* Fab. The details of material used and method followed during the course of investigations have been presented in this chapter.

3.1 Experimental site

3.1.1 Location

The studies were carried out at the Apiary of the AICRP on honey bees and pollinators, Odisha University of Agriculture and Technology, Bhubaneswar.

3.1.2 Climatic Conditions

Out of the 10 agro-climatic zones of Odisha, Bhubaneswar is coming under east zone. The climatic conditions of bhubaneswar are characterized by warm and moist climate with hot and humid summer and mild winter. Broadly the climate falls into “hot and moist sub humid” group. Environmental factors during sugar feeding, particularly temperature and relative humidity of the atmosphere, influence the quality of honey.

3.2 Selection of *Apis cerana indica* colonies

Bee colonies (*Apis cerana indica*) with no clinical signs of disease were used for the study. *Apiscerana* colonies with replications R1, R2, R3, R4 were selected in September for examining colony parameters *viz*., brood area, honey area, pollen area and bee strength. Total 24 colonies were selected involving six treatments .Four different pollen substitute diets were prepared as per specification collected from AICRP centers of different Agricultural Universities like, PAU diet(T1), GBPAUT diet(T2), YSPUHF diet(T3), and OUAT diet(T5).One fresh corbicular pollen diet(T4) and one only sugar solution diet (T6) was also included. Normal colony maintenance practices were regularly followed in all the colonies selected for the present studies. The present experiment was carried out during September 2020-December 2020.

A) Treatments-6

T1 - Brewer's yeast(41.8$_{gm}$) + Skimmed milk powder(4$_{gm}$) + Dehusked parched gram(4.2$_{gm}$) + Sugar solution (Sugar : Water =13:12, w/w)(50.0ml)

T2 - Soy Bari (18.75$_{gm}$) + Honey (50$_{gm}$) + Amul (18.75$_{gm}$) + Yeast(12.5$_{gm}$)

T3 - Soy (150$_{gm}$) + Wheat (150$_{gm}$) + Yeast (100$_{gm}$) + Sugar solution (400ml) (Sugar : Water = 2 :1) + Dark rum (20ml)

T4 - Corbicular pollen feeding)

T5 - Soy (60$_{gm}$) + Honey (35$_{gm}$) + Yeast (5$_{gm}$) + Multivitamin (1$_{gm}$)

T6 - (Only sugar solution@ 200 grams sugar per colony (1;1)

B) Replications- 4

Experimental design- Experiment laid out in RBD

3.3 Material used

Feeding bowl, sugar, honey, water, dark rum, soy, amul, yeast.

3.3.1 Preparation and feeding of pollen substitute

3.3.1.1 Preparation of pollen substitute

According to all the above treatments we prepared all the mixture. Every mixture was stirred vigorously until all the material mixed well. (Plate 1)

3.3.1.2 Feeding of pollen substitute

The slurry of the pollen substitute diet was prepared as per ingredient mentioned against each treatment (Sihag and Gupta, 2011). Freshly collected corbicular pollen was weighed and made ready for application. Fifty grams of each pollen substitute diet was given to each colony at each feeding. Similarly for control treatment 200 grams of sugar per colony is provided with 50% concentration (1;1). The pollen substitute diet was provided on a feeding bowl and fed to honeybee colonies at evening after all the bees stopped their activity. While feeding care was taken that pollen substitute should not fall on the ground; otherwise there would be robbing among the colonies (Plate 2). Pollen substitute was given 4 times from September to December in following date-

September – 14.09.2020

October – 5.10.2020

November – 28.10.2020

December – 19.11.2020

3.4 Observation to be taken:

3.4.1 Effect of pollen substitute diet on colony performance attributes

3.4.1.2 Measurement of consumption of pollen substitute:

After feeding of 50grams of pollen substitute diet to each experimental beehive the weight of each pollen substitute diet was recorded at 2^{nd}, 7^{th} and 10^{th} days interval.

3.4.1.3 Measurement of colony performance attributes

a) Brood area, honey and pollen area in (cm^2)

Brood, honey and pollen area were measured in sq. cm once in 21 days from every feeding. The above parameters were measured with help of frame sized wire grid, which fitted well on the four wooden bars of the comb, when placed on it. The wire grid consisted of squares each having 6.45 sq. cm area. The wire grid placed on combs having unsealed and sealed brood, pollen and honey. Number of squares of wire grid covering the different parameters was counted on all the combs in a colony and from the total brood, pollen and honey area was obtained. (Plate 3)

b) Bee strength (Numbers)

Number of frames covered by bees was taken as a measure of bee strength. Bee strength was recorded once in every 21 days from September to December 2020. The colony was opened and combs of bees were sequentially removed and the number of frames covered by bees in box was recorded.

3.5 Effect of pollen substitute diet on foraging behaviour of bees:

After giving pollen substitute and sugar solution to the 24 bee hives the bee activity at the hive entrance was recorded at 3 times of the day viz., morning (8-9hr) , afternoon (11-12hr) and evening (15-16hr) after every feeding at weekly interval.. The pollen foragers and nectar foragers observations were recorded by counting number of bees coming in by standing near at every box for 5 mins. Foraging acitivity recorded from September to December 2020 at weekly interval..

3.6 Assessment of economics of pollen substitute diet:

Honey was harvested at end of December 2020 with the help of manual honey extractor.The cost of pollen substitute was calculated and profitability was estimated.

Plate 1: Preparation of Pollen substitute feeding

Plate 2: Pollen substitute feeding to bee colonies

Plate 3: Observation of colony performance attributes (brood area, pollen area, honey area, bee strength in sq cm)

RESULTS

The present studies entitled “Impact of some pollen substitute diet on colony performance of *Apisceranaindica* F. in Odisha” have been undertaken during 2020-2021 at Apiary of AICRP on Honeybees and Pollinators, Odisha University of Agriculture and Technology, Bhubaneswar so as to evince the impact of some pollen substitute to *Apisceranaindica*Fab. The details of experiment results are presented in the following sections.

4.1 Colony Performance Attributes

4.1.1 Brood Area

The data from the present investigation indicated that the brood area before feeding was around 300 cm^2. (Table 1 and Fig. 1)

After 21 days of first feeding the brood area ranged between 194.25 cm^2 to 322.50cm^2 with a mean of 300.45 cm^2. The minimum brood area (194.25 cm^2) was observed in control plot while maximum brood area (322.50 cm^2) was observed in PAU diet followed by GBPUAT diet, YSPUHF diet and OUAT diet.

After 21 days of second feeding the brood area ranged between 337.50cm^2 to 366.25cm^2 with a mean of 352.45cm^2 .The minimum brood area (337.50cm^2) was observed in control plot while maximum brood area (366.25 cm^2) was observed in PAU diet followed by corbicular pollen feeding, GBPUAT diet, YSPUHF diet, and OUAT diet.

After 21 days of third feeding the brood area ranged between 373.75cm^2 between 431.25cm^2 with a mean of 399.58 cm^2. The minimum brood area (373.75cm^2) was observed in control plot while maximum brood area (431.25 cm^2) was observed in corbicular pollen feeding followed by PAU diet, GBPUAT diet, YSPUHF diet and OUAT diet.

After 21 days of fourth feeding the brood area ranged between 412.50 cm^2 to 502.50 cm^2 with a mean of 450.00 cm^2. The minimum brood area (412.50 cm^2) was observed in control plot while maximum brood area (502.50cm^2) was observed in corbicular pollen feeding followed by PAU diet, OUAT diet, GBPUAT diet and YSPUHF diet.

On an average of four feeding the brood area ranged between 329.50 cm^2 to 403.44 cm^2 with a mean of 373.81 cm^2. The minimum overall brood area (329.50 cm^2) was observed in control plot while maximum overall brood area (403.44 cm^2) was observed in corbicular pollen fed colonies which is at par with PAU diet. Further it was observed that the brood area gradually increased in all the treatments after pollen substitute fed except the control treatments where the brood area almost same after 1st feeding (300.45 cm^2) then it gradually increased.

Table No : 1 Effect of pollen substitute diet on brood area in *Apis cerana indica* during 2020

Treatment	Brood Area (Cm^2)					
	Before feeding 13.09.2020	21 days after 1st feeding 05.10.2020	21 days after 2nd feeding 26.10.2020	21days after 3rd feeding 18.11.2020	21 days after 4th feeding 09.12.2020	Overall Area
T1:PAU pollen substitute	300.00 (17.33)	322.50 (17.97)	366.25 (19.15)	418.75 (20.47)	466.25 (21.60)	393.44 (19.85)
T2:GBPUAT pollen substitute	298.75 (17.30)	310.00 (17.62)	352.50 (18.79)	392.50 (19.82)	438.75 (20.96)	373.44 (19.34)
T3:YSPUHF pollen substitute	294.75 (17.18)	307.50 (17.55)	348.50 (18.68)	391.25 (19.79)	427.50 (20.69)	368.69 (19.21)
T4:Corbicular pollen feeding	301.25 (17.37)	317.50 (17.83)	362.50 (19.05)	431.25 (20.78)	502.50 (22.43)	403.44 (20.10)
T5:OUAT pollen substitute	299.25 (17.31)	307.50 (17.55)	347.50 (18.65)	390.00 (19.76)	452.50 (21.28)	374.38 (19.36)
T6:Only sugar solution	308.75 (17.59)	194.25 (13.85)	337.50 (18.38)	373.75 (19.34)	412.50 (20.32)	329.50 (18.17)
Mean	300.5	300.45	352.45	399.58	450.00	373.81
	C.D: N/A	C.D: 1.139	C.D: 0.221	C.D: 0.168	C.D.0.266	C.D: 0.249
	SE(m): 0.132	SE(m): 0.375	SE(m): 0.073	SE(m): 0.055	SE(m)0.088	SE(m): 0.082

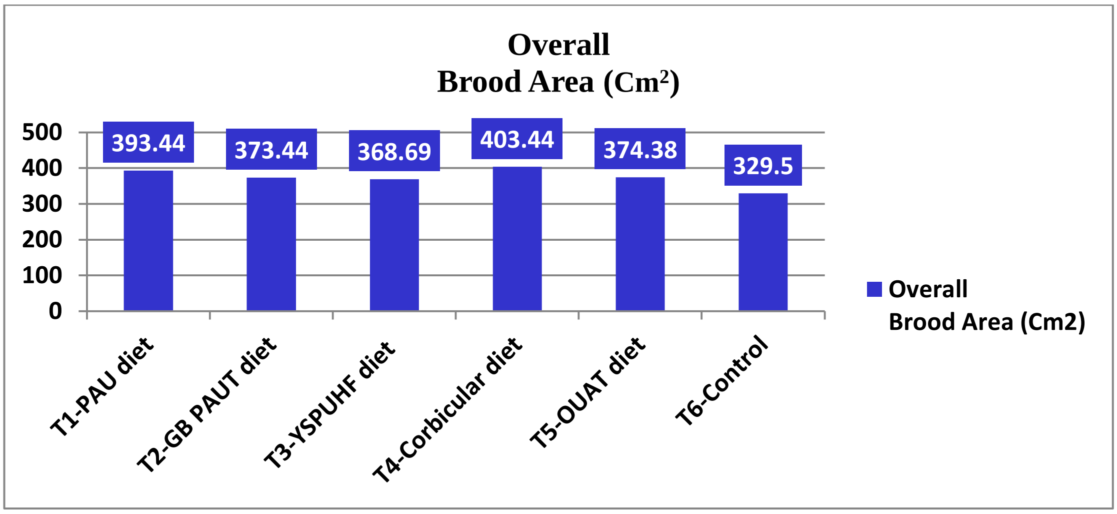

Fig. 1 Effect of pollen substitute diet on brood area in *Apis cerana indica* during 2020

4.1.2 Honey Area

The data on effect of pollen substitute on change in honey area indicated that the honey area before feeding was around 92.00 cm^2. (Table 2 and Fig. 2)

After 21 days of first feeding the honey area ranged between 72.75 cm^2 to 114.2 cm^2 with a mean of 85.67 cm^2. The minimum honey area (52.25 cm^2) was observed in YSPUHF diet, Solan diet while maximum honey area (114.25 cm^2) was observed in CPF followed by PAU diet, GBPUAT diet, OUAT diet and control plot.

After 21 days of second feeding the honey area ranged between 88.50 cm^2 to 132.25 cm^2 with a mean of 104.63 cm^2 . The minimum honey area (88.50 cm^2) was observed in control plot while maximum honey area (132.25 cm^2) was observed in corbicular pollen fed traetment followed by PAU diet, OUAT diet, YSPUHF diet and GBPUAT diet.

After 21 days of third feeding the honey area ranged between 83.50 cm^2 to 140.75 cm^2 with a mean of 110.88 cm^2 . The minimum honey area (83.50 cm^2) was observed in GBPUAT while maximum honey area (140.75 cm^2) was observed in corbicular pollen fed treatment followed by PAU diet, OUAT diet, control plot and GBPUAT diet.

After 21 days of fourth feeding honey area ranged between 82.25 cm^2 to 181.50 cm^2 with a mean of 124.46 cm^2. The minimum honey area (82.25 cm^2) was observed in YSPUHF while maximum honey area (181.50 cm^2) was observed in corbicular pollen followed by PAU diet, OUAT diet, control plot, GBPUAT diet.

On an average of four feeding the honey area ranged between 80.19 cm^2 to 142.19 cm^2 with a mean of 106.41 cm^2 . The minimum overall honey area (80.19 cm^2) was observed in YSPUHF while maximum overall honey area (142.19 cm^2) was observed in corbicular pollen fed traetment followed by PAU diet, OUAT diet, control plot and GBPUAT diet. Further it was observed that the honey area gradually increased in the treatment PAU, CPF and OUAT treatments where in other treatments the honey area decreased after 1st feeding while it increase after 2nd feeding and continue up to 4th feeding.

Table No 2: Effect pollen substitute diet on Honey storage area in *Apis cerana indica* during 2020

Treatment	Honey Area (Cm^2)					
	Before feeding 13.09.2020	21 days after 1st feeding 05.10.2020	21 days after 2nd feeding 26.10.2020	21days after 3rd feeding 18.11.2020	21 days after 4th feeding 09.12.2020	Overall Area
T1:PAU pollen substitute	92.00 (9.62)	102.75 (10.16)	120.75 (11.01)	126.50 (11.27)	141.50 (11.92)	122.88 (11.11)
T2:GBPUAT pollen substitute	89.00 (9.46)	72.75 (8.56)	90.75 (9.55)	83.50 (9.17)	86.50 (9.33)	83.38 (9.16)
T3:YSPUHF pollen substitute	91.50 (9.59)	52.25 (7.26)	94.25 (9.73)	92.00 (9.62)	82.25 (9.10)	80.19 (8.98)
T4:Corbicular pollen feeding	93.25 (9.68)	114.25 (10.71)	132.25 (11.52)	140.75 (11.88)	181.50 (13.49)	142.19 (11.95)
T5:OUAT pollen substitute	88.25 (9.42)	93.00 (9.67)	101.25 (10.09)	119.25 (10.94)	132.75 (11.54)	111.56 (10.59)
T6:Only sugar solution	92.50 (9.64)	79.00 (8.92)	88.50 (9.43)	103.25 (10.19)	122.25 (11.08)	98.25 (9.94)
Mean	91.08	85.67	104.63	110.88	124.46	106.41
	C.D. N/A	C.D. 0.26	C.D. 0.523	C.D. 0.293	C.D. 0.173	C.D. 0.153
	SE(m) 0.109	SE(m) 0.085	SE(m) 0.172	SE(m) 0.096	SE(m) 0.057	SE(m) 0.05

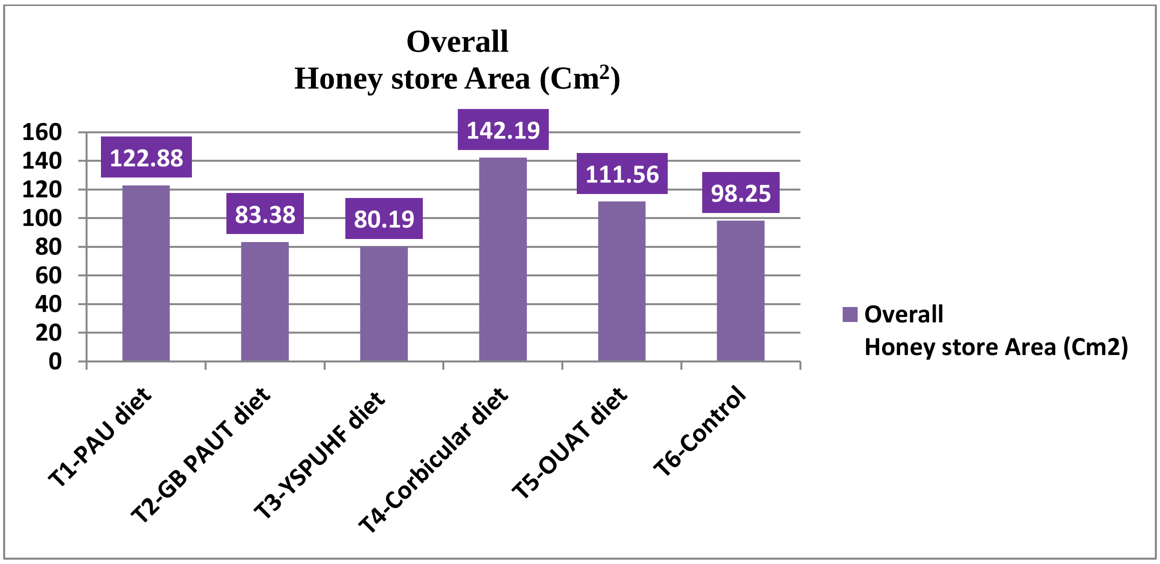

Fig. 2 Effect pollen substitute diet on Honey storage area in *Apis cerana indica* during 2020

4.1.3 Pollen Area

The data on effect of pollen substitute on change in pollen area indicated that the honey area before feeding was around 11.50 cm^2 .(Table 3 and Fig. 3)

After 21 days of first feeding the pollen area ranged between 9.50 cm^2 to 15.00 cm^2 with a mean of 12.04 cm^2 . The minimum pollen area (9.50 cm^2) was observed in control plot while maximum pollen area (15.00 cm^2) was observed in corbicular pollen feeding followed by OUAT diet, PAU diet , YSPUHF diet and GBPUAT diet .

After 21 days of second feeding the pollen area ranged between 9.75 cm^2 to 16.50 cm^2 with a mean of 13.00 cm^2 . The minimum pollen area (9.75 cm^2) was observed in control plot while maximum pollen area (16.50 cm^2) was observed in CPF followed by PAU diet, CPF, YSPUHF diet, and GBPUAT diet .

After 21 days of third feeding the pollen area ranged between 10.00 cm^2 to 17.00 cm^2 with a mean of 13.08 cm^2 . The minimum pollen area (10.00 cm^2) was observed in control plot while maximum pollen area (17.00 cm^2) was observed in CPF followed by OUAT diet, PAU diet, YSPUHF diet, and Pantnagar diet.

After 21 days of fourth feeding pollen area ranged between 3.50 cm^2 to 17.50 cm^2 with a mean of 9.96 cm^2 . The minimum pollen area (3.50 cm^2) was observed in control plot while maximum pollen area (17.50 cm^2) was observed in CPF followed by OUAT diet, PAU diet, YSPUHF diet, and Pantnagar diet. On an average of four feeding the pollen area ranged between 8.19 cm^2 to 16.50 cm^2 with a mean of 12.02 cm^2 . The minimum overall pollen area (8.19 cm^2) was observed in control plot while maximum overall pollen area (16.50 cm^2) was observed in CPF followed by OUAT diet, PAU diet, Solan diet and Pantnagar diet . Further it was observed that the pollen area increased gradually after 1^{st} feeding and it continued up to 4^{th} feeding in all the treatments.

Table 3: Effect pollen substitute diet on Pollen storage area in *Apis cerana indica* during 2020

Treatment	Pollen Area (Cm^2)					
	Before feeding 13.09.2020	21 days after 1st feeding 05.10.2020	21 days after 2nd feeding 26.10.2020	21days after 3rd feeding 18.11.2020	21 days after 4th feeding 09.12.2020	Overall Area
T1:PAU pollen substitute	11.50 (3.46)	12.75 (3.64)	15.00 (3.94)	14.50 (3.87)	12.75 (3.64)	13.75 (3.77)
T2:GBPUAT pollen substitute	11.75 (3.50)	10.50 (3.32)	10.00 (3.24)	10.25 (3.28)	5.00 (2.35)	8.94 (3.07)
T3:YSPUHF pollen substitute	11.25 (3.43)	10.75 (3.35)	11.75 (3.50)	11.50 (3.46)	6.25 (2.60)	10.06 (3.25)
T4:Corbicular pollen feeding	11.50 (3.46)	15.00 (3.94)	16.50 (4.12)	17.00 (4.18)	17.50 (4.24)	16.50 (4.12)
T5:OUAT pollen substitute	11.00 (3.39)	13.75 (3.77)	15.00 (3.94)	15.25 (3.97)	14.75 (3.91)	14.69 (3.90)
T6:Only sugar solution	11.75 (3.50)	9.50 (3.16)	9.75 (3.20)	10.00 (3.24)	3.50 (2.00)	8.19 (2.95)
Mean	11.45	12.04	13.00	13.08	9.96	12.02
	C.D.N/A	C.D.0.285	C.D.0.407	C.D. 0.614	C.D. 0.494	C.D:0.201
	SE(m)0.105	SE(m)0.094	SE(m)0.134	SE(m) 0.202	SE(m) 0.162	SE(m):0.066

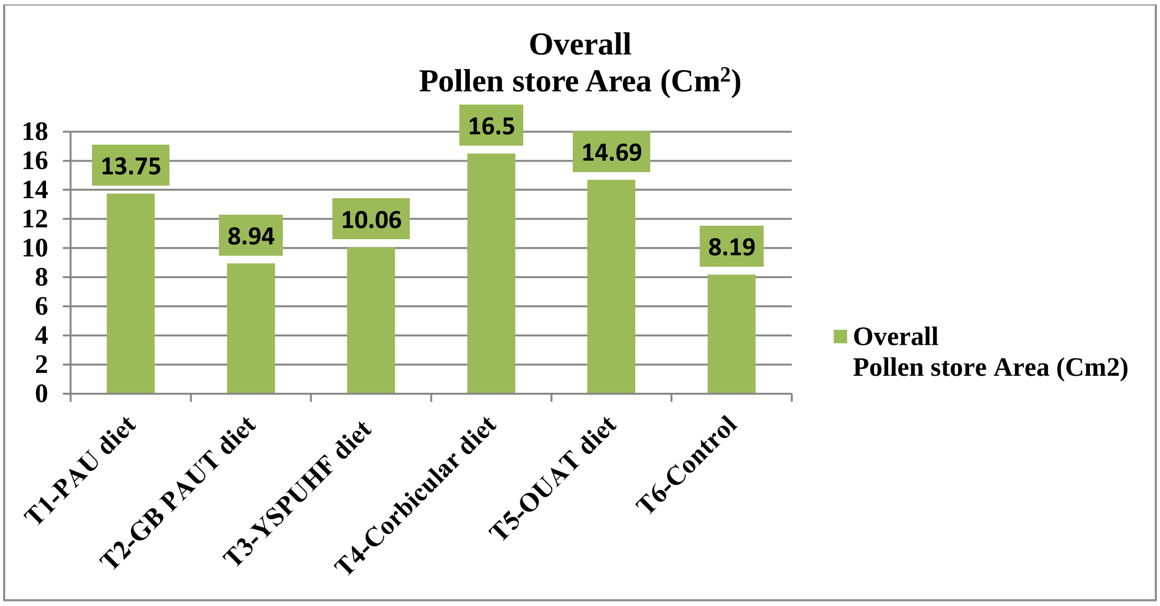

Fig. 3 Effect pollen substitute diet on Pollen storage area in *Apis cerana indica* during 2020

4.1.4 Bee Strength

The data on effect of pollen substitute on change in bee strength indicated that the bee strength before feeding was around 3.25 . (Table 4 and Fig. 4). After 21 days of first feeding the bee strength ranged between 2.50 to 4.50 with a mean of 3.25. The minimum bee strength (2.50) was observed in control plot while maximum bee strength (4.50) was observed in CPF followed by PAU diet , GBPUAT diet, Solan diet and OUAT diet.

After 21 days of second feeding the bee strength ranged between 3.00 to 5.50 with a mean of 4.08 . The minimum bee strength (3.00) was observed in control plot while maximum bee strength (5.50) was observed in CPF followed by PAU diet, GBPUAT diet, YSPUHF diet, and OUAT diet .

After 21 days of third feeding bee strength ranged between 3.25 to 6.00 with a mean of 7.57 . The minimum bee strength (3.25) was observed in control plot while maximum bee strength (6.00) was observed in CPF followed by GBPUAT diet, PAU diet, YSPUHF diet, Pantnagar diet and OUAT diet.

After 21 days of fourth feeding bee strength ranged between 3.75 to 7.00 with a mean of 5.46 .The minimum bee strength (3.75) was observed in control plot while maximum bee strength (7.00) was observed in CPF followed by OUAT diet, PAU diet, GBPUAT diet, and Solan diet. On an average of four feeding the bee strength ranged between 3.13 to 5.75 with a mean of 4.33. The minimum overall bee strength (3.13) was observed in control plot while maximum overall bee strength (5.75) was observed in CPF followed by PAU diet, GBPUAT diet, Solan diet and OUAT diet. Further it was observed that the bee strength was gradually increased in all treatments and it continues up to 4^{th} feeding except the control plot where the bee strength decreases after 1^{st} feeding (2.50) then gradually increased up to 4^{th} feeding.

Table 4: Effect pollen substitute diet on Bee Strength in *Apis cerana indica* during 2020

Treatment	Bee Strength (no.)					
	Before feeding 13.09.2020	21 days after 1st feeding 05.10.2020	21 days after 2nd feeding 26.10.2020	21days after 3rd feeding 18.11.2020	21 days after 4th feeding 09.12.2020	Overall Area
T1:PAU pollen substitute	3.25 (1.94)	3.50 (2.00)	4.50 (2.24)	4.75 (2.29)	5.75 (2.50)	4.63 (2.26)
T2:GBPUAT pollen substitute	3.00 (1.87)	3.00 (1.87)	4.00 (2.12)	5.00 (2.35)	5.25 (2.40)	4.31 (2.19)
T3:YSPUHF pollen substitute	3.25 (1.94)	3.00 (1.87)	3.75 (2.06)	4.25 (2.18)	5.00 (2.35)	4.00 (2.12)
T4:Corbicular pollen feeding	3.75 (2.06)	4.50 (2.24)	5.50 (2.45)	6.00 (2.55)	7.00 (2.74)	5.75 (2.50)
T5:OUAT pollen substitute	3.00 (1.87)	3.00 (1.87)	3.75 (2.06)	4.00 (2.12)	6.00 (2.55)	4.19 (2.17)
T6:Only sugar solution	3.50 (2.00)	2.50 (1.73)	3.00 (1.87)	3.25 (1.94)	3.75 (2.06)	3.13 (1.90)
Mean	3.29	3.25	4.08	7.57	5.46	4.33
	C.D:N/A	C.D:0.269	C.D:0.237	C.D. 0.249	C.D. 0.347	C.D.0.203
	SE(m):0.101	SE(m):0.088	SE(m):0.078	SE(m) 0.082	SE(m) 0.114	SE(m)0.067

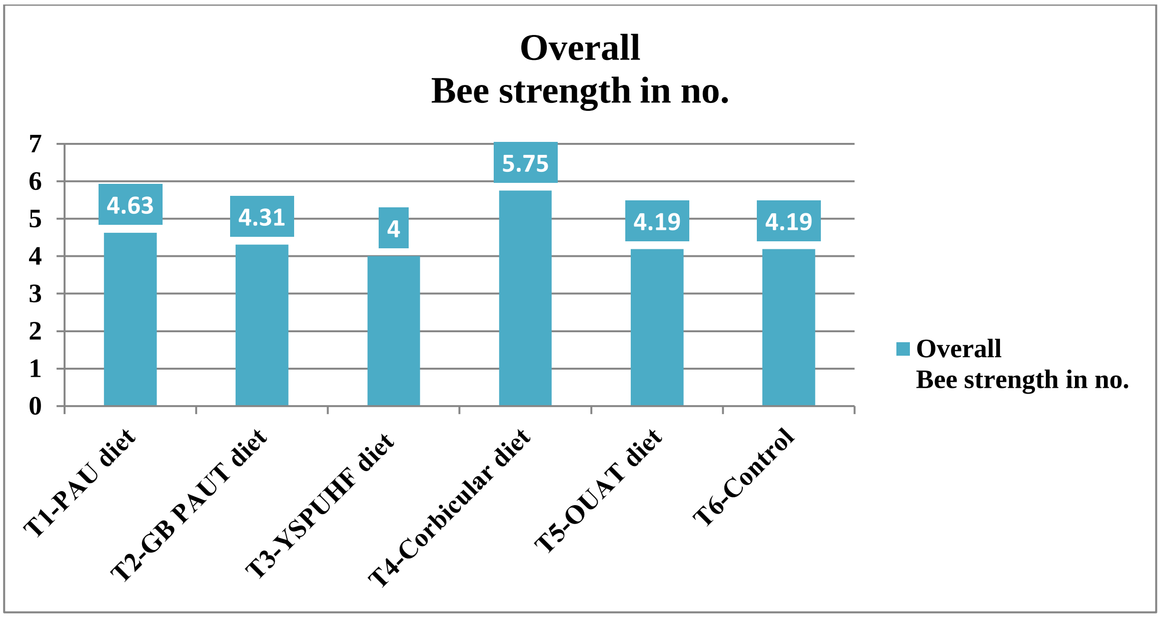

Fig. 4 Effect pollen substitute diet on Bee Strength in *Apis cerana indica* during 2020

4.1.5 Extent of pollen substitute diet consumption in ***Apis cerana indica*** during 2020

The data on extent of pollen substitute diet consumption indicated that the weight of the diet went on decreasing in 2^{nd} , 7^{th}, and 10^{th} day of every feeding.

After first feeding the consumption of pollen substitute diet ranged between 10.91_{gm} to $14.79_{gm}$with a mean of 12.22. (Table 5 and Fig. 5).The minimum diet consumption (10.91_{gm}) was observed in GBPUAT diet while maximum diet consumption (14.79_{gm}) was observed in CPF followed by PAU diet, OUAT diet and Solan diet.

After second feeding the consumption of pollen substitute diet ranged between 8.46_{gm} to $10.86_{gm}$with a mean of 9.8. The minimum diet consumption (8.46_{gm}) was observed in T3 while maximum diet consumption (10.86_{gm}) was observed in CPF followed by PAU diet, OUAT diet and GBPUAT diet.

After third feeding the consumption of pollen substitute diet ranged between 11.73_{gm} to $16.23_{gm}$with a mean of 13.6. The minimum diet consumption (11.73_{gm}) was observed in Solan diet while maximum diet consumption (16.23_{gm}) was observed in CPF followed by PAU diet, OUAT diet and Pantnagar diet.

After fourth feeding the consumption of pollen substitute diet ranged between 15.57_{gm} to $20.89_{gm}$with a mean of 17.3. The minimum diet consumption (15.57_{gm}) was observed in PAU diet while maximum diet consumption (20.89_{gm}) was observed in CPF followed by GBPUAT diet, Solan diet and OUAT diet.

On an average of four feeding the consumption of pollen substitute diet ranged between $12.11_{gm}$to 15.69_{gm} with a mean of 13.2 . The minimum overall consumption of pollen substitute diet (12.11) was observed in Solan diet while maximum overall consumption of pollen substitute diet (15.69) was observed in CPF followed by PAU diet, GBPUAT diet and OUAT diet.

The percentage of pollen substitute diet consumed after all feeding is ranged between 24.2 pct to 31.4 pct. The minimum amount of pollen substitute diet consumed (24.2 pct) in YSPUHF diet while the maximum amount of pollen substitute diet consumed (31.4 pct) in CPF followed by PAU diet, GBPUAT diet and OUAT diet.

Further the data indicated that maximum consumption (31.4 pct) in corbicular pollen fed treatment followed by PAU diet, GBPUAT and OUAT diet.

Table 5: Extent of pollen substitute diet consumption in *Apis cerana indica* during 2020

Treatment	Pollen substitute consumption per colony(gm)					Percentage pollen substitute diet consumed (gm)
	1st feeding	2nd feeding	3rd feeding	4th feeding	Overall	
T1:PAU pollen substitute	12.51 (3.61)	10.40 (3.30)	14.63(3.89)	15.57(4.01)	13.28(3.71)	26.6
T2:GBPUAT pollen substitute	10.91 (3.38)	9.36(3.14)	12.53(3.61)	17.48(4.24)	12.57(3.62)	25.1
T3:YSPUHF pollen substitute	11.17 (3.42)	8.46(2.99)	11.73(3.50)	17.07(4.19)	12.11(3.55)	24.2
T4:Corbicular pollen feeding	14.79 (3.91)	10.86(3.37)	16.23(4.09)	20.89(4.63)	15.69(4.02)	31.4
T5:OUAT pollen substitute	11.72 (3.50)	9.81(3.21)	12.74(3.64)	15.66(4.02)	12.48(3.60)	25.0
T6:Only sugar solution	-	-	-	-	-	-
Mean	12.22	9.8	13.6	17.3	13.2	
	C.D. 0.275	C.D. 0.121	C.D. N/A	C.D. 0.133	C.D. 0.169	
	SE(m) 0.088	SE(m) 0.039	SE(m) 0.119	SE(m) 0.051	SE(m) 0.054	

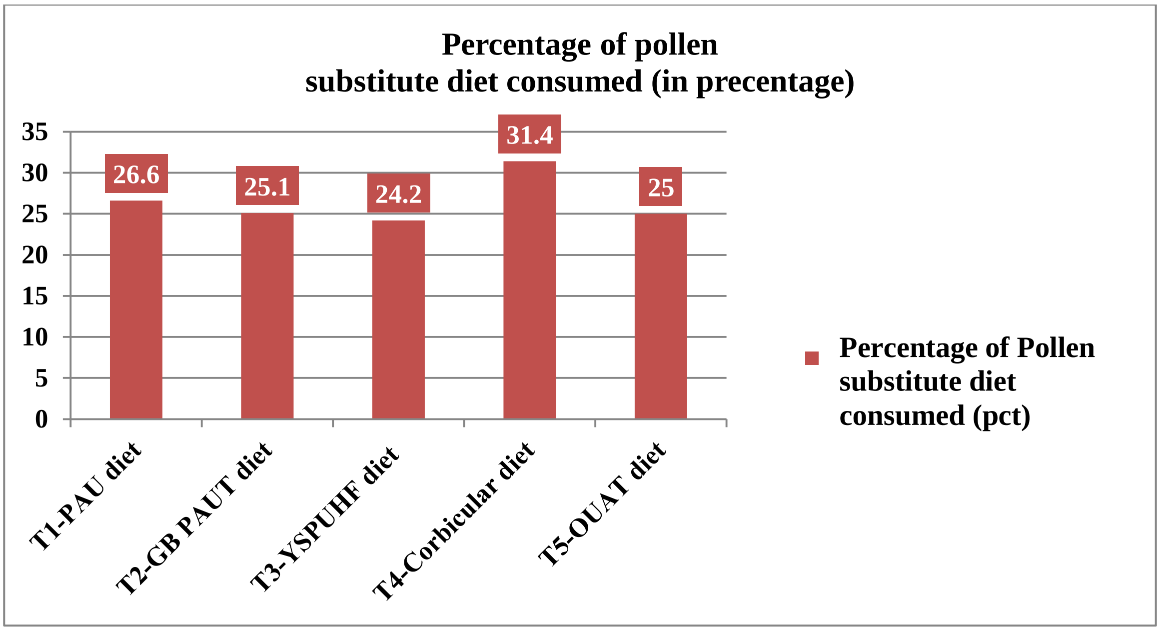

Fig. 5 Percentage of pollen substitute diet consumed in different diet

4.1.6 Effect of pollen substitute diet on nectar forager

Before feeding with pollen substitute to different colonies the foraging activity was almost same with a mean number of 3.61 and after 1st feeding the nectar forager ranged between 3.31 to 4.89 (Table 6 and Fig. 6). The minimum foraging range (3.31) was observed in control plot while maximum foraging range (4.89) was observed in corbicular pollen fed treatment which is at par with PAU diet. After 2nd feeding the nectar forager was observed with a mean number of 6.54. The nectar forager ranged between 5.43 to 8.67. The minimum nectar forager (5.43) was observed in control plot, where as maximum nectar forager (8.67) was observed in CPF followed by PAU diet, GBPUAT diet, OUAT diet and Solan diet.

After 3rd feeding the nectar forager was observed with a mean number of 5.81. It ranged between 4.19 to 7.22. The minimum nectar forager (4.19) was observed in control plot while maximum nectar forager was observed in corbicular pollen fed treatment which is significantly par with PAU diet.

After 4th feeding the mean of nectar forager/5min was 6.42. with a range of 4.89 to 7.58. The minimum nectar forager (4.89) was observed in control plot and maximum nectar forager (7.58) was observed in corbicular pollen fed treatment which is significantly at par with PAU diet.

With regards to overall nectar forager observations it was revealed that a mean of 5.75 it ranges between 4.45 to 7.09. The minimum nectar forager (4.45) was observed in control plot while maximum nectar forager (7.09) was observed in corbicular pollen fed treatment followed by PAU diet, OUAT diet, Pantnagar diet and Solan diet.

With regards to timing of nectar forager before feeding it was observed that maximum nectar forager was at evening (15-16) hour with a mean number of 3.83 followed by morning (8-9) hour with a mean number of 3.79 and afternoon hour (11-12) hour with a mean number of 3.21.

After 1st feeding it was reported that maximum nectar forager was observed in morning (8-9) hour with a mean number of 5.21 followed by afternoon (11-12) hour with a mean number of 4.06 and evening (15-16) hour with a mean number of 3.40. (Table 6 and Fig. 6)

After 2nd feeding again maximum nectar forager was observed in morning (8-9) hour with a mean number of 6.85 followed by evening (15-16) hour with a mean number of 4.97 and afternoon (11-12) hour with a mean number of 4.90.

After 3rd and 4th feeding the nectar forager was maximum in morning (8-9) hour with a mean number of 6.90 and 7.35 followed by evening (15-16) hour with a mean number of 6.07 and 6.99 and afternoon (11-12) hour with a mean number of 4.46 and 4.92 respectively.

Further it is observed that in all the treatments the nectar forager increases after and it continued up to 4th feeding.

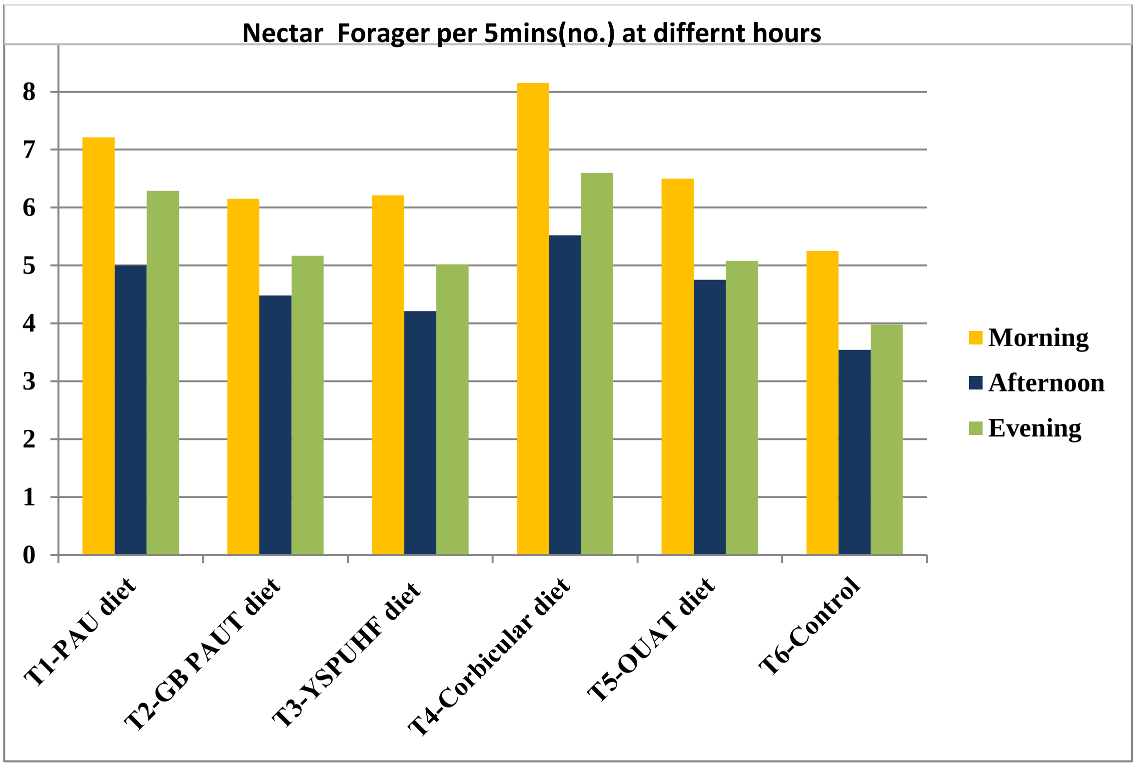

Fig. 6 Effect of pollen substitute diet on foraging activities of Nectar forager in different hours

Table 6: Effect of pollen substitute diet on foraging activities of Nectar Forager of *Apis cerana indica* after different days of feeding during 2020

Treatment	Nectar Forager per 5mins(no.)																	
	Day before 1st feeding			After 1st feeding			After 2nd feeding			After 3rd feeding			After 4th feeding			Overall		
	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr
	4.08 (2.14)			4.89 (2.32)			7.36 (2.80)			6.67 (2.68)			6.83(2.71)			6.44 (2.63)		
T1	4.25	3.50	4.50	5.75	4.17	4.75	7.25	5.83	5.75	8.17	4.83	7.00	7.67	5.17	7.67	7.21	5.00	6.29
	3.25 (1.94)			3.78 (2.07)			6.21 (2.59)			5.81(2.51)			6.17(2.58)			5.49 (2.45)		
T2	3.25	3.25	3.25	3.92	3.83	3.58	6.42	4.75	4.75	7.17	4.17	6.08	7.08	5.17	6.25	6.15	4.48	5.17
	3.00 (1.87)			3.92 (2.10)			5.68 (2.49)			5.19(2.39)			6.64(2.67)			5.36 (2.42)		
T3	3.50	2.50	3.00	5.00	4.00	2.75	6.08	4.25	4.17	6.17	3.58	5.83	7.58	5.00	7.33	6.21	4.21	5.02
	4.17 (2.16)			4.89 (2.32)			8.67 (3.03)			7.22(2.78)			7.58(2.84)			7.09 (2.76)		
T4	4.50	3.50	4.50	6.58	4.17	3.92	8.42	6.42	7.17	9.00	5.42	7.25	8.58	6.08	8.08	8.15	5.52	6.60
	3.83 (2.08)			4.56 (2.25)			5.89 (2.53)			5.78(2.51)			6.39(2.62)			5.65 (2.48)		
T5	3.75	3.75	4.00	5.75	4.83	3.08	6.50	4.33	4.33	6.25	5.25	5.83	7.50	4.58	7.08	6.50	4.75	5.08
	3.33 (1.96)			3.31 (1.95)			5.43 (2.44)			4.19(2.17)			4.89(2.32)			4.45 (2.23)		
T6	3.50	2.75	3.75	4.25	3.33	2.33	6.42	3.83	3.67	4.67	3.50	4.42	5.67	3.50	5.50	5.25	3.54	3.98
Mean	**3.61**			**4.22**			**6.54**			**5.81**			**6.42**			**5.75**		
Mean of morning, afternoon and evening	**3.79**	**3.21**	**3.83**	**5.21**	**4.06**	**3.40**	**6.85**	**4.90**	**4.97**	**6.90**	**4.46**	**6.07**	**7.35**	**4.92**	**6.99**	**6.58**	**4.58**	**5.36**
	C.D. N/A			**C.D. 0.083**			**C.D. 0.131**			**C.D. 0.094**			**C.D. 0.096**			**C.D. 0.073**		
	SE(m) 0.07			**SE(m) 0.027**			**SE(m) 0.043**			**SE(m) 0.031**			**SE(m) 0.032**			**SE(m) 0.024**		

4.1.7 Effect of pollen substitute diet on pollen forager

Before feeding with pollen substitute to different colonies the foraging activity was almost same with a mean number of 3.39 and after 1st feeding the pollen forager ranged between 2.83 to 6.36 (Table7 and Fig. 7). The minimum foraging range (2.83) was observed in control plot while maximum foraging range (6.36) was observed in corbicular pollen fed treatment which is at par with PAU diet.

After 2nd feeding the pollen forager was observed with a mean number of 4.52. The pollen forager ranged between 3.06 to 6.28. The minimum pollen forager (3.06) was observed in control plot, where as maximum pollen forager (6.28) was observed in CPF followed by PAU diet, YSPUHF diet, OUAT diet and GBPUAT diet.

After 3rd feeding the pollen forager was observed with a mean number of 4.86. It ranged between 3.00 to 6.89. The minimum pollen forager (3.00) was observed in control plot while maximum pollen forager (6.89) was observed in corbicular pollen fed treatment which is significantly par with PAU diet.

After 4th feeding the mean of pollen forager/5min was 5.25. with a range of 3.86 to 6.92. The minimum pollen forager (3.86) was observed in control plot and maximum pollen forager (6.92) was observed in corbicular pollen fed treatment which is significantly at par with PAU diet.

With regards to overall pollen forager observations it was revealed that a mean of 4.72 it ranges between 3.19 to 6.61. The minimum pollen forager (3.19) was observed in control plot while maximum pollen forager (6.61) was observed in corbicular pollen fed treatment followed by PAU diet, OUAT diet, GBPUAT diet and YSPUHF diet.

With regards to timing of pollen forager before feeding it was observed that maximum pollen forager was at morning (8-9) hour with a mean number of 4.38 followed by evening (15-16) hour with a mean number of 3.46 and afternoon hour (11-12) hour with a mean number of 2.33 (Table 7 and Fig. 7).

After 1st feeding it was reported that maximum pollen forager was observed in morning (8-9) hour with a mean number of 5.06 followed by evening (15-16) hour with a mean number of 4.57 and afternoon (11-12) hour with a mean number of 3.11.

After 2nd feeding maximum pollen forager was observed in evening (15-16) hour with a mean number of 5.15 followed by morning (8-9) hour with a mean number of 4.64 and afternoon (11-12) hour with a mean number of 3.63.

After 3rd and 4th feeding the pollen forager was maximum in morning (8-9) hour with a mean number of 5.81 and 6.39 followed by evening (15-16) hour with a mean number of 4.65 and 5.89 and afternoon (11-12) hour with a mean number of 4.13 and 3.47 respectively.

Further it is observed that in all the treatments the pollen forager increases after and it continued up to 4th feeding.

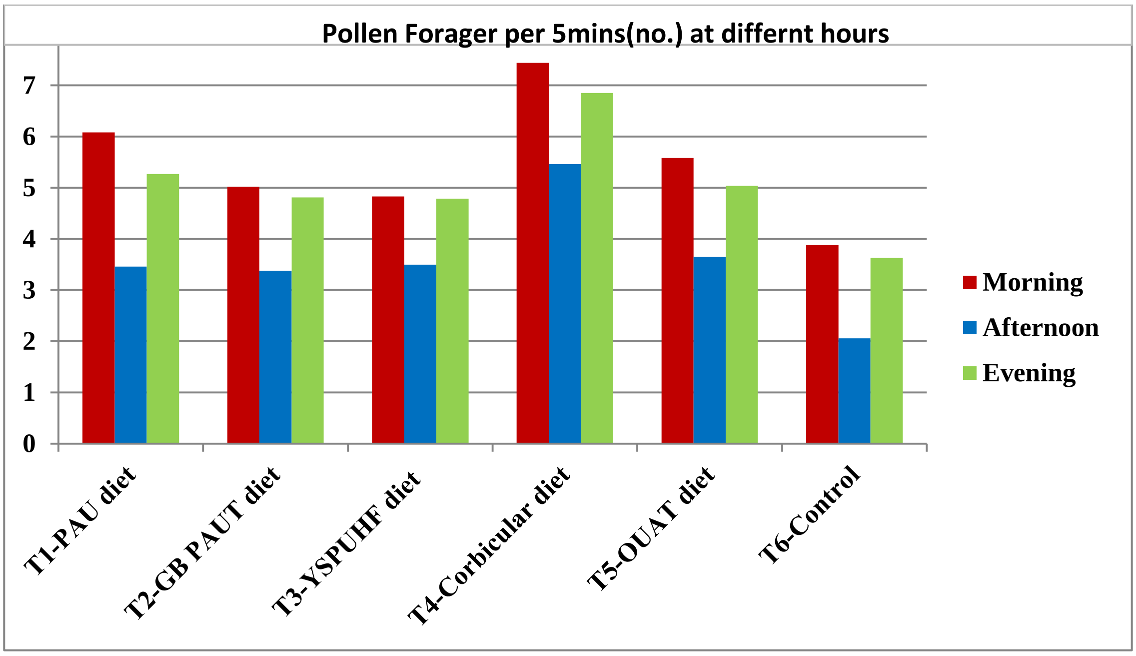

Fig. 7 Effect of pollen substitute diet on foraging activities of Pollen forager in different hours

Table: 7 Effect of pollen substitute diet on foraging activities of pollen Forager of *Apis cerana indica* after different days of feeding during 2020

Treatment	Pollen Forager per 5mins(no.)																	
	Day before 1st feeding			After 1st feeding			After 2nd feeding			After 3rd feeding			After 4th feeding			Overall		
	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr	08-09 hr	11-12 hr	15-16 hr
	3.25 (1.94)			4.50 (2.24)			4.92 (2.33)			5.17 (2.38)			5.03 (2.35)			4.90 (2.32)		
T1	4.50	2.25	3.00	6.33	2.58	4.58	5.42	3.42	6.33	6.17	4.83	4.50	6.42	3.00	5.67	6.08	3.46	5.27
	3.25 (1.94)			3.97 (2.11)			4.08 (2.14)			4.39 (2.21)			5.19 (2.39)			4.41 (2.22)		
T2	4.00	2.25	3.50	4.83	2.83	4.25	4.25	3.67	4.25	4.92	3.25	5.00	6.08	3.75	5.75	5.02	3.38	4.81
	3.33 (1.96)			4.11 (2.15)			4.39 (2.21)			4.19 (2.17)			4.92 (2.33)			4.40 (2.21)		
T3	4.25	2.25	3.50	4.33	3.42	4.58	4.33	3.67	4.83	4.50	3.67	4.42	6.17	3.25	5.33	4.83	3.50	4.79
	3.50 (2.00)			6.36 (2.62)			6.28 (2.60)			6.89 (2.72)			6.92 (2.72)			6.61 (2.67)		
T4	4.50	2.25	3.75	7.17	5.00	6.92	6.17	5.50	6.83	8.25	6.25	6.17	8.17	5.08	7.50	7.44	5.46	6.85
	3.58 (2.02)			3.69 (2.05)			4.39 (2.21)			5.53 (2.46)			5.58 (2.47)			4.80 (2.30)		
T5	4.50	2.50	3.75	4.42	2.58	4.08	4.17	3.42	5.08	6.75	5.17	4.67	7.00	3.42	6.33	5.58	3.65	5.04
	3.42 (1.98)			2.83 (1.83)			3.06 (1.89)			3.00 (1.87)			3.86 (2.09)			3.19 (1.92)		
T6	4.50	2.50	3.25	3.25	2.25	3.00	3.50	2.08	3.58	4.25	1.58	3.17	4.50	2.33	4.75	3.88	2.06	3.63
Mean	3.39			4.25			4.52			4.86			5.25			4.72		
Mean of morning, afternoon and evening	4.38	2.33	3.46	5.06	3.11	4.57	4.64	3.63	5.15	5.81	4.13	4.65	6.39	3.47	5.89	5.47	3.58	5.07
	C.D. N/A			C.D. 0.132			C.D. 0.118			C.D. 0.148			C.D. 0.152			C.D.0.085		
	SE(m) 0.032			SE(m) 0.043			SE(m) 0.039			SE(m) 0.049			SE(m) 0.054			SE(m)0.028		

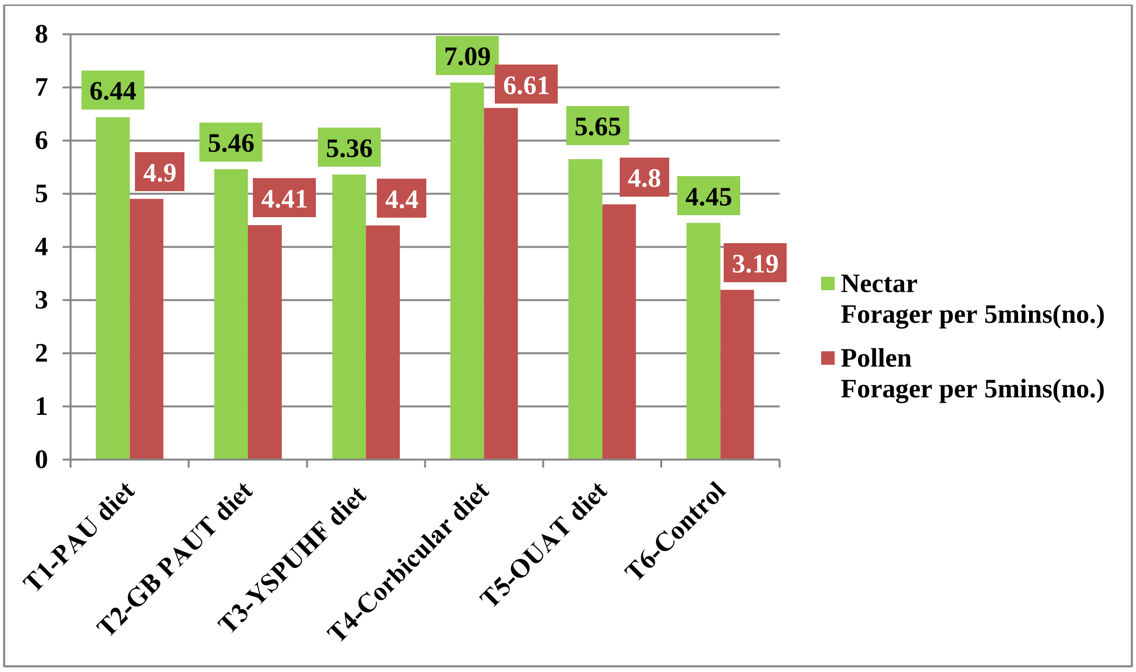

Fig. 8 Effect of pollen substitute diet on foraging activities of Nectar forager and Pollen forager of *Apis cerana indica* after different days of feeding during 2020

4.1.8 Assesment of economics of pollen substitute diet

The effect of pollen substitute diet on honey yield and the cost involved thereof in both the parameters revealed (Table 8) that the diet supplied is cost effective as there is better return obtained through honey production. Barring the cost of feeding of only sugar solution (1:1) (four times during experimental period) as a general management practice was the least (Rs 32/hive) so also the honey yield in the treatment as the cost of produce being Rs 400/ hive. In the contrary, substitution of diet except in the diet developed by YSPUHF diet all other diets enhanced the honey yield there by giving higher return. The highest return was obtained by providing PAU developed diet (Rs 800/hive) with involvement of Rs 60/- towards cost of diet/ colony fed four times. Natural colony substitute although gave same return but the cost of diet i.e natural pollen was very high (Rs 320/box) which is more than five times than the cost of PAU diet. The effect of diet developed in OUAT was moderate i.e there was return of Rs 600/box from the produce investing only Rs 54/- for four feedings.

Table No-8: The cost of pollen substitute diet and the cost of honey produced by feeding the pollen substitutes

Treatments	Cost of diet (4 FEEDINGS) (Rs)	Honey yield/hive (one harvest) (Kg)	Cost of Honey produced/hive (Rs)
T1- PAU diet	60	2.0	800
T2- GBPUAT diet	52	1.5	600
T3- YSPUHF diet	35	1.0	400
T4- Natural pollen	320	2.0	800
T5- OUAT diet	54	1.5	600
T6- Sugar feeding only	32	1.0	400

DISCUSSION

The studies on impact of some pollen substitute diet on colony performance (brood area, honey area, pollen store area, bee strength), foraging activity and economics of *Apis cerana indica* Fab have been conducted during 2020 and 2021 at apiary of the AICRP on honeybees and pollinators, Odisha University of Agriculture and Technology, Bhubaneswar. From various investigations presented in previous chapter have been discussed thoroughly in this chapter.

5.1.1 Effect of pollen substitute diet on brood area

Before provision of pollen substitute diet bee colonies with approximate uniform brood area were installed. The average brood area of the different treatments were approximately 300 cm^2 . Twenty one days after first feeding of different pollen substitute it was observed that there is no increase in mean brood area (297.5 cm^2). But in each treatment the brood area increases after first feeding except in control treatment where there is decrease in brood area (194.25 cm^2). This is perhaps due to low natural pollen available in nature. But after second feeding onward there was increase in brood area in each treatments including control treatments. The mean brood area also gradually increased (334.20 cm^2 to 419.20 cm^2) up to 4^{th} feeding. After 4^{th} feeding it was observed that maximum brood area (502.50 cm^2) was observed in corbicular pollen feeding (T4) which was significantly higher than any other treatments and it was followed by PAU diet, T1, (466.22 cm^2) treatment. In overall treatments also similar trend was observed that maximum brood area (403.44 cm^2) observed in corbicular pollen consumption treatment which was at par with PAU diet (393.44 cm^2). Ram C. Sihag and Manisha Gupta (2013) observed that a colony's strength was directly proportionate to the number of broods it produced, because strong colonies always reared more broods. The strength of a colony was directly related to brood raising according to Bhusal and Thapa (2011).The use of a pollen replacement boosts egg laying (brood) and, as a result, colony development (Kumar and singh,2000).

5. 1. 2 Effect of pollen substitute diet on Honey storage area

Before feeding of 50gm of pollen substitute there was approximate uniform honey area i.e. 91.08 cm^2 in each colony. 21 days after 1st feeding the average honey area was decreased to 87.67 cm^2 , but after 2nd feeding onwards the honey area gradually increased from 104.63 cm^2 to 124.48 cm^2 till 4th feeding. Further it was observed that the honey area gradually increased in corbicular pollen fed colonies (T4), followed by PAU diet fed colonies (T1) and OUAT diet fed colonies (T5), even after 1st feeding. But in other treatments (GBPUAT, YSPUHF and control diet) after 1st feeding the honey area decreased but after 2nd feeding onwards there was increase in honey area in all the treatments. The decreases in honey area after 1st feeding was due to low forager in nature as it was rainy season.

In overall it was observed that maximum honey area (142.19 cm^2) recorded in corbicular pollen fed treatment (T4) which was at par(122.48cm2) with PAU diet (T1). Kumar and Singh (2000), Bhusal and Thapa (2011), and Patruica and Hutu (2012) all made similar observations .

5. 1. 3 Effect of pollen substitute diet on pollen storage area

Before feeding of artificial pollen to different colonies the average pollen store area was approximately uniform with a mean of 11.45cm^2 .

The average mean pollen store area gradually increased after 1st feeding (12.04 cm^2) to 3rd feeding (13.08 cm^2) then the average pollen store area was decreased (9.95 cm^2) after 4th feeding. However after 4th feeding the pollen store area was maximum (17.50 cm^2) in fresh corbicular pollen area which was significantly higher than even PAU diet, T1, (12.75 cm^2). It indicated that the natural pollen were highly preferred by the bees.

As regards to overall pollen area it was recorded that maximum pollen store area (16.50 cm^2) in cobicular pollen fed treatment (T4) which was significantly higher (13.75 cm^2) than PAU diet, T1. Very low pollen area (8.19 cm^2) was observed in control treatment (T6). It indicated that in nature less pollen was available during the period of observation.

Also, a low quantity of pollen was observed in December, which could be attributable to limited egg laying due to the cold (Fathyet al.2018 and Bisth et al.1983)

5. 1. 4 Effect of pollen substitute diet on bee strength

Before artificial pollen feeding to different colonies there was uniform bee strength (3 to 4 nos) in different colonies with mean of 3.29 . Though after 1st pollen substitute feeding the mean bee strength was slightly reduced (3.25) but it gradually increased after 2nd feeding (4.08) and 3rd feeding (7.57) and it again decreased after 4th feeding (5.46). But in corbicular pollen feeding treatment (T4) there was a gradual increase in bee strength after 1st feeding (4.52) and it went on increasing (7.00) even after 4th feeding. Similar trend was also observed in PAU diet(T1). When it was observed in overall it was revealed that maximum bee strength (5.75) was observed in corbicular pollen fed treatment (T4) which was significantly higher(4.63) than the bee strength of PAU diet,(T1), Andelkovic et al. (2011) observed that the greatest rise in the number of bee frames when bees were fed with pollen substitute. Tomar and Singh (2014) found that bee colonies without pollen substitute had very low bee strength (1 and 1.2 number of frames).

5.1.5 Effect of pollen substitute diet consumption –

The different pollen substitute diet and sugar solution(1:1)was fed to each experimental hive and twenty one days after 1st feeding it was observed that on an average 12gm of pollen substitute diet was consumed per colony. Maximum pollen substitute diet was consumed in natural corbicular pollen treatment (T4) i.e. 14.79gm which was followed by PAU diet (T1) i,e 12.51gm . It was observed that after 21 days of second feeding the mean consumption was reduced to 9.8gm .But from 3rd feeding onwards there was increase in pollen substitute diet in each treatments. It continued up to 4th feeding where the mean consumption was 17.3gms per colony. The maximum pollen substitute consumption was 20.89gm in natural pollen diet followed by PAU diet (15.57gm). In overall same trend was observed and maximum consumption of natural corbicular pollen diet (15.69gm) followed by PAU diet (13.28gm). It was further concluded that 31.4% natural corbicular pollen was consumed followed by 26.6% in PAU diet, 25.1% in GBPAUT , 25% in OUAT diet and 24.2% in YSPUHF diet.

Nabors (2000) reported that consumption of pollen substitute diet decreased as pollen became available in nature As per Free and williams (1971) the provision of pollen substitute diet inside the bee colonies reduce the bees instinct for pollen collection from the fields and bees returned to the hive with lighter load., Ram C. Sihag and Manisha Gupta (2013) observed that strength of a colony was directly proportional to the brood rearing since strong colonies always reared more broods in the colony.

5. 2. 1 Effect of pollen substitute diet on foraging activity of nectar forager

Before feeding of pollen substitute to different colonies the mean nectar forager was almost similar and the mean was 3.61 per 5 minutes. It was also observed that maximum forager was in morning followed by evening hours (3.79 to 3.83) .

After feeding of pollen substitute diet the mean nectar forager number went on increasing and even continue up to 4th feeding (4.22 to 6.42). But after 1st feeding onwards the nectar foragers increased in morning hour than noon and afternoon hour. When the overall treatments were observed it was found that the maximum nectar forager (7.09) was in corbicular pollen fed treatment (T4) which was significantly higher (6.44) than PAU diet T1. Similarly the maximum nectar forager was observed in morning hour (6.58) followed by in afternoon hour (5.36). Also it was observed that after feeding of pollen substitute diet there was increasing of nectar forager in all treatments up to 4th feeding.

The commencement of flight was delayed after the summer, and bees also stopped feeding earlier in the rainy, autumn, and winter seasons, (Cherian et al., 1947 and Subbareddy et al., 1980.)

5. 2. 2 Effect of pollen substitute diet on foraging activity of pollen forager

Before feeding of pollen substitute the pollen forager count was almost uniform and the mean was 3.39. It was indicated that after feeding of pollen substitute the mean forager was gradually increased and it continued up to 4th feeding (4.25 to 5.25). Further it was observed that in all the treatments except the control treatment there was increase in pollen forager number. It indicated that there was no sufficient natural pollen, so by providing the pollen substitute the number of pollen forager increased in number. Further in overall it was found that maximum forager (6.61) recorded in corbicular pollen fed colonies (T4) which is significantly higher (4.96) than PAU diet

(T1). Minimum pollen forager (3.19) was recorded in only sugar solution diet treatments (T6). Further it was observed that maximum pollen forager was recorded in morning hours in all the dates recorded followed by evening hours and noon hours. It was also reported that in all the period of observation the pollen forager was maximum in morning hours. In overall it was observed that maximum pollen forager in morning hours (5.47) followed by evening hours (5.07) and noon hours (3.58). Similar trend was observed in all the treatments i.e. maximum in morning hour followed by evening and noon hour. Mattu and verma (1985) reported that in the rainy season, because of continuous monsoon and foggy weather, the percentage of bees leaving the hive was low, whereas, in the winter, foraging activity may be at its lowest due to scarcity bee flora and low ambient temperature.

5. 3. Assessment of economics of pollen substitute diet:

Feeding with different pollen substitute enhanced all the yield attributing traits resulting in higher honey production thereby giving a return of Rs 600-800/- per hive excepting in the diet developed by YSPUHF diet. From the cost point of view PAU diet was more remunerative followed by the diet developed by OUAT which may be recommended for use by the beekeeper. The present finding is supported by the author Doull, 1975b, Ram C. Sihag and Manisha Gupta, 2013

SUMMARY AND CONCLUSION

Field experiment on the Impact of some pollen substitute diet on colony performance, foraging activity and economics of Indian hive bee, *Apis cerana indica* Fab in Odisha have been under taken during 2020 at AICRP on Honeybees and Pollinators, College of Agriculture, OUAT, Bhubaneswar.

Twenty four colony were selected and was laid in RBD with six treatments and four replication. Twenty colonies were fed with 50gm of different pollen substitute diets prepared as per specification collected from different Agricultural university AICRP Centres (PAU diet, YSPUHF diet, GBPUT diet, OUAT diet and one natural pollen) and four colonies were fed with 50% sugar solution (1:1) as control treatment. The pollen substitute diet and sugar solution was given four times at an interval of 21 days.

The consumption of different pollen substitute diet was weighed after 2^{nd} ,7^{th} and 10^{th} day of application and colony performance(brood area, pollen area, nectar store area and bee strength)was observed at 21days interval. The foraging activities (nectar forager and pollen forager bees per 5mins) were recorded at weekly interval after each feeding. The economics of pollen substitute diet was calculated after completion of the experiment.

Studies on the effect of pollen substitute diet indicated that the brood area went on increasing up to the 4^{th} feeding in each treatment except the control treatment where the brood area remain same after 1^{st} feeding but it increased later i.e., after 2^{nd} feeding and continue up to 4^{th} feeding. It was found that maximum brood area(403.44 cm^2) was observed in corbicular pollen fed colonies(T4) which was at par (393.44cm^2) in colonies fed with PAU diet (T1).The minimum brood area (329.52cm^2) was observed in control treatment(T6).

The effect of Pollen substitute diet on honey store area revealed that the honey store area increased after 1^{st} feeding and it continued up to 4^{th} feeding in corbicular pollen feeding (T4), PAU pollen substitute (T1) and OUAT pollen substitute(T5) where as in control treatments it was first decreased(52.25cm^2) then it gradually increased , Maximum honey store area(142.19) was recorded in corbicular pollen fed treatments which is significantly higher than any other treatments. Among other treatments the

PAU substitute was second (122.83cm^2) where as it was minimum (98.25cm^2) in control treatment.

As regards the pollen store area it was observed that there was an increase in pollen store area after 1st feeding of pollen substitute diet in all the treatments except YSPUHF diet(T2), GBPUT diet (T3) and control plot(72.75cm^2, 52.25 cm^{2}and 79cm^2) where as it increased in all the treatments after 2nd feeding of pollen substitute diet . The maximum pollen substitute diet was recoded in corbicular pollen feed colony(16.50 cm^2) and minimum pollen store area (8.19 cm^2) was recorded in control plot.

When considering the bee strength it was observed that bee strength increases after 1st feeding and continues up to 4th feeding in all treatments except the control plot where after 1st feeding it was decreased but then went on increasing up to 4th feeding. It was observed that maximum bee strength (5.75) in corbicular pollen substitute diet and minimum bee strength (3.13) was recorded in control treatments.

When the consumption of different pollen substitute diet was tested it was observed that a range of 12.11 gm to 15.69 gm of pollen substitute was consumed per colony by each treatment. Further it was concluded that maximum of 31.4 % pollen substitute of natural corbicular pollen was consumed followed by PAU diet (26.6 %), GBPUAT diet (25.1%), OUAT diet (25.0%) and YSPUHF diet (24.2 %).

When the activity of incoming nectar forager observed it was observed that number of nectar forager went on increasing from (3.61 to 6.42) 1st to 4th pollen substitute feeding. The maximum nectar forager member (7.09) was recorded in corbicular pollen substitute diet and minimum (4.45) was recorded in control treatment. As regards time of nectar forager it was revealed that maximum pollen forager (6.58) was recorded in morning hour followed by evening hour(5.38) and noon hour(4.55)

Observation on foraging activity of incoming pollen foragers went on increasing in all the treatments from 1st feeding to 4th feeding except in control where the pollen forager activity was irregular. Maximum pollen forager (6.61) was recorded in corbicular pollen feed colony and minimum (3.19) was observed in control treatment. However, while observing the timing of pollen forager it was observed maximum pollen forager (5.88) was recorded in morning hour followed by evening hour (3.63) and noon hour (2.06).

Study on the effect of pollen substitute diet on honey yield indicated that feeding with pollen substitute diet enhanced all the yield attributing traits resulting in higher honey production and giving a return of Rupees 600 to 800 excepting in the diet of YSPUHF. Though maximum return obtained from both corbicular feeding and PAU diet but from cost point of view the PAU diet was more remunerative followed by OUAT diet. . The low honey yield was received as it was harvested at the end of the experiment in December which was cold month unsuitable for bees.

Thus it was concluded that maximum colony performance attribute and foraging activity is obtained if the pollen substitute diet is fed to the colony in dearth period. Therefore profitability can be achieved by providing pollen substitute diet particularly in rainy season.

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