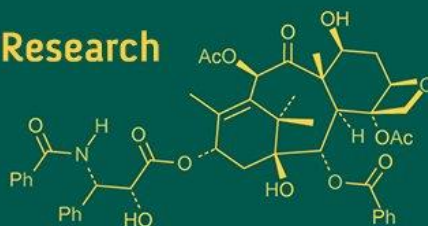


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Effect of multi-seasonal pollen substitute feeding on foraging behaviour of *Apis cerana indica* (Fabricius)

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Abstract

The study evaluated the effect of different pollen substitute diets on the foraging behaviour of *Apis cerana indica* under dearth and honey flow conditions during 2022-23 and 2023-24 at the apiary of AICRP on Honey Bees and Pollinators, OUAT, Bhubaneswar. Seven treatments were tested in a Completely Randomized Design using standardized colonies. Results showed that pollen substitute feeding significantly increased pollen foraging activity over control. The Solan diet (T₃) consistently recorded the highest number of pollen foragers, reaching 8.78-9.00 foragers/2 min during dearth (first feeding) and increasing to 15.89-16.33 foragers/2 min during honey flow (third feeding). In contrast, control colonies showed markedly lower activity (2.33-3.00 and 8.78-9.89 foragers/2 min, respectively). Intermediate responses were observed in PAU (T₁: 7.89-11.56) and Pantnagar (T₂: 5.67-10.33) diets, while the OUAT diet (T₄) showed moderate performance (4.56-8.44 foragers/2 min). Repeated feeding enhanced foraging intensity across the treatments indicated cumulative nutritional benefits. Seasonal variation was evident, with higher foraging during honey flow than dearth periods. The findings demonstrate that nutritionally balanced pollen substitutes, particularly the Solan diet, significantly improve foraging efficiency and colony performance, providing an effective strategy for sustaining honey bee colonies during floral scarcity.

Keywords: *Apis cerana indica*, pollen substitute, foraging behaviour, dearth period, Honey flow, colony performance

1. Introduction

Honeybees represent one of the most advanced forms of eusocial insects, characterized by a highly coordinated division of labour and complex communication systems. Their ecological and economic importance is immense, as they contribute to biodiversity conservation while simultaneously supporting agricultural productivity. Historical records and ancient literature have long acknowledged the value of honeybees, emphasizing their role in sustaining both natural ecosystems and human livelihoods (Mishra, 1995) [9].

Among the various services provided by honeybees, pollination remains the most valued, contributing significantly to agricultural productivity and ecosystem stability (Klein *et al.*, 2007) [6]. In addition to producing valuable hive products such as honey, royal jelly, propolis and bee bread, honeybees facilitate the reproduction of a vast number of flowering plants (Potts *et al.*, 2016) [15]. Nectar serves as the principal energy source for adult bees, whereas pollen supplies essential nutrients including proteins, amino acids, lipids, vitamins and minerals required for brood development and colony maintenance (Brodshneider and Crailsheim, 2010) [3]. The availability of these floral resources, however, is highly variable and dependent on plant species composition and seasonal changes (Paray *et al.*, 2021) [14]. While some plants provide only nectar or pollen, many serve as dual sources, supporting the nutritional needs of bee colonies (Wright *et al.*, 2018) [24].

Globally, a significant proportion of food production relies on insect pollination, with honeybees playing a dominant role. It is estimated that a majority of major crop species depend, either directly or indirectly, on bee-mediated pollination, which enhances not only yield but also quality attributes such as size, uniformity and shelf life (UNEP, 2010) [20]. In the Indian context, *Apis cerana indica* is a key indigenous species adapted to diverse agro-climatic conditions, making it particularly suitable for traditional and small-scale beekeeping systems (Koetz, 2013; Radloff *et al.*, 2010) [7, 9].

Although *Apis mellifera* has expanded commercial apiculture, *A. cerana indica* continues to be indispensable due to its resilience and ecological compatibility.

A major constraint in beekeeping is the occurrence of seasonal dearth periods, during which the availability of nectar and pollen declines sharply (Brodschneider and Crailsheim, 2010; Paray *et al.*, 2021) [7, 14]. Such scarcity adversely affects colony strength, brood rearing and overall foraging efficiency, often leading to reduced productivity and, in extreme cases, absconding of colonies (Neumann and Carreck, 2010) [10]. To mitigate these challenges, supplementary feeding practices are commonly adopted. While carbohydrate feeding through sugar solutions resolves the immediate energy requirements of adult bees, it does not fulfil the protein demands essential for larval growth and colony development (DeGrandi-Hoffman *et al.*, 2015; Wright *et al.*, 2018) [4, 24].

In this context, pollen substitutes have emerged as an important nutritional intervention to bridge the gap during periods of pollen deficiency. These artificial diets are designed to mimic the nutritional composition of natural pollen and have been reported to improve brood production, colony population and subsequent honey yield when provided during resource-scarce periods (Woyke, 1976; Kumar and Agrawal, 2014; Shehata, 2016; Abd El-Wahab *et al.*, 2016) [23, 8, 17, 1]. Enhanced colony strength resulting from such feeding strategies can also influence foraging behaviour by increasing the number of active foragers and improving resource collection efficiency.

However, the effectiveness of pollen substitutes may vary depending on their composition and the season in which they are provided. Seasonal changes influence both colony requirements and environmental conditions, thereby affecting the behavioural responses of foraging bees. Despite the recognized importance of nutritional supplementation, there is limited systematic information on how different pollen substitutes influence foraging intensity and resource collection patterns across seasons in *Apis cerana indica* (Radloff *et al.*, 2010) [16].

Therefore, the present study was undertaken to evaluate the effect of multi-seasonal feeding of different pollen

substitutes on foraging intensity and resource collection patterns in *Apis cerana indica*, with the aim of developing effective nutritional strategies for improving colony performance under varying seasonal conditions.

2. Materials and Methods

2.1 Experimental site and duration

The present investigation was carried out during the years 2022-23 and 2023-24 under stationary beekeeping conditions at the apiary of the AICRP on Honey Bees and Pollinators, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha. The study location represents a tropical climatic condition with distinct seasonal variations influencing floral availability. The experiment was conducted across different seasons, including dearth and flowering periods, to evaluate seasonal variation in foraging response.

2.2 Experimental design and colony standardization

The experiment was conducted following a Completely Randomized Design (CRD), wherein different pollen substitute diets were considered as treatments and each treatment was replicated using uniform and healthy colonies of *Apis cerana indica*. The experiment consisted of seven treatments with three replications. The experimental colonies were maintained in standard ISI A-type-2 wooden hives following recommended apicultural practices.

Prior to the initiation of the study, all experimental colonies were standardized based on key parameters including adult bee population, brood area, queen status (ensuring the presence of an actively laying queen) and available food reserves. Only colonies exhibiting comparable strength and uniformity were selected for the experiment to minimize variation and ensure reliability of the results.

2.3 Preparation and composition of pollen substitute diets

Different pollen substitute diets were formulated using locally available ingredients such as protein sources, carbohydrate sources and additives. The composition of the selected diets is presented in Table 1.

Table 1: Simplified composition of pollen substitute diets

Treatment (Diet Source)	Composition	Quantity per hive
T ₁ (PAU diet)	Brewer's yeast (41.8 g) + Skimmed milk powder (4 g) + Dehusked parched gram (4.2 g) + Sugar solution (Sugar : water 13:12, w/w) (50 ml)	50 g
T ₂ (Pantnagar diet)	Brewer's yeast (12.5 g) + Skimmed milk powder (18.75 g) + Soya bari flour (18.75 g) + Honey (50 g)	50 g
T ₃ (Solan diet)	Brewer's yeast (100 g) + Wheat flour (150 g) + Soya bari flour (150 g) + Dark rum (20 ml) + Sugar Solution (Sugar: Water 2:1) (400 ml)	50 g
T ₄ (OUAT diet)	Brewer's yeast (5 g) + Soya bari flour (60 g) + Honey (35 g) + Multivitamin (1 ml)	50 g
T ₅ (Proteinex diet)	Proteinex powder @ 2 g per 10 ml sugar syrup (1:1)	200 ml
T ₆ (Corbicular pollen diet)	Corbicular pollen + sugar syrup (1:1) in 1:0.5 ratio	50 g
T ₇ (Control)	No supplementary diet	—

2.4 Feeding of experimental colonies

The prepared pollen substitute diets were provided to respective colonies in the form of soft patties placed over the brood frames. Feeding was carried out during dearth periods across different seasons to assess multi-seasonal effects. Fresh diets were supplied at regular intervals to ensure continuous availability of supplemental nutrition.

2.5 Observation on foraging activity

Foraging behaviour was assessed by recording foraging intensity in terms of pollen and nectar foragers. Observations were made at 1, 3, 5, 7 and 9 days after feeding the pollen substitute diets. The number of incoming bees at the hive entrance was counted by distinguishing pollen foragers, identified by visible pollen loads in their corbicula and nectar foragers, identified by the absence of

pollen loads. Counts were recorded for duration of 2 minutes using a stopwatch at four time intervals of the day, namely 07:00-08:00 hrs, 09:00-10:00 hrs, 11:00-12:00 hrs and 15:00-16:00 hrs. Observations were conducted by standing near the hive entrance ensuring minimal disturbance to the colonies. All observations were recorded under similar weather conditions on clear days to minimize environmental bias.

2.6 Data recording and parameters studied

The parameters were systematically recorded to quantify foraging responses, namely the number of pollen foragers (per 2 min) and total pollen foraging activity. In addition, diurnal variation in pollen foraging behaviour was assessed across defined observation periods within a day and seasonal variation in pollen foraging response was evaluated to determine the influence of pollen substitute feeding under varying environmental conditions.

2.7 Statistical analysis

The experimental data were analysed using Completely Randomized Design (CRD). Mean values were calculated and treatment comparisons were performed using standard statistical procedures. All statistical analyses were carried out using Microsoft Excel (MS Excel). Where required, appropriate data transformations were applied to normalize the data and statistical parameters such as standard error (SE) and critical difference (CD) were computed for comparison of treatment means.

3. Results and Discussion

3.1 Foraging response of *Apis cerana indica* to different pollen substitutes following first feeding under dearth conditions (2022-23 and 2023-24)

The data presented in Table 2 revealed that pollen substitute feeding markedly influenced the foraging activity of *Apis cerana indica* under dearth conditions during both years. Among the treatments, T₃ (Solan pollen substitute) consistently recorded the highest number of incoming pollen foragers (8.78 and 9.00 at 3 DAFF during forenoon in 2022-23 and 2023-24, respectively), followed by T₁ (7.89 and 8.33) and T₂ (5.67 and 7.00) at the same interval. At 5 DAFF, T₃ again registered higher foraging activity (7.78 and 7.89), followed by T₁ (7.22 and 8.11) and T₂ (5.89 and 6.89). A declining trend was observed thereafter, with T₃ maintaining relatively higher values at 7 DAFF (7.22 and 7.33) and 9 DAFF (6.67 and 6.67). The lowest number of pollen foragers was consistently recorded in T₇ (control) across all intervals (2.33 and 3.00 at 1 DAFF, declining to 1.00 and 0.67 at 9 DAFF). The OUAT diet (T₄) showed comparatively lower acceptance by bees, as reflected in reduced pollen foragers (4.56 and 5.78 at 3 DAFF; 3.89 and 4.00 at 5 DAFF; and 3.44 and 3.00 at 9 DAFF) compared to T₁, T₂ and T₃. Across all treatments, foraging activity was generally higher during forenoon than afternoon periods.

The present findings are in agreement with Thapa and Pokhrel (2005) [18], who reported enhanced foraging activity with nutritionally enriched diets and with Pande *et al.* (2011) [13] and Vijayakumari *et al.* (2021) [22], who emphasized the importance of protein-rich and well-balanced pollen substitutes in stimulating foraging behaviour compared to less acceptable or nutritionally inferior diets.

3.2 Foraging response of *Apis cerana indica* to different pollen substitutes following second feeding under dearth conditions (2022-23 and 2023-24)

The data presented in Table 3 indicated that second feeding of pollen substitutes further enhanced the foraging activity of *Apis cerana indica* under dearth conditions during both years. Among the treatments, T₃ (Solan pollen substitute) recorded the highest number of incoming pollen foragers (11.11 and 11.00 at 1 DASF and 10.89 and 11.89 at 3 DASF during forenoon in 2022-23 and 2023-24, respectively), followed by T₁ (10.67 and 11.00) and T₂ (9.33 and 10.33) at 3 DASF. At 5 DASF, T₃ maintained higher activity (9.78 and 10.22), closely followed by T₁ (9.56 and 10.22) and T₂ (7.89 and 9.44). A gradual decline was observed towards 9 DASF; however, T₃ continued to register comparatively higher values (7.44 and 8.56) followed by T₁ (7.67 and 8.67) and T₂ (5.89 and 7.78). The lowest number of pollen foragers was consistently recorded in T₇ (control) (3.33 and 3.89 at 1 DASF declining to 0.67 and 2.00 at 9 DASF). The OUAT diet (T₄) showed comparatively lower acceptance (7.78 and 8.44 at 3 DASF and 4.44 and 6.33 at 9 DASF) than T₁, T₂ and T₃. Foraging activity was generally higher during forenoon than afternoon across treatments.

These findings are supported by Usha *et al.* (2014) [21], who reported higher foraging activity in colonies fed with protein-rich diets, particularly soybean-based formulations. Similar results were observed by Ullah *et al.* (2021) [19], who reported increased returning foragers in colonies receiving nutritionally enriched diets compared to control. Further, Ahmad *et al.* (2021) [1] demonstrated that balanced pollen substitute diets significantly enhanced pollen foraging activity, highlighting the role of diet composition in regulating foraging behaviour during dearth periods.

3.3 Foraging response of *Apis cerana indica* to different pollen substitutes following third feeding under dearth conditions (2022-23 and 2023-24)

The data presented in Table 4 revealed that pollen substitute feeding after third feeding significantly influenced the foraging activity of *Apis cerana indica* under dearth conditions during both years. Among the treatments, T₃ (Solan pollen substitute) recorded the highest number of incoming pollen foragers (9.33 and 10.33 at 1 DATF and 10.22 and 10.44 at 3 DATF during forenoon in 2022-23 and 2023-24, respectively), closely followed by T₁ (10.11 and 10.22) and T₂ (8.22 and 9.44) at 3 DATF. At 5 DATF, T₃ maintained higher foraging activity (10.22 and 10.11) followed by T₁ (9.78 and 10.00) and T₂ (8.44 and 9.22). A gradual decline in foraging activity was observed towards 9 DATF; however, T₃ continued to exhibit relatively higher values (7.00 and 7.67) followed by T₁ (6.67 and 7.67) and T₂ (5.33 and 6.67). The lowest number of pollen foragers was consistently recorded in T₇ (control) throughout the observation period (3.33 and 3.89 at 1 DATF declining to 1.33 and 1.67 at 9 DATF). The OUAT diet (T₄) showed comparatively lower foraging activity (7.00 and 7.22 at 3 DATF and 3.67 and 5.00 at 9 DATF) compared to T₁, T₂ and T₃. Across all treatments, foraging activity was generally higher during forenoon than afternoon periods in both years.

3.4 Foraging response of *Apis cerana indica* to different pollen substitutes following first feeding during honey flow period (2022-23 and 2023-24)

The data presented in Table 5 revealed that pollen substitute feeding during the honey flow period significantly

influenced the foraging activity of *Apis cerana indica* during both years of study. Among the treatments, T₃ (Solan pollen substitute) recorded the highest number of incoming pollen foragers (11.56 and 11.67 at 3 DAFF during forenoon in 2022-23 and 2023-24, respectively), followed by T₁ (10.56 and 10.44) and T₂ (9.22 and 8.89). At 5 DAFF, T₃ maintained higher foraging activity (10.11 and 10.11) followed by T₁ (9.44 and 9.67) and T₂ (8.11 and 8.33). A declining trend was observed towards 9 DAFF; however, T₃ continued to show relatively higher values (5.33 and 7.33) followed by T₁ (6.67 and 7.22) and T₂ (6.44 and 6.78). The lowest number of pollen foragers was consistently recorded in T₇ (control) (3.22 and 3.44 at 1 DAFF declining to 1.00 and 1.33 at 9 DAFF). The OUAT diet (T₄) showed comparatively lower foraging activity (7.44 and 7.89 at 3 DAFF and 3.33 and 5.00 at 9 DAFF) than T₁, T₂ and T₃. Across all treatments, foraging activity was generally higher during forenoon than afternoon periods.

3.5 Foraging response of *Apis cerana indica* to different pollen substitutes following second feeding during honey flow period (2022-23 and 2023-24)

The data presented in Table 6 indicated that pollen substitute feeding during the honey flow period after second feeding significantly influenced the foraging activity of *Apis cerana indica* during both years. Among the treatments, T₃ (Solan pollen substitute) recorded the highest number of incoming pollen foragers (12.44 and 11.89 at 3 DASF during forenoon in 2022-23 and 2023-24, respectively), followed by T₁ (11.56 and 11.22) and T₂ (10.11 and 10.11). At 5 DASF, T₃ maintained higher foraging activity (11.00 and 10.67) followed by T₁ (10.78 and 10.56) and T₂ (9.33 and 9.11). A gradual decline was observed towards 9 DASF; however, T₃ continued to exhibit relatively higher values (8.67 and 9.78) followed by T₁ (8.78 and 10.22) and T₂ (8.00 and 9.00). The lowest number of pollen foragers was consistently recorded in T₇ (control) (4.67 and 4.11 at 1 DASF and 4.67 and 5.00 at 9 DASF). The OUAT diet (T₄) showed comparatively lower foraging activity (8.56 and 8.56 at 3 DASF and 6.67 and 7.67 at 9 DASF) compared to T₁, T₂ and T₃. Across all treatments, foraging activity was generally higher during forenoon than afternoon periods.

3.6 Foraging response of *Apis cerana indica* to different pollen substitutes following third feeding during honey flow period (2022-23 and 2023-24)

The data presented in Table 7 revealed that pollen substitute feeding during the honey flow period after third feeding further enhanced the foraging activity of *Apis cerana indica* during both years. Among the treatments, T₃ (Solan pollen substitute) recorded the highest number of incoming pollen foragers (15.89 and 13.89 at 3 DATF and 16.00 and 14.33 at 5 DATF during forenoon in 2022-23 and 2023-24, respectively), followed by T₁ (13.56 and 12.11) and T₂ (12.44 and 11.56). At 7 DATF, T₃ maintained higher activity (16.11 and 15.67) followed by T₁ (14.22 and 12.89) and T₂ (12.56 and 11.89). At 9 DATF, T₃ continued to show the highest foraging (16.33 and 16.00) followed by T₁ (14.89 and 13.78) and T₂ (13.11 and 12.78). The lowest number of pollen foragers was consistently recorded in T₇ (control) throughout the observation period (6.67 and 6.11 at

1 DATF and 9.00 and 8.67 at 9 DATF). The OUAT diet (T₄) exhibited comparatively lower foraging activity (11.33 and 10.67 at 3 DATF and 11.00 and 10.33 at 9 DATF) than T₁, T₂ and T₃. Across all treatments, foraging activity was generally higher during forenoon than afternoon periods.

The present investigation clearly demonstrated that pollen substitute feeding significantly enhanced pollen foraging activity of *Apis cerana indica* under both dearth and honey flow conditions, with consistent superiority of the Solan diet (T₃) across successive feedings. The progressive increase in foraging response from first to third feeding indicates a cumulative nutritional effect, likely mediated through improved brood rearing and increased worker population, which in turn enhances foraging intensity. This trend aligns with established knowledge that pollen-derived protein is essential for hypopharyngeal gland development and brood nourishment, ultimately regulating colony-level foraging dynamics, as nutritional physiology directly governs division of labour and foraging behaviour in honey bees (Wright *et al.*, 2018; Nicolson *et al.*, 2018)^[24, 11].

The superior performance of T₃ may be attributed to its balanced composition of brewer's yeast, soybean flour and wheat, which likely provided a more optimal amino acid profile, digestibility and palatability. Diet palatability and consumption are critical determinants of colony response, as demonstrated by studies showing that nutritionally balanced pollen substitutes are consumed at rates comparable to natural pollen and significantly improve brood and adult bee populations (DeGrandi-Hoffman *et al.*, 2008)^[5]. Furthermore, the importance of protein quality and diet composition in influencing colony growth, physiological status and foraging behaviour has been widely emphasized in recent reviews (Paray *et al.*, 2021)^[14].

The observed enhancement in foraging activity following repeated feeding cycles suggests that sustained nutritional supplementation strengthens colony fitness over time. This is consistent with findings of DeGrandi-Hoffman *et al.*, 2015^[4], that improved nutrition increases haemolymph protein levels, gland development and worker longevity, thereby promoting greater foraging efficiency. Additionally, seasonal variation observed in the study reflects the strong interaction between nutritional availability and environmental conditions, as pollen scarcity during dearth periods is a major limiting factor for colony performance (Noordyke and Ellis, 2021)^[12].

Although the OUAT-formulated diet (T₄) showed moderate improvement over control, its relatively lower acceptance compared to T₃ suggests possible limitations in protein diversity, amino acid balance, or phagostimulatory properties. Palatability, texture and nutrient composition are known to directly influence consumption and subsequent colony response and suboptimal formulations may reduce diet intake and limit physiological benefits (Noordyke and Ellis, 2021)^[12].

The findings established that nutritionally balanced, palatable pollen substitutes can effectively enhance foraging activity, with repeated feeding further amplifying colony performance. The consistent superiority of T₃ highlights the importance of diet composition in designing efficient pollen substitutes for sustainable beekeeping.

Table 2: Effect of pollen substitutes on foraging behaviour of *Apis cerana indica* during the dearth period after first feeding (2022-23 and 2023-24)

Treatments	Number of Incoming pollen foragers/2 minute at hive entrance																			
	1 DAFF				3 DAFF				5 DAFF				7 DAFF				9 DAFF			
	Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T ₁	5.67 (2.48)	6.44 (2.63)	5.00 (2.34)	5.67 (2.47)	7.89 (2.89)	8.33 (2.97)	4.67 (2.26)	5.33 (2.41)	7.22 (2.78)	8.11 (2.93)	5.00 (2.34)	5.33 (2.40)	6.89 (2.71)	7.11 (2.76)	5.00 (2.34)	5.33 (2.41)	5.44 (2.43)	5.89 (2.53)	3.33 (1.93)	4.67 (2.27)
T ₂	4.67 (2.27)	6.56 (2.65)	3.33 (1.95)	5.00 (2.32)	5.67 (2.48)	7.00 (2.74)	3.67 (2.03)	3.67 (2.03)	5.89 (2.53)	6.89 (2.72)	4.00 (2.11)	4.67 (2.27)	6.11 (2.57)	6.22 (2.58)	4.67 (2.26)	5.00 (2.34)	4.33 (2.20)	5.56 (2.46)	2.33 (1.64)	4.33 (2.20)
T ₃	7.11 (2.75)	8.22 (2.95)	4.00 (2.11)	7.00 (2.73)	8.78 (3.05)	9.00 (3.08)	6.67 (2.67)	7.00 (2.73)	7.78 (2.87)	7.89 (2.89)	6.00 (2.54)	6.33 (2.60)	7.22 (2.78)	7.33 (2.80)	6.00 (2.53)	5.33 (2.40)	6.67 (2.68)	6.67 (2.67)	5.00 (2.32)	5.00 (2.32)
T ₄	4.33 (2.20)	4.67 (2.27)	3.33 (1.93)	4.00 (2.11)	4.56 (2.24)	5.78 (2.51)	3.33 (1.95)	3.33 (1.93)	3.89 (2.09)	4.00 (2.12)	2.67 (1.76)	3.00 (1.86)	3.56 (2.00)	3.67 (2.03)	2.67 (1.76)	2.67 (1.74)	3.44 (1.98)	3.00 (1.87)	1.33 (1.29)	2.33 (1.64)
T ₅	4.00 (2.12)	4.78 (2.29)	3.00 (1.86)	3.67 (2.04)	3.56 (2.01)	4.33 (2.19)	2.33 (1.68)	3.00 (1.86)	3.78 (2.07)	4.22 (2.17)	2.33 (1.66)	2.67 (1.77)	3.22 (1.93)	3.22 (1.93)	2.33 (1.66)	2.67 (1.77)	3.56 (2.00)	2.89 (1.84)	2.00 (1.56)	2.00 (1.56)
T ₆	3.11 (1.90)	3.67 (2.02)	2.33 (1.68)	3.00 (1.86)	3.44 (1.99)	3.78 (2.07)	2.33 (1.68)	2.67 (1.77)	3.11 (1.90)	3.89 (2.09)	2.00 (1.56)	2.33 (1.68)	2.89 (1.84)	3.00 (1.86)	2.00 (1.56)	2.33 (1.68)	1.78 (1.50)	2.11 (1.62)	1.33 (1.34)	1.33 (1.34)
T ₇	2.33 (1.68)	3.00 (1.87)	1.67 (1.44)	2.67 (1.74)	2.89 (1.84)	2.56 (1.75)	1.67 (1.46)	2.33 (1.68)	2.67 (1.78)	2.11 (1.61)	1.33 (1.34)	1.67 (1.46)	2.00 (1.58)	1.67 (1.46)	1.33 (1.34)	1.00 (1.17)	1.11 (1.27)	1.00 (1.22)	1.00 (1.22)	0.67 (1.05)
SE _{(m)±}	0.107	0.098	0.165	0.193	0.071	0.080	0.107	0.134	0.073	0.084	0.167	0.125	0.100	0.117	0.171	0.183	0.111	0.070	0.205	0.168
CD _(5%)	0.329	0.303	0.509	0.593	0.218	0.247	0.329	0.414	0.224	0.260	0.515	0.385	0.307	0.360	0.526	0.565	0.341	0.214	0.631	0.518

T₁-PAU Pollen Substitute; T₂-Pantnagar Pollen Substitute; T₃-Solan Pollen Substitute; T₄-OUAT Pollen Substitute; T₅-Proteinex; T₆-Corbicular Pollen; T₇-Control

*Values in parentheses are $\sqrt{x} + 0.5$ transformed values

DAFF-Days after first feeding

Table 3: Effect of pollen substitutes on foraging behaviour of *Apis cerana indica* during the dearth period after second feeding (2022-23 and 2023-24)

Treatments	Number of Incoming pollen foragers/2 minute at hive entrance																			
	1 DASF				3 DASF				5 DASF				7 DASF				9 DASF			
	Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T ₁	9.33 (3.13)	10.78 (3.35)	7.00 (2.73)	8.00 (2.91)	10.67 (3.34)	11.00 (3.39)	8.33 (2.96)	9.33 (3.11)	9.56 (3.17)	10.22 (3.27)	7.00 (2.73)	9.33 (3.13)	8.33 (2.97)	9.78 (3.20)	7.67 (2.85)	8.67 (3.01)	7.67 (2.86)	8.67 (3.02)	6.00 (2.54)	7.00 (2.73)
T ₂	7.89 (2.89)	9.44 (3.15)	5.33 (2.41)	7.00 (2.73)	9.33 (3.13)	10.33 (3.29)	5.67 (2.47)	9.67 (3.16)	7.89 (2.90)	9.44 (3.15)	5.00 (2.32)	8.33 (2.95)	7.11 (2.75)	8.78 (3.04)	5.00 (2.32)	7.67 (2.83)	5.89 (2.53)	7.78 (2.88)	4.33 (2.20)	6.67 (2.67)
T ₃	11.11 (3.40)	11.00 (3.39)	5.67 (2.46)	8.00 (2.89)	10.89 (3.37)	11.89 (3.52)	8.67 (3.02)	10.33 (3.29)	9.78 (3.21)	10.22 (3.27)	6.00 (2.54)	9.33 (3.13)	8.44 (2.99)	9.67 (3.19)	5.67 (2.48)	9.00 (3.08)	7.44 (2.82)	8.56 (3.01)	4.67 (2.27)	7.33 (2.79)
T ₄	7.11 (2.76)	7.44 (2.81)	2.67 (1.77)	6.67 (2.67)	7.78 (2.88)	8.44 (2.99)	5.00 (2.34)	7.33 (2.78)	6.44 (2.63)	7.89 (2.89)	4.33 (2.18)	7.00 (2.72)	6.22 (2.55)	7.00 (2.74)	4.00 (2.11)	6.00 (2.53)	4.44 (2.22)	6.33 (2.61)	1.67 (1.39)	5.00 (2.32)
T ₅	5.78 (2.49)	5.89 (2.52)	3.00 (1.86)	5.33 (2.39)	6.11 (2.57)	7.00 (2.74)	5.33 (2.40)	6.33 (2.61)	4.67 (2.27)	6.11 (2.57)	3.00 (1.81)	5.33 (2.38)	4.33 (2.20)	5.67 (2.48)	3.00 (1.81)	5.00 (2.32)	3.78 (2.07)	5.00 (2.33)	2.33 (1.57)	4.33 (2.18)
T ₆	4.22 (2.17)	5.33 (2.40)	2.33 (1.68)	4.6 (2.26)	4.67 (2.27)	6.11 (2.57)	3.00 (1.86)	5.33 (2.35)	4.33 (2.20)	6.11 (2.57)	2.67 (1.74)	5.00 (2.34)	3.44 (1.98)	5.56 (2.46)	2.33 (1.66)	4.67 (2.27)	2.78 (1.81)	4.33 (2.18)	1.33 (1.29)	4.00 (2.06)
T ₇	3.33 (1.95)	3.89 (2.09)	1.67 (1.46)	3.00 (1.86)	3.67 (2.03)	4.78 (2.30)	2.33 (1.68)	4.33 (2.19)	2.67 (1.77)	4.11 (2.13)	1.67 (1.46)	3.00 (1.86)	2.22 (1.65)	3.56 (2.01)	1.00 (1.17)	2.67 (1.72)	1.67 (1.47)	3.00 (1.87)	0.67 (1.05)	2.00 (1.52)
SE _{(m)±}	0.123	0.122	0.165	0.169	0.076	0.072	0.097	0.242	0.083	0.118	0.214	0.213	0.074	0.079	0.208	0.236	0.048	0.111	0.255	0.247
CD _(5%)	0.378	0.375	0.507	0.521	0.235	0.222	0.300	0.745	0.254	0.363	0.658	0.657	0.229	0.243	0.642	0.728	0.246	0.341	0.786	0.762

T₁-PAU Pollen Substitute; T₂-Pantnagar Pollen Substitute; T₃-Solan Pollen Substitute; T₄-OUAT Pollen Substitute; T₅-Proteinex; T₆-Corbicular Pollen; T₇-Control

* Values in parentheses are $\sqrt{x} + 0.5$ transformed values

DASF-Days after second feeding

Table 4: Effect of pollen substitutes on foraging behaviour of *Apis cerana indica* during the dearth period after third feeding (2022-23 and 2023-24)

Treatments	Number of Incoming pollen foragers/2 minute at hive entrance																			
	1 DATF				3 DATF				5 DATF				7 DATF				9 DATF			
	Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T ₁	9.22 (3.11)	10.44 (3.31)	7.00 (2.73)	9.00 (3.07)	10.11 (3.25)	10.22 (3.27)	7.33 (2.80)	9.33 (3.12)	9.78 (3.20)	10.00 (3.24)	9.33 (3.13)	9.33 (3.12)	8.22 (2.95)	9.56 (3.17)	7.33 (2.80)	9.00 (3.07)	8.00 (2.80)	8.33 (2.97)	6.67 (2.67)	7.67 (2.83)
T ₂	8.11 (2.93)	9.44 (3.15)	6.33 (2.59)	7.67 (2.85)	8.22 (2.95)	9.44 (3.15)	6.33 (2.56)	9.00 (3.06)	8.44 (2.99)	9.22 (3.12)	7.67 (2.85)	9.00 (3.08)	7.56 (2.84)	8.44 (2.99)	6.00 (2.53)	7.67 (2.81)	6.78 (2.53)	7.44 (2.82)	5.33 (2.41)	6.67 (2.67)
T ₃	9.33 (3.13)	10.33 (3.29)	7.33 (2.80)	8.67 (3.03)	10.22 (3.27)	10.44 (3.31)	8.33 (2.95)	9.33 (3.13)	10.22 (3.27)	10.11 (3.24)	8.67 (3.02)	9.00 (3.06)	8.89 (3.06)	9.78 (3.21)	8.00 (2.91)	9.00 (3.07)	7.67 (2.91)	8.33 (2.97)	7.00 (2.73)	7.67 (2.86)
T ₄	6.11 (2.57)	7.00 (2.73)	4.00 (2.11)	6.33 (2.56)	7.00 (2.74)	7.22 (2.76)	4.00 (2.11)	6.33 (2.61)	6.00 (2.55)	6.56 (2.65)	4.67 (2.26)	5.67 (2.48)	5.78 (2.50)	6.33 (2.61)	4.33 (2.20)	5.67 (2.47)	5.11 (2.20)	5.67 (2.48)	3.67 (2.04)	5.00 (2.34)
T ₅	4.78 (2.29)	6.33 (2.61)	3.67 (2.04)	5.33 (2.41)	6.11 (2.57)	6.11 (2.57)	4.33 (2.16)	5.33 (2.39)	5.89 (2.53)	5.89 (2.52)	4.67 (2.26)	5.00 (2.32)	5.22 (2.39)	5.67 (2.48)	4.33 (2.18)	5.00 (2.32)	5.33 (2.18)	5.33 (2.40)	4.33 (2.19)	4.67 (2.27)
T ₆	4.33 (2.20)	5.33 (2.41)	3.00 (1.84)	4.67 (2.27)	4.67 (2.26)	4.89 (2.27)	3.67 (2.02)	4.00 (2.11)	4.00 (2.12)	4.44 (2.22)	3.00 (1.86)	3.67 (2.02)	3.33 (1.95)	4.33 (2.20)	2.33 (1.64)	3.67 (2.00)	3.22 (1.64)	3.67 (2.04)	2.33 (1.68)	3.00 (1.86)
T ₇	3.33 (1.95)	3.89 (2.12)	2.67 (1.74)	3.33 (1.94)	3.33 (1.95)	3.78 (2.05)	2.00 (1.56)	3.00 (1.84)	2.67 (1.77)	3.00 (1.87)	2.00 (1.56)	2.33 (1.68)	2.22 (1.65)	2.67 (1.78)	1.33 (1.27)	1.33 (1.27)	2.00 (1.27)	2.33 (1.68)	1.33 (1.34)	1.67 (1.44)
SE _{(m)±}	0.098	0.089	0.182	0.194	0.136	0.182	0.250	0.195	0.076	0.127	0.138	0.183	0.091	0.089	0.207	0.258	0.207	0.105	0.121	0.154
CD _(5%)	0.301	0.275	0.561	0.598	0.418	0.561	0.769	0.602	0.235	0.391	0.426	0.564	0.279	0.273	0.638	0.794	0.638	0.322	0.373	0.474

T₁-PAU Pollen Substitute; T₂-Pantnagar Pollen Substitute; T₃-Solan Pollen Substitute; T₄-OUAT Pollen Substitute; T₅-Proteinex; T₆-Corbicular Pollen; T₇-Control

* Values in parentheses are $\sqrt{x} + 0.5$ transformed values

DATF-Days after third feeding

Table 5: Effect of pollen substitutes on foraging behaviour of *Apis cerana indica* during the honey flow period after first feeding (2022-23 and 2023-24)

Treatments	Number of Incoming pollen foragers/2 minute at hive entrance																			
	1 DAFF				3 DAFF				5 DAFF				7 DAFF				9 DAFF			
	Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T ₁	8.11 (2.93)	8.56 (3.01)	7.67 (2.84)	8.00 (2.89)	10.56 (3.32)	10.44 (3.31)	6.67 (2.67)	9.00 (3.08)	9.44 (3.15)	9.67 (3.19)	6.33 (2.60)	8.33 (2.97)	8.11 (2.93)	8.67 (3.02)	6.00 (2.54)	7.67 (2.84)	6.67 (2.67)	7.22 (2.78)	3.00 (1.86)	6.00 (2.54)
T ₂	7.11 (2.75)	7.00 (2.74)	7.33 (2.80)	7.00 (2.73)	9.22 (3.12)	8.89 (3.06)	6.00 (2.54)	8.00 (2.90)	8.11 (2.93)	8.33 (2.97)	5.67 (2.47)	7.67 (2.86)	7.00 (2.73)	7.56 (2.84)	5.33 (2.41)	7.33 (2.79)	6.44 (2.63)	6.78 (2.70)	1.67 (1.46)	6.00 (2.54)
T ₃	8.67 (3.03)	8.89 (3.06)	8.00 (2.91)	8.33 (2.97)	11.56 (3.47)	11.67 (3.49)	7.67 (2.86)	9.33 (3.13)	10.11 (3.26)	10.11 (3.26)	7.33 (2.79)	8.33 (2.97)	8.67 (3.03)	8.67 (3.03)	6.67 (2.68)	8.00 (2.90)	5.33 (2.41)	7.33 (2.79)	4.67 (2.22)	6.67 (2.67)
T ₄	6.00 (2.55)	6.44 (2.63)	5.33 (2.41)	6.33 (2.61)	7.44 (2.82)	7.89 (2.90)	5.00 (2.34)	7.33 (2.79)	6.89 (2.72)	7.00 (2.74)	5.00 (2.34)	6.67 (2.67)	6.22 (2.59)	6.00 (2.55)	4.67 (2.27)	5.33 (2.40)	5.56 (2.46)	5.67 (2.47)	3.33 (1.93)	5.00 (2.34)
T ₅	5.22 (2.39)	5.22 (2.39)	4.67 (2.26)	5.00 (2.34)	7.33 (2.80)	7.22 (2.78)	5.00 (2.32)	6.00 (2.53)	6.44 (2.64)	6.67 (2.67)	4.33 (2.20)	5.00 (2.34)	5.78 (2.51)	6.11 (2.57)	4.00 (2.11)	4.67 (2.27)	4.44 (2.22)	5.67 (2.48)	2.67 (1.77)	4.33 (2.18)
T ₆	4.67 (2.27)	4.78 (2.29)	4.33 (2.18)	4.33 (2.19)	7.33 (2.80)	7.11 (2.76)	5.33 (2.40)	6.00 (2.54)	6.44 (2.64)	6.56 (2.65)	6.33 (2.60)	6.33 (2.60)	5.89 (2.53)	5.33 (2.42)	5.67 (2.47)	5.33 (2.40)	4.67 (2.27)	4.78 (2.30)	3.33 (1.88)	4.00 (2.10)
T ₇	3.22 (1.92)	3.44 (1.98)	3.00 (1.86)	3.00 (1.84)	4.56 (2.25)	3.67 (2.04)	2.67 (1.77)	3.33 (1.95)	3.56 (2.01)	3.33 (1.96)	2.33 (1.68)	3.00 (1.86)	2.00 (1.58)	2.33 (1.68)	1.33 (1.34)	1.67 (1.46)	1.44 (1.39)	2.00 (1.58)	1.00 (1.22)	1.33 (1.34)
SE _{(m)±}	0.075	0.084	0.163	0.184	0.081	0.057	0.159	0.158	0.031	0.090	0.142	0.120	0.078	0.073	0.111	0.140	0.080	0.084	0.243	0.160
CD _(5%)	0.233	0.260	0.503	0.566	0.249	0.175	0.489	0.458	0.096	0.278	0.437	0.369	0.241	0.224	0.341	0.432	0.246	0.258	NS	0.493

T₁-PAU Pollen Substitute; T₂-Pantnagar Pollen Substitute; T₃-Solan Pollen Substitute; T₄-OUAT Pollen Substitute; T₅-Proteinex; T₆-Corbicular Pollen; T₇-Control

* Values in parentheses are $\sqrt{x} + 0.5$ transformed values

DAFF-Days after first feeding

Table 6: Effect of pollen substitutes on foraging behaviour of *Apis cerana indica* during the honey flow period after second feeding (2022-23 and 2023-24)

Treatments	Number of Incoming pollen foragers/2 minute at hive entrance															
	1 DASF				3 DASF				5 DASF				7 DASF			
	Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T ₁	9.33 (3.13)	9.11 (3.10)	8.33 (2.67)	8.33 (2.96)	11.56 (3.47)	11.22 (3.42)	6.67 (2.67)	7.33 (2.79)	10.78 (3.36)	10.56 (3.32)	8.67 (3.02)	7.67 (2.85)	9.56 (3.17)	10.33 (3.29)	7.00 (2.73)	7.67 (2.85)
T ₂	8.11 (2.93)	7.78 (2.87)	7.67 (2.54)	7.67 (2.86)	10.11 (3.26)	10.11 (3.26)	6.00 (2.54)	6.67 (2.67)	9.33 (3.14)	9.11 (3.10)	8.00 (2.91)	7.00 (2.73)	8.44 (2.99)	8.89 (3.06)	6.33 (2.61)	7.00 (2.73)
T ₃	9.44 (3.15)	9.33 (3.13)	8.00 (2.86)	8.00 (2.91)	12.44 (3.60)	11.89 (3.52)	7.67 (2.86)	8.33 (2.96)	11.00 (3.39)	10.67 (3.34)	8.67 (3.02)	7.67 (2.83)	9.89 (3.22)	9.89 (3.22)	6.67 (2.68)	8.00 (2.89)
T ₄	6.78 (2.70)	6.67 (2.68)	5.67 (2.34)	5.67 (2.48)	8.56 (3.01)	8.56 (3.01)	5.00 (2.34)	6.33 (2.61)	7.78 (2.88)	8.00 (2.91)	6.67 (2.67)	6.00 (2.54)	7.11 (2.76)	7.67 (2.86)	6.33 (2.60)	6.33 (2.60)
T ₅	6.33 (2.61)	6.00 (2.55)	5.00 (2.32)	5.00 (2.34)	8.22 (2.95)	8.22 (2.95)	5.00 (2.32)	5.33 (2.40)	7.33 (2.80)	7.44 (2.82)	5.67 (2.45)	4.67 (2.24)	6.67 (2.68)	6.78 (2.70)	5.33 (2.41)	5.00 (2.34)
T ₆	5.22 (2.39)	5.00 (2.34)	4.33 (2.40)	4.33 (2.18)	8.22 (2.95)	7.89 (2.89)	5.33 (2.40)	5.33 (2.41)	7.33 (2.80)	7.44 (2.82)	7.33 (2.80)	6.67 (2.68)	7.44 (2.82)	7.22 (2.78)	7.00 (2.73)	7.00 (2.73)
T ₇	4.67 (2.27)	4.11 (2.14)	4.33 (2.41)	4.33 (2.18)	5.78 (2.50)	4.89 (2.32)	5.33 (2.41)	4.33 (2.20)	5.33 (2.41)	5.00 (2.35)	4.67 (2.27)	4.00 (2.11)	5.00 (2.35)	5.00 (2.34)	4.33 (2.20)	4.33 (2.19)
SE _{(m)±}	0.085	0.082	0.156	0.138	0.070	0.088	0.156	0.147	0.050	0.075	0.158	0.180	0.059	0.072	0.131	0.177
CD _(5%)	0.261	0.253	NS	0.425	0.216	0.270	NS	0.453	0.154	0.230	0.487	NS	0.181	0.223	NS	NS

T₁-PAU Pollen Substitute; T₂-Pantnagar Pollen Substitute; T₃-Solan Pollen Substitute; T₄-OUAT Pollen Substitute; T₅-Proteinex; T₆-Corbicular Pollen; T₇-Control

* Values in parentheses are $\sqrt{x + 0.5}$ transformed values

DASF-Days after second feeding

Table 7: Effect of pollen substitutes on foraging behaviour of *Apis cerana indica* during the honey flow period after third feeding (2022-23 and 2023-24)

Treatments	Number of Incoming pollen foragers/2 minute at hive entrance															
	1 DATF				3 DATF				5 DATF				7 DATF			
	Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon		Forenoon		Afternoon	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T ₁	10.44 (3.31)	10.00 (3.24)	10.33 (3.28)	9.67 (3.18)	13.56 (3.74)	12.11 (3.55)	11.67 (3.48)	11.00 (3.38)	13.78 (3.78)	11.89 (3.52)	12.67 (3.62)	11.67 (3.48)	14.22 (3.84)	12.89 (3.66)	13.00 (3.66)	13.00 (3.66)
T ₂	9.89 (3.22)	9.33 (3.13)	8.33 (2.97)	8.00 (2.91)	12.44 (3.60)	11.56 (3.47)	10.00 (3.24)	10.00 (3.24)	12.78 (3.64)	10.89 (3.37)	13.33 (3.71)	12.67 (3.62)	12.56 (3.61)	11.89 (3.52)	12.67 (3.63)	12.00 (3.53)
T ₃	11.11 (3.41)	10.56 (3.32)	9.67 (3.18)	9.00 (3.08)	15.89 (4.05)	13.89 (3.79)	10.67 (3.34)	10.33 (3.29)	16.00 (4.06)	14.33 (3.85)	14.00 (3.79)	12.33 (3.57)	16.11 (4.08)	15.67 (4.02)	13.67 (3.75)	13.33 (3.71)
T ₄	8.67 (3.03)	8.22 (2.95)	8.67 (3.02)	8.00 (2.89)	11.33 (3.44)	10.67 (3.34)	10.33 (3.28)	9.67 (3.18)	11.89 (3.52)	10.11 (3.26)	10.67 (3.33)	9.33 (3.23)	12.33 (3.58)	11.11 (3.41)	11.00 (3.39)	10.67 (3.34)
T ₅	8.11 (2.93)	7.67 (2.85)	7.67 (2.85)	7.00 (2.74)	11.56 (3.47)	9.78 (3.21)	10.33 (3.29)	9.33 (3.13)	11.67 (3.49)	10.22 (3.27)	10.00 (3.22)	9.33 (3.13)	12.11 (3.55)	10.56 (3.32)	11.33 (3.43)	10.00 (3.24)
T ₆	7.11 (2.76)	6.56 (2.66)	6.67 (2.68)	6.00 (2.54)	10.89 (3.37)	9.22 (3.12)	10.00 (3.23)	9.33 (3.13)	10.89 (3.37)	9.44 (3.15)	10.67 (3.34)	9.33 (3.13)	11.22 (3.42)	10.11 (3.26)	11.00 (3.39)	10.33 (3.29)
T ₇	6.67 (2.67)	6.11 (2.57)	5.33 (2.40)	5.00 (2.34)	8.78 (3.04)	6.78 (2.70)	7.67 (2.85)	6.33 (2.61)	9.11 (3.10)	8.11 (2.93)	8.33 (2.97)	7.00 (2.73)	9.44 (3.15)	8.44 (2.99)	8.33 (2.97)	8.00 (2.91)
SE _{(m)±}	0.073	0.083	0.153	0.115	0.086	0.056	0.128	0.086	0.060	0.050	0.190	0.150	0.065	0.058	0.134	0.133
CD _(5%)	0.224	0.257	0.473	0.355	0.265	0.173	NS	0.266	0.185	0.154	NS	0.462	0.201	0.178	0.413	0.410

T₁-PAU Pollen Substitute; T₂-Pantnagar Pollen Substitute; T₃-Solan Pollen Substitute; T₄-OUAT Pollen Substitute; T₅-Proteinex; T₆-Corbicular Pollen; T₇-Control

* Values in parentheses are $\sqrt{x + 0.5}$ transformed values

DATF-Days after third feeding

4. Conclusion

The study demonstrated that pollen substitute feeding significantly enhanced pollen foraging activity of *Apis cerana indica*, particularly under dearth conditions. The Solan diet (T₃), comprising brewer's yeast (100 g), wheat (150 g), soya bari flour (150 g), sugar syrup (2:1; 400 ml) and dark rum (20 ml), consistently showed superior performance. The OUAT diet (T₄), consisting of soya bari flour (60 g), brewer's yeast (5 g), honey (35 g) and multivitamin (1 ml), showed moderate response. Repeated feeding improved colony performance indicated the

cumulative nutritional benefits. Overall, balanced and palatable diets effectively enhance foraging activity, colony strength and productivity under varying floral conditions.

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