

**COMPARATIVE STUDIES ON THE PERFORMANCE OF
YELLOW AND BLACK COLOUR MORPHS OF *Apis
cerena indica* F. AT SIRSI, KARNATAKA**

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the
Degree of

Master of Science (Agriculture)

in

Agricultural Entomology

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DECEMBER, 2009

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1. INTRODUCTION

Honey bees are highly evolved social insects gaining greater importance as efficient pollinators in present days. Honey bees are also well known for honey and wax production. Beekeeping can play a vital role in improving crop yields besides being an additional source of income.

Beekeeping in Karnataka state is a popular and complimentary activity along with the agriculture and horticulture practices. In Karnataka, beekeeping depends mainly on Indian bee, *Apis cerana indica* (Fabricius). Another species of domesticated honey bee, *A. mellifera* which is introduced to many Indian states, is also seen in Karnataka. However, this species constitutes only a minor portion of beekeeping in the state. Karnataka had occupied third position in the country until 1990's. The Western Ghats of the state provides all required pollen and nectar sources round the year to both wild and domesticated bees, which is providing greater opportunities for beekeeping. This area is of highly reputed value in the country for beekeeping. Karnataka also offers a diversified food sources for beekeeping through both agricultural and horticultural crops. Karnataka produced about 7,50,000 kg of honey and about 6,000 kg of bees wax and also helped in pollination activity of many crops and increased the crop yields. But after 1990, the beekeeping industry collapsed due to appearance of *Thai sac brood virus* disease in a devastating manner. This largely decreased the honey production and also the interest of beekeepers. However, after passing a depression of one decade in beekeeping industry, 2000 onwards several regaining colonies of Indian bees, *Apis cerana* exhibited tolerance against the *Thai sac brood virus*. Efforts have been made in regaining the beekeeping activities and encouraging the beekeepers by several government and non government agencies. Beekeeping practice has been gaining popularity in recent days with increased opportunities for increasing the honey yield.

The Indian bee, *Apis cerana* Fab. is a predominant one in Karnataka among other species, such as *A. dorsata* Fab, *A. florea* Fab, *Trigona irridipennis* Smith, *A. mellifera* Linn. Indian honey bee, *Apis cerana* Fabricius is the base of Indian beekeeping and is widely distributed in India. The Indian honey bee, *Apis cerana* Fabr. is also distributed in Pakistan, Sri-Lanka, Malaysia, Indo-China, Philippines, China, USSR, Japan and Indonesia (Ruttner, 1988; Hepburn *et al.*, 2001). It thrives up to 2500 m above mean sea level. It has many desirable characters of biological and economic importance, which include their docile nature, less prone to the attack of parasitic mites and *nosema* disease.

Apis cerana Fabr. found in Asia has exhibited variation in morphological characteristics and geographical variations of populations. Maa (1953) recognized 11 different subspecies in his revision of *Apis cerana* group. Later in 1988, Ruttner, further reviewed and distinguished four sub species: *Apis cerana cerana* in Afghanistan, Northern Pakistan, Northern India, Northern China, Taiwan, Korea and Russia (Ussaria); *Apis cerana indica* in South East Asia and Southern India; *Apis cerana himalaya* from the Himalayan region to Yunon in China and *Apis cerana japonica* in Japan.

The sub species of *A. cerana* in Karnataka is *A. cerana indica* which again exhibits variation in morphological characteristics recognized as "colour morphs" by Oldroyd *et al.* (2006). *Apis cerana* population in Karnataka is composed of two distinct colour morphs: the yellow 'plain' morph and the black 'hill' morph. Oldroyd *et al.* (2006) established the variation between two colour morphs of Karnataka and reported that Hill morph is associated with a widely distributed mitochondrial haplotype that is present throughout the mainland populations of South East Asian *A. cerana*. In contrast, the plain morph is apparently confined to low to moderate elevations in India and Sri Lanka. Similarly in China also, *Apis cerana* can be grouped into 5 geographical races (Peng *et al.*, 1989). In Japan, genetic variations among the *Apis cerana* were also seen (Takahashi *et al.*, 2007). In Philippines four different haplotypes were found (De La Rúa *et al.*, 2000). Two distinct cavity nesting morphs of bees were collected in south Sulawesi, Indonesia (Hadisoesilo *et al.*, 1995).

Black 'Hill' morph is distributed in Uttara Kannada, Udupi, Dakshina Kannada, Chikmagalur, Shimoga, Kodagu, parts of Dharwad, Belgaum, Mysore, and Chamarajanagar

districts. Yellow 'Plain' morph of *A. cerana* bees, is restricted to Haveri, Chitradurga and parts of Dharwad districts. The two colour morphs live in different habitat with varied temperature and rainfall. Black morph is seen in moderate to high rainfall areas with low to moderate temperatures. Yellow morph is seen in areas with low rainfall and high temperature situations. In the literature there are no studies as such to compare both the colour morphs for their performance in different characters.

In view of improving and exploiting the benefits of bee keeping in Karnataka and also to find improved populations which can thrive well against disease and natural enemies, the two colour morphs need to be compared for their performance in the field level conditions. There is need to introduce the yellow 'plain' morph into hilly areas of Western Ghats, where there are larger opportunities for pollen and nectar availability. Although there are ample sources of pollen and nectar for bees in Karnataka, there are meager efforts made in developing better genetic populations of Indian honey bees.

However, there is only one long term study made at Agricultural Research Station, Sirsi regarding the introduction of yellow colour morph to Western Ghats. In the year 2000 few colonies of yellow colour morph were brought to ARS, Sirsi from neighboring district, Haveri. The performance of yellow color morphs were observed closely by professional beekeepers in Sirsi for about 8 years. The yellow plain colour morphs performed well under hill conditions and very much convinced by the beekeepers of Uttara Kannada district for their rare absconding behaviour and comparatively more docile than the native black morphs.

However, there is no systematic study of the comparison of these colour morphs under Western Ghats ecosystem and hence, study was undertaken at Agricultural Research Station, Sirsi with the following objectives.

1. To study the comparative foraging behaviour of yellow and black colour morphs of *A. cerana*.
2. To study the brood rearing, pollen and nectar storage activities of yellow and black colour morphs of *A. cerana*.
3. To identify the important pollen and nectar sources of yellow and black colour morphs of *A. cerana* in Sirsi area.

2. REVIEW OF LITERATURE

Literature pertaining to the studies on comparative performance of colour morphs of *A. cerana* bees has been given below.

2.1 Geographic variation of *Apis cerana*

Diversity of Indian bee, *A. cerana* populations found in Karnataka offer opportunity to search better group for increased honey yield and success in beekeeping.

Hadisoesilo *et al.* (1995) reported that in Indonesia, two distinct cavity nesting morphs of bees were found. Morphometric analyses indicate that the smaller, darker morph corresponds to *Apis cerana*. The morph is larger, with yellowish clypeus and legs. This is referred to as *Apis nigrocincta*.F.

According to Oldroyd *et al.* (2006), in South India there are two distinct colour morphs of cavity nesting honey bees: the yellow 'plain' morph and the black 'hill' morph which are collectively known as *Apis cerana*. They showed that the hill morphs are associated with a widely distributed mitochondrial haplotypes that is present throughout mainland populations of Southeast Asian *A. cerana*. In contrast, the plain morph, which is apparently confined to low to moderate elevations in India and Srilanka, is associated with a unique mitochondrial haplotypes that is not present in other cavity nesting honey bees. The plain morph is distinguished from the hill morph by the first three abdominal tergites of the worker, which are completely yellow in the plain morph, whereas in the hill morph they are black or black with yellow patches.

According to Peng *et al.* (1989) *Apis cerana* in China can probably be grouped into five geographical races, including the Hainan, Eastern, Southern Yunnan, Aha and Xizang (Tibet) races and possibly further into 7 biotypes, including the Palm Forest, and Mountain of Hainan, Guangdong-Guangxi, Hunnan, Yunnan plateau, Northern and Changbei Shan biotypes.

Takahashi *et al.* (2007) reported that genetic variation among *Apis cerana japonica* isolates from Japan and *Apis cerana* isolates from the neighboring areas of Russia, South Korea, and Taiwan was determined from DNA sequences of the mitochondrial DNA non-coding region between tRNA leu and COII. Three haplotypes were identified among 470 colonies samples at 47 Japanese sites. All isolates from the main Japanese Islands of Honshu, Shikoku, and Kyushu belonged to a single haplotype, a previously reported Japan 1 haplotype. Two new haplotypes were found on far southern Japanese islands of Amami-Oshima and Tsushima the Japan 3 and Japan 4 haplotypes, respectively.

In Philippines Genetic variation was estimated by restriction and sequence analysis of PCR-amplified fragments of the tRNA leu-COII region. They found four different haplotypes, Ce1, Ce2, Ce3 and Ce4, which discriminate among the bee populations from different islands. The Ce1 haplotype is present in Mindanao and Visayan Islands, Ce2 is restricted to Luzon, and both Ce3 and Ce4 are only present in Palawan. (De La Rua *et al.*, 2000).

There are only few references found on comparative performance studies. However, there were no records found on comparative performance within colour morphs of Indian honey bees.

2.2 Foraging behaviour

The individual bees quickly changed from nectar collection to pollen collection and vice-versa, in accordance with their colony needs. The proportion of pollen foragers and the amount of pollen collected increased with the amount of brood present. When colonies were deprived of brood, they foraged less and many former pollen gatherers shifted to nectar

collection. Irrespective of the presence or absence of brood, absence of queen increased nectar collection and decreased pollen collection (Free, 1967).

Bisht and Pant (1968) reported that *A. cerana* gathered pollen pellets throughout the year under Delhi conditions. The highest pollen gathering activity was recorded during January to March, where as May to June were the periods of lesser activity.

Rangarajan *et al.* (1974) studied the foraging behaviour of *A. cerana* and *A. florea* on *Helianthus annuus* L. bloom and noticed maximum activity from 0600 h to 1000 h, whereas 1200 h to 1430h was the period of limited activity.

Naim and Phadke (1976) divided the annual foraging cycle of *A. cerana* season-wise and found that January to March was peak period of pollen collection, while honey storing activity was at its peak during March to April.

Naim and Bisht (1978) reported that January to March was peak period of pollen collection and honey-storing activities were peak during March to April.

Tanda and Goyal (1979 a, b) observed the peak period of pollen collection by *A. cerana* and *A. mellifera* in the morning hours on *Gossypium* spp. They conclude that no bees from either species collected mixed pollen on all foraging trips on the same day. Pollen availability was maximum in the morning and decreased in the afternoon, consequently some pollen foragers of both the species shifted to nectar collection and they assumed pollen collection next day morning.

Maximum foraging activity of the Indian honey bee, *A. cerana* was noticed in the month of July and minimum activity during January. More number of pollen plus nectar collectors was recorded than pollen or nectar collectors alone. It was also observed that there was greater variation among pollen collectors over nectar or water collectors (Reddy, 1980).

Singh (1980) found that pollen was collected throughout the year by *A. cerana* at Saharanpur (U.P.) with maximum activity during October. The second peak was recorded during February to April. From June to October pollen foragers started their activity at 0600 or 0700 h, but in November and December pollen foraging did not commence till 1000 h. The foraging activity began at 1400 h and 1800 h in December and July respectively.

Foraging activity was directly proportional to the increasing ambient temperature and also with increasing radiation up to certain level. However, it did not appear to be correlated with changes in atmospheric humidity and pressure (Burrill and Dietz, 1981).

Thakur *et al.* (1982) reported that at noon, the foraging activity was maximum (300 bees returning in 5 minutes) and there were more pollen foragers in the morning than during afternoon.

Foraging activity was greater during 0800-1200 h followed by 1700 h – 1800 h. The number of nectar gatherers was high in the early morning (0600 - 0800 h) or from 1200 - 1600 h. Whereas, the number of pollen gatherers was highest in the late morning (0900 - 1200 h), decreased in the afternoon and there was a sharp increase between 1700 – 1800 h (Reddy, 1983).

Bhalla *et al.* (1983) reported that honey bees started foraging after 0900 h and were most active from 1100 h to 1600 h.

Honey bees gathered pollen and nectar throughout the year irrespective of climatic conditions. The number of pollen foragers was highest between 0900 and 1200 h, while the number of nectar foragers was highest between 1000 h and 1500 h. There was little foraging before 0600 h and after 1800 h. Pollen foraging was highest during February to March and July to October (Verma, 1983).

Gupta *et al.* (1984) studied the foraging activity of *A. cerana* and *A. mellifera* on plectranthus flowers at Rampur (Himachal Pradesh) and noticed the variation in the rate of foraging activity during different day hours. Maximum number of pollen gatherers of *A. cerana* was seen during 0700-0900 h, while nectar collection activity reached the peak at 1200 h. Whereas *A. mellifera* showed peak pollen collection activity between 0900 and 1000 h.

The peak period of foraging activity of *A. cerana* was in the month of May and June. Foraging data showed the varying peak activity during different seasons. In summer peak activity at 0800 and 1000 to 1600 h, during rainy season at 0900 and 1000 h, in autumn between 0900 and 1000 to 1200 h, in early winter between 0900 and 1400 h, in late winter at 1100 h and in spring season between 0800 and 1100 h. The percentage of nectar collectors were greater than pollen or pollen plus nectar collectors in all the seasons of the year and greater seasonal variations were observed in the percentage of nectar collectors as compared to other categories of foraging bees (Mattu and Verma, 1985).

Verma and Chauhan (1985) observed the maximum foraging activity of *A. cerana* between 1100 and 1200 h and again between 1400 and 1500 h.

Verma and Dulta (1986) compared the foraging behaviour of *A. mellifera* and *A. cerana* on apple flowers. *Apis cerana* workers started their activity significantly earlier in the morning than *A. mellifera* and their activity ceased late in the evening hours.

Abrol and Bhat (1987) observed that foraging activity of *A. cerana* was positively and significantly correlated with temperature and non-significant with relative humidity. But cessation of foraging activity seemed to be independent of atmospheric temperature and relative humidity.

Dustmann *et al.* (1988) have reported the direct correlation of flight activity of *A. mellifera* with the maximum day temperature.

The maximum foraging activity of *A. cerana* occurred during December – January and a second peak activity during February. Peak pollen collection tended to coincide with those of nectar collection (Annon, 1989)

Virakthamath (1990) studied the foraging profile of *A. cerana* in Raichur, Karnataka. He observed major pollen foraging (80 per cent) before noon and foraging throughout the day with a major peak during 0600 -1100 hr and minor peak during 1600 -1800 hr. He further observed more number of pollen and nectar foragers during August – February and August-March respectively, with a dearth period during May- July.

Sattagi and Lingappa (1993) reported that peak foraging activity of *A. cerana* was between 0800 hr. to 1300 hr. during monsoon season (June-September), 0800 hr to 1100 hr. in winter season (October-January), 0800 hr. to 1100 hr. and 1600 hr. to 1800 hr. during summer season (February-March). During remaining hours of the day, the activity was low in different season at Dharwad, Karnataka.

The visits of *A. cerana* to mango flowers gradually increased from 0600 h to 1200 h. The peak activity was noticed between 0900 h to 1100 h (16-20 bees per panicle per 5 minutes). The bee visits decreased from 1400 h to 1700 h (2-5 bees per panicle per 5 minutes) and no visits were observed after 1800 h. The bee activity was low in the beginning, but picked up gradually to reach the peak at flowering from late February to early March (60-95 bees per panicle per 5 minutes) at Bangalore (Jyothi, 1994).

Singh and Singh (1997) reported that *A. cerana* was main foragers (46.37%) followed closely by *A. dorsata* (41.99 per cent). The peak foraging activities was noticed between 0600 - 0900 h and that of later was between 0700 - 0900 h and 1500 - 1700 h on sunflower at Manipur.

Holi and Viraktamath (1997) reported that foraging behaviour was more or less similar in monsoon and winter with a peak activity of outgoing foragers, pollen and nectar

foragers during 1100-1300 h. In summer, there were two distinct peaks as against only one during monsoon and winter season. A major outgoing and pollen foragers occurred between 0700-0800 h and a minor peak between 1700-1800 hr. The nectar foragers were maximum between 0700-1000 h and 1700-1800 h. Foraging activities had positive correlation with the temperature and negative correlation with the rainfall and RH.

Chowde Gowda *et al.* (2005) reported that in *A. cerana* number of pollen foragers was more during 9.00 to 11.00 hr; nectar foragers were maximum during 13.00 to 16.00 hr of the day. The number of nectar foragers was maximum during January to April and pollen foragers were maximum during November to December.

2.2.1 Brood rearing activity

Ramachandran (1939) studied the brood rearing in *Apis cerana* Fab. and reported egg laying by the queen varied between 300-500 eggs per day.

Rahman and Sharma (1945) observed a high rate of brood area during the winter months at Lyallpur (Pakistan).

Sharma (1948) again at Lyallpur studied variation in brood area during different seasons. Brood rearing was observed in winter season also and a slight decline in the latter half of March, after which brood rearing was carried out at almost the same rate. Practically none of the colonies reared brood continuously throughout summer. He recorded up to 1,800 cm² of brood (24,816 cells) amounting to 1,240 eggs per day during February.

Ramachandran and Mahadevan (1950) observed a steady decline in brood rearing from June to September at Coimbatore (South India). There was an initial expansion of brood in November and December and the peak brood rearing was noticed during January to March.

Ramachandran and Cherian (1952) studied the brood rearing cycles of *Apis cerana* at Coimbatore. They reported 692 cm² or 10,799 cells of brood in a thriving colony at the peak brood-rearing period. This gave an average output of 514 eggs per day.

Kapil (1957) Studies of the brood rearing activity of *Apis cerana* at Allahabad, Uttar Pradesh revealed 6,178 and 878 sealed cells for a period of 12 days during February and April respectively, suggesting an average oviposition rate of 515 and 681 eggs per day, respectively.

Sharma (1958) compared the brood-rearing activity of the mountain grey race of *Apis cerana* in the plains and at higher altitudes. He concluded that the brood rearing activity was suspended at higher altitudes with the approach of winter, but it did not happen in the plains. The maximum egg laying rate of the mountain grey race of queen bees was about 1000 eggs per day, whereas the golden race of the plains laid about 600 eggs per day.

Bisht (1966) found that maximum brood rearing activity of *Apis cerana* in February and March at Delhi and December was quite unfavourable.

Saraf and Wali (1972) calculated the egg laying rate of *Apis cerana* (hill strain) in Kashmir by measuring the brood area at every three weeks. Brood rearing was maximum in May and early June and declined in October.

According to Reddy (1980) who made observation on the annual cycle of brood rearing by *Apis cerana* at Bangalore, brood rearing occurred throughout the year and this activity was maximum from March to November and minimum in December and January. The greatest amount of sealed brood was present in April.

Shah and Shah (1981) studied the egg-laying capacity of *Apis cerana* in Kashmir and concluded that the egg laying capacity of Kashmiri bees was higher in the *Apis cerana* group

in India and also higher than exotic *Apis mellifera* L. Maximum brood rearing was reported in May and it was minimum in January.

Bisht *et al.* (1982) reported from Delhi that brood rearing of *Apis cerana* was highest in February – May with a minimum in December. Pollen storage was highest in April –July.

Fukuda (1983) observed that during colony development early in the season, most food was brought during period of maximum population. The amount of pollen collected was related to the amount of brood. In this colony total oviposition was 1.5×10^5 eggs.

In *Apis mellifera*, Harbor (1986) observed that colonies of 4500 bees population produced the most brood per bees population increased above 4500, bees brood production per bee decreased. However, during summer dearth, the colonies of 9000 bees population produced the most brood per bee. Overall optimal colony size was 9000 bees under Louisiana, USA condition.

Dustman *et al.* (1988) reported that cold snaps prevent flight activity which resulted in an interruption of pollen intake, low foraging activity also had a negative effect on brood rearing by increasing brood cannibalism. Accordingly the nurse bees population in next generation was reduced. Due to an insufficient supply of pollen during larval and early imaginal stage of the nurse bees, hypopharyngeal glands were not adequately supplying open brood with worker jelly.

Rana and Goyal (1994) reported that in May there was a maximum brood area of $3225 \text{ cm}^2 \pm 21.6$ and the minimum brood area during January is 1371 cm^2 brood area in *A. cerana*. In winter Indian bee construct more brood area as compared to exotic species.

Verma (1998) reported that the average brood area was maximum in October followed by March, April, November and September; this shows that the brood area was directly related to the availability of pollen grains.

2.2.2 Pollen stores in the brood chamber

Ramachandran and Mahadevan (1950) reported that *Apis cerana indica* stored greater amount of honey and pollen in February and April months at Coimbatore in Tamil Nadu.

Naim and Phadke (1976) reported that maximum honey storing activity of *Apis cerana* during March – April at Pusa (Bihar).

Reddy (1980) reported greater amount of honey and pollen stores in February and April at Bangalore (Karnataka).

Hellmich and Rothenbuler (1980) reported that the difference of pollen hoarding was not found between the line of high pollen hoarding behaviour (HPH) and the line of low pollen hoarding behaviour (LPH) when brood was in the egg stages and pollen stores were small, but were more abundant difference in the lines during larval stage were maintained after brood cells were capped. However, the amount of pollen stored did not change significantly. HPH bees also hoarded more pollen in the absence of brood. The two lines used similar amount of pollen and reared similar amounts of brood. Mortality was higher in LPH bees than that of HPH bees. Bees which hoard a large amount of pollen are either less inhibited from collecting pollen by the presence of stored pollen or more stimulated to collect pollen by its absence.

Bisht *et al.* (1982) reported that *Apis cerana* stored highest number of cells with pollen in the month of April, May, June and July in the order mentioned least in the month of December. Pollen storage was positively correlated with the dimension of the bee hive. Many pollen stored honey cells were observed during April to December. Whereas, in January, February and March the stored honey cells was less than the expected numbers.

Mattu and Verma (1985) observed that, Honey and Pollen stores were greater in summer and autumn than in other seasons in Shimla.

Handal (1986) reported that the annual intake of pollen was 14.07 kg per bee colony in La liberated, EL Salvador. In the rainy season (May – October) the mean intake was 1452 g, while in the dry season (November - April) it was 867 g. From August to April the average rate of pollen consumption per 100 larvae was 3.01 g for every 21 days.

Rahman and Rahman (1993) reported that in colonies of *A. cerana* the maximum pollen area was found to be 1042.36 ± 250.00 cm² in February and minimum pollen area was recorded to be 425.20 ± 143.89 cm² in October.

Rana and Goyal (1994) reported that a maximum pollen area of 648 ± 9.5 cm² during December and minimum pollen area of 1.8 ± 0.1 cm² during May in *A. cerana*.

2.2.3 Honey yield

Ahmed *et al.* (1983) reported that the colonies of *Apis cerana* from Swat and Margalla in Pakistan yielded on an average annual honey yield of 8.17 kg for the swat strain and 7.75 kg for the margalla strain.

Liu Zui-Sheng (1984) reported that *Apis cerana* collected 30 per cent less nectar during a foraging trip than *Apis mellifera* and attributed to its smaller size of body and honey sacs. The difference in the body size was speculated to ultimately affect the honey production potentials.

According into Wongsiri *et al.* (1986), the native *Apis cerana* colonies, produced 70 per cent less honey per colony annually than the exotic *Apis mellifera* in the Guangdong province of china, where beekeeping with this native bee species is very popular and it represents 90 per cent of all bees. They also stated that since the colony size of *Apis cerana* is 30 per cent smaller than the exotic bee *A. mellifera*, the individual worker bee of *A. cerana* is in no way inferior to *Apis mellifera* in respect of honey production.

Oldroyd and Goodman (1988) found that the hybrid queens did not lead to increased honey production.

Szado and Lefkovitch (1989) noticed , during the honey flow period, hives which contain queens of 2 or 3 years old produced 120.2 (60.9 to 210.8) kg honey per colony.

Pidek (1989) reported that when queen was caged for a period of 24 days in early July, led to increase in honey and wax yield.

2.3 Pollen and nectar sources

Sharma and Nair (1965) made pollen analytical studies on 13 honey samples collected from Uttar Pradesh. The dominant honey plants represented by pollen in the honeys were the *Rumax* sp., *Nephelinum* sp, and other plants of the family Myrtaceae, Liliaceae, Rosaceae, Meliaceae, Brassicaceae and Euphorbiaceae.

The pollen of *Antigonan leptopus* Hook and Arn. And *Moringa pterygosperma* Gaertn. were predominant in the honey of Lucknow (Nair and Singh, 1965).

Chaturvedi (1973, 1977) reported the high floral fidelity of *A. c. indica* by analysing the pollen loads from Banthra.

Chaudhary (1978) analysed 5,200 pollen loads from Indian honey bee, *Apis cerana indica* and observed only 56 percent of pollen from more than one plant species.

The analysis of twelve different apiary honeys from eight different states (Maharastra, Bihar, Jammu and Kashmir, Uttar Pradesh, Andra Pradesh, Karnataka, Keral and Tamil Nadu) indicated the presence of *Syzygium cumini* Skeels, *Terminalia chebula* Retz, *Nephelium litchi* Sonner, *Isodon regosus* Wall, *Brassica rugosus* Prain, *Phyla nodiflora* (L.)

Greene, *Borassus flabellifera* L. *Schefflera* sp., *Sapindus emerginatus* Vahl, *Havea brasiliensis* (Muell) Arg., *Eucalyptus* spp and *Tamarindus indica* L. as dominant pollens in honeys (Seethalakshmi, 1980).

Lieux (1980) analysed 54 honey samples in Louisiana and observed 23 species of plants as minor sources contributing 1.0 – 1.5 per cent pollen.

Padagoan honey indicated the presence of *Schefflera venulosa* Harns. (Araliaceae), *Syzygium cumini* as dominant sporomorphs (Chaubal and Kotmire, 1980).

Dhaliwal and Atwal (1980) found that *A. florae*, *A. dorsata* and *A. mellifera* foraging on alfalfa (*Medicago sativa* L.) carried 60.0, 60.0 and 66.6 percent pure pollen respectively.

The melissopalynological analysis of apiary honey from Pauri Garwhal (U.P.) indicated the presence of 30 types of pollen. Among these major ones were Myrtaceae, Lamiaceae, Apiaceae and Poaceae groups (Gour and Nanwani, 1989).

In more than 400 honey samples from different regions of Brazil, the pollen spectra indicated that 190 of them were from monofloral honeys. The most common plant species for these honeys were *Eucalyptus* and *Citrus* species from crops and wild species that produce honey appreciated by humans were from Asteraceae and Mimosidae with different pollen types (Barth, 1990).

The analysis of pollen loads and honey collected from *A. cerana* colonies at west Godavari districts (Andhra Pradesh) has shown that nearly 50 percent of pollen was from *Cocos nucifera* L. (Suryanarayan *et al.*, 1990).

Melissopalynological studies conducted on 21 honey samples collected from 10 localities of the North-East Himalayan region revealed the presence of dominant sporomorphs as *Brassica* sp., *Adhatoda* sp., *Clematis* sp., *Mussaenda* sp., *Helianthus* sp. and Papilionaceous, Rubiaceae, Rutaceae and Zingiberaceae members. Pollen analytical studies also indicated both unifloral and multifloral types of honey samples (Singh *et al.*, 1994).

Kalpna and Ramanujam (1997) analysed 250 samples of honeys from different apiculture enterprises of three districts of Andhra Pradesh (Godavari, Krishna and Guntur) and reported that *Sapindus*, *Eucalyptus*, *Borassus*, *Anacardium* and *Cocos nucifera* L. (in east Godavari), *Borassus* and *Hygrophila* (in Krishna), *Phoenix*, *Sapindus*, *Borassus*, *Hygrophila*, *Mimosa* and *Cleome* (in Guntur) as major pollens in honeys.

Sattagi (1997) studied the bee – flora in and around Dharwad (Karnataka) and recorded 165 plants species as bee forage plants. Of which 12 were identified as major sources and also revealed that the major share was from field crops which have limited flowering period and do not supply food throughout the year which lead to the uncertainty of bee keeping in this area.

Holi and Virakthamath (1997) reported that Totally 132 plants spp were found to yield pollen and nectar source, they constituted 26 field crops, 27 forest trees, 22 vegetable crops, 21 ornamental plants 19 fruits and plantation crops and 17 herbs, shrubs and bushes in Dharwad region.

Joshi *et al.* (1998) reported that eight of the honey samples were unifloral *Eucalyptus* spp and *Syzygium cumini* and predominant source, *Peltophorum pterocarpum* is a major source of nectar for *A. cerana*, *A. dorsata* and *Trigona iridipennis*.

Vasudeva (2009) list out the flora of Sirsi taluk by conducting the survey and listed of about 255 tree species, 131 shrubs and 40 herbs.

3. MATERIAL AND METHODS

The comparative performance of two colour morphs of *A. cerana* was studied with three important activities of honey bees. They include

1. To study the comparative foraging behaviour of yellow and black colour morphs of *A. cerana*
2. To study the brood rearing, pollen and nectar storage activities of yellow and black colour morphs of *A. cerana*.
3. To identify the important pollen and nectar source of yellow and black colour morphs of *A. cerana* in Sirsi taluk.

All the aspects of this study were conducted in the apiary of Agricultural Research Station, Sirsi, Karnataka during October 2008 to May 2009. Sirsi is located at 11° 56' and 15° 46' N latitude and 74° 31' and 76° 4' E longitude and 619 meters above the mean sea level (MSL). Sirsi is located in the rich biodiversity spot of Western Ghats. Sirsi taluk is lying in 'Hill' zone of agro climatic region and it is also called as '*Malnad*' region. Sirsi is featured with rolling topography of mountains and deep valleys. Sirsi taluk receives a rainfall of an average 2456.5 mm (average of 53 years). The temperature ranges from 14 - 35°C and relative humidity ranges from 29 - 89 per cent.

Five *A. cerana* colonies required for the study were captured in Sirsi taluk which is a native for black colour morph. Five yellow colonies of *A. cerana* were brought from Ranebennur taluk of Haveri district. Ranebennur is located at 14°39'N latitude, 75°33'E longitude and at altitude of 394.36 meter above mean sea level (MSL) in the Northern Transitional Agro climatic Zone (Zone 8).

The colonies were placed suitably in the vicinity of research station in two sets. The black colonies were kept separated from yellow colonies by a distance of 200 meters. All the colonies were brought in October 2008 and kept in ISI standard wooden bee hives supported on iron stand with ant pan.

3.1 Foraging behaviour

The present study was undertaken with five colonies of yellow and black colour morphs of Indian bees of having uniform strength. The observations such as number of bees leaving the colony, number of bees returning with pollen load and number of bees returning without pollen load per five minutes were recorded at hourly intervals starting from 0600 to 1800 hours. The incoming bees with pollen load in their legs (Corbiculae) were considered as pollen foragers and those without pollen loads as nectar foragers. Such observations were made at fortnight interval starting from October 2008 to May 2009. Data at each hour was averaged to a week and later to a month. The data on treatments mean obtained by averaging five replications was subjected to statistical analysis by following paired t-test. This test is used for comparison of foraging performance of two colour morphs. However, the variation in foraging activity within a day for individual colourmorph was analyzed separately by following randomized block design test.

3.2 Brood rearing activities

Brood rearing activity of two morphs of *Apis cerana* was studied on five colonies of yellow and black morphs each. The colonies selected were of uniform strength in population. The brood area, pollen stores and honey stores were recorded at an interval of 15 days in all the experimental colonies using the grid, which consisted number of squares and each squares with an area of 2.5 square centimeters.

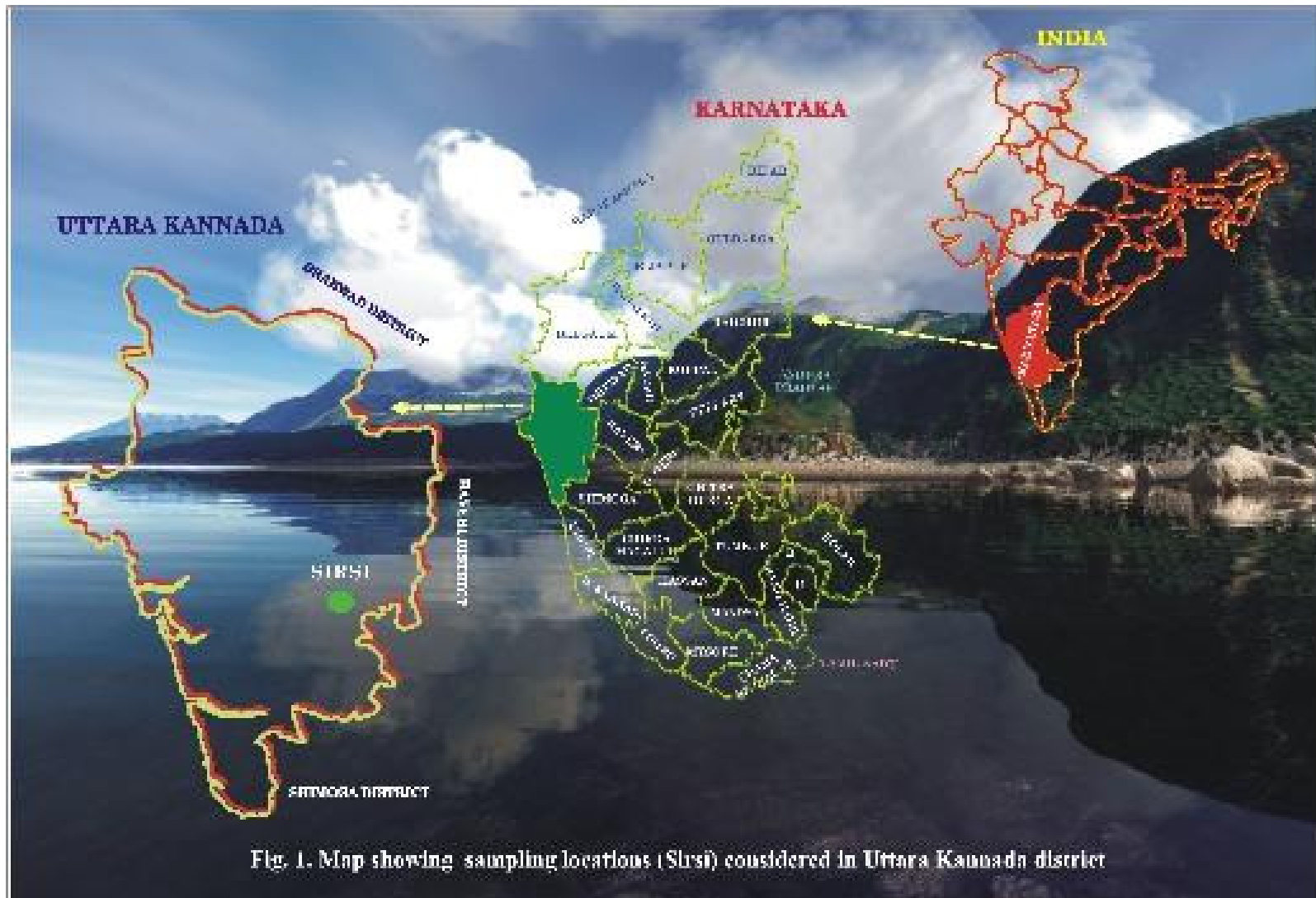


Fig. 1. Map showing sampling locations (Sirsi) considered in Uttara Kannada district

Fig.1. Map showing sampling locations (Sirsi) considered in Uttara Kannada district



Plate.1a. Yellow colour morphs



Plate.1b. Black colour morphs



Plate.2 Experimental set up



Plate.3a. Comb showing the brood area



Plate.3b. Frame showing the pollen store

Brood area was counted separately by placing the grid on the brood frame and the number of squares with brood area was recorded. The cells with brood scattered in different places in a comb was counted separately and converted into square centimeters.

Pollen area was counted separately by placing the grid on the brood frame and the number of squares with pollen area was recorded. The cells with pollen scattered in different places in a comb was counted separately and converted into square centimeters.

Honey area was counted separately by placing the grid on the brood and super frame and the number of squares with honey was recorded. The cells with honey scattered in different places in a comb was counted separately and converted into square centimeters.

The above parameters were recorded in all brood frames and on both faces of each frame. The squares covered by more than 50% with brood, pollen and honey were counted as 1; squares with less than 50% were rejected.

The data obtained in five replications was averaged into treatment means which are further subjected to statistical analysis by following paired t-test.

3.3 Pollen sources

For studying the pollen sources, five colonies of uniform strength of both colour morphs were selected. From each colony, three foragers returning with pollen loads were captured at 0900, 1200 and 1600 hours in a day. The pollen loads were collected by using fine brush and fixed in 70 per cent alcohol in small vials. Pollen slides were prepared by using acetolysis method as described by Erdtman (1952) and Nair (1964). The pollen grains were identified by comparing with reference pollen slides, prepared by collecting the pollen from different species of flowers, which are visited by honey bees. The pollen sources were classified into three categories *viz.* major (45% and above) secondary (16-45%) and minor pollen type (<15%) as given by Louveaux *et al.* (1970).

3.4 Nectar sources

For identifying the nectar sources during honey flow season, five uniform colonies of both colour morphs were selected and honey was collected from each colony at an interval of 15 days. Pollen slides from honey samples were prepared using the methods described by Louveaux *et al.* (1970). Pollen types in various honey samples were identified with the help of reference pollen slides and pollen grains were counted using haemocytometer. Based on the frequencies of pollen grains present in various honey samples the absolute pollen count and percentages of pollen types were made and pollen spectra were constructed on the basis of these percentages.

The bee plants which are sources of pollen and nectar for both the colour morphs of *A. cerana* were identified by taking up a routine survey in Sirsi taluk for every 15 days interval. The trees, shrubs and herbs of all flowering plants were noted down and samples of twigs and flowers were brought to laboratory and further identified the plants at College of Forestry, Sirsi. The foraging worker bees are seen working on floral sources either collecting nectar and / or pollen and recorded the floral source. The plants were identified up to species level and also the flowering period of each plant was noted down. The information regarding whether the plant is a pollen source or nectar source or both as pollen and nectar source was also recorded during the survey.

4. EXPERIMENTAL RESULTS

The results of the investigations carried out on foraging behaviour, brood rearing activities, identification of pollen and nectar sources of yellow and black colour morphs of *A. cerana* F. in Sirsi are presented in this chapter.

4.1 Foraging behaviour of yellow and black colour morphs of *A. cerana*

Foraging behaviour of yellow and black colour morphs of *A. cerana* was studied in two seasons, viz. winter and summer during October 2008 to May 2009 in the apiary of the Agriculture Research Station, Sirsi, Karnataka.

Results of foraging behaviour are classified into three categories namely number of outgoing bees, number of pollen gatherers and number of nectar gatherers and compared between yellow and black colour morphs of *A. cerana*.

4.1.1 Number of outgoing bees in winter month

Number of outgoing bees for 5 min. was counted for yellow and black colour morphs colonies were statistically analysed and are summarised in Table 1 and Table 2. Figures in the Table 1 and 2 indicate the average number of outgoing bees per five min. by both the colour morphs throughout the day for each month.

In the month of October, outgoing bees in yellow colour morphs ranged from 18.4 to 84.8 per 5 min. period, where as in black colour morphs they ranged from 22.0 to 81.0 bees for 5 min. period. Highest number of outgoing bees was recorded 84.8 at 1200 hr and 81.0 at 1000 hr in yellow and black colour morphs respectively. Lowest outgoing bee activity 18.4 in yellow colour morphs recorded at 0600 hrs and in black morphs 22.0 at 1800 hr of the day.

During November, number of outgoing bees in yellow colonies ranged from 25.2 to 85.0 per 5 min.. In black colour morphs colonies it ranges from 22.0 to 77.8 bees per 5 min.. The highest activity of yellow bees occurred at 1200 hr of the day and highest outgoing bee activity of black bees recorded at 1100 hr of the day.

In December month results of outgoing bees of yellow and black colour morphs colonies revealed that lowest of 22.0 bees seen at 1800 hr and highest of 81.0 at 1000 hrs of the day in yellow colour morphs colonies. In black colour morphs colonies average outgoing bees per 5 min. ranged from 23.4 at 0600 hr to 78.4 at 1000 hr of the day.

In January, the outgoing bee of yellow colour morphs ranged from 14.8 to 75.2 bees per 5 min. In black bees the ranges from 25.2 to 75.4 outgoing bees per 5 min. were seen. The highest activity of yellow bees occurred at 1100 hr of the day and highest outgoing bee activity of black colour morphs recorded at 1000 hr of the day.

4.1.1.1 Number of outgoing bees in summer month

Further, in February yellow bees recorded 34.8 to 97.6 outgoing bees per 5 min. at 0600 hr and 1000 hr respectively. In black colour morphs outgoing activity ranges from 31.0 bees for 5 min. at 1400 hr to 93.4 bees at 1000 hr of the day.

In the month of March, outgoing bees activity of yellow and black bees as seen in Table 2 recorded 22.4 to 82.2 bees per 5 min. in yellow colour morphs and 22.4 to 85.8 bees per 5 min. in black colour morphs colonies. Both yellow and black bees exhibited highest outgoing bees activity in the morning hours at 0800 (Table 2).

Table 1: Comparative variation in the out going bees of yellow and black colour morphs of *Apis cerana* during winter season of 2008-09

Sl. No.	Time (hours)	October		November		December		January	
		Yellow	Black	Yellow	Black	Yellow	Black	Yellow	Black
Number of bees for every five minutes									
1	0600	18.4i	28.2h	25.2i	28.2g	21.2k	23.4i	14.8j	25.2k
2	0700	32.4h	38.8f	43.2e	41.8e	36.6h	39.0e	24.2h	27.4j
3	0800	42.0e	60.2d	55.8d	62.4d	60.2e	62.0d	25.2gh	44.8g
4	0900	53.2d	68.8c	57.8d	64.4cd	67.6d	73.8b	46.8d	66.4b
5	1000	82.2b	81.0a	64.8c	74.8b	81.0a	78.4a	68.4b	75.4a
6	1100	81.4b	74.8b	74.6b	77.8a	75.0b	73.6b	75.2a	66.6b
7	1200	84.8a	71.8b	85.0a	75.0b	72.0c	74.2b	46.0d	62.8c
8	1300	64.0c	54.2e	75.6b	66.0c	57.2f	63.8c	42.0e	53.0e
9	1400	42.6e	39.6f	42.6e	34.8f	39.6g	35.4f	35.4f	44.4g
10	1500	38.4f	33.0g	38.0f	34.4f	33.8i	33.4g	26.6g	42.6h
11	1600	35.2g	22.2i	35.2g	33.6g	22.2k	31.8g	21.2i	47.6f
12	1700	33.4gh	26.6h	32.0h	26.6h	24.2j	26.0h	54.0c	54.8d
13	1800	39.6f	22.0i	39.6f	22.0i	22.0k	25.0hi	34.6f	35.4i
	SEm \pm	0.72	0.89	0.75	0.74	0.56	0.58	0.52	0.53
	CD at 5%	2.05	2.54	2.14	2.09	1.59	1.65	1.47	1.51

Each value is average of 5 replications. Figures followed by same letters in the column do not differ significantly by DMRT

In summer month April, outgoing bees activity of yellow and black bees recorded in Table 2. Yellow bees recorded lowest of 22.4 to highest of 82.2 average outgoing bees for 5 min.. Black bees recorded 24.8 to 83.4 outgoing bees for 5 min. period. The highest activity of outgoing bees in yellow bees was at 0800 hr and in black bees at 0900 hour. Lowest activity of yellow bees 22.4 was recorded at 1400 hour where as in black bees, lowest of 24.8 bees for 5 min. recorded at 1300 hr.

In the month of May outgoing activity yellow bees were measured (Table 2) as 23.2 bees per 5 min. at 1300 hr to 85.2 bees per 5 min. at 0900 hr of the day. Black bees outgoing activity recorded in May shown lowest activity of 22.6 bees for 5 min. at 1300 hr and highest activity of 76.2 bees for 5 min. duration at 0800 hr of the day.

4.1.2 Pollen gathering activity

Pollen gathering activity of both yellow and black colour morphs has been observed in 5 colonies of each colour morphs and averaged and presented in Table 3 for winter season and in Table 4 for summer season months.

Pollen gathering activity in October month of yellow and black bees ranged from 7.0 to 35.8 bees and 8.2 to 35.2 bees for 5 min. duration respectively. Highest pollen gathering activity of both yellow and black bees was seen at 0900 hr.

In November, highest pollen gathering bees were recorded 45.2 bees for 5 min. at 1000 hr in yellow bees and 40.8 bees per 5 min. were recorded in black bees at 0900 hr. Pollen gathering activity was minimum at 0600 hr for yellow bees (7.6 bees per 5 min.) and at 1400 hr in black bees (6.8 bees per 5 min.).

Pollen gathering activity of both colour morphs in December exhibited 5.8 to 27.6 and 8.2 to 35.8 bees per 5 min for yellow and black colour morphs of *A. cerana* respectively.

In January, pollen gathering activity where compared for two colour morphs of *A. cerana*. Yellow colour morph recorded of 9.6 to 32.8 bees carrying pollen grain loads in five min. at 0600 and 1600 hr respectively. In black colour morphs bees recorded a minimum of 10.8 to maximum of 31.6 bees with pollen loads at 0600 and 1100 hr respectively.

4.1.2.1 Pollen gathering activity in summer season

In February month pollen gathering activity of yellow bees varied from 11.6 to 45.4 in five min. at 1200 hr and 0800 hr time respectively for the day. Pollen gathering activity of black colour morphs worker bees recorded a minimum of 8.4 bees at 1400 hr and maximum of 44.0 bees at 0900 hr with pollen loads in 5 min.

Later in March, pollen gathering activity of yellow bees recorded lowest of 6.8 bees at 1400 hr and highest of 56.4 bees at 0700 hr carrying pollen loads in their legs per five min.. In black bees, highest of 64.0 bees at 0700 hr and lowest of 6.8 bees returning with pollen loads at 1400 hr of the day per 5 min was recorded.

In April, average number of pollen carriers recorded was 6.8 to 36.4 bees per 5 min. in case of yellow colour morphs at 1400 and 1600 hr respectively. Black bees recorded the pollen gathering activity with a minimum of 8.4 bees at 1300 hr and maximum of 42.8 bees at 0800 hr of the day (Table 4).

During May, Yellow colour morphs bees recorded a minimum activity of 12.8 bees per 5 min. duration at 1300 and 1400 hr and maximum number of pollen gatherers of 35.0 bees per 5 min. at 0700 hr. Pollen gathering activity of black bees was minimum with 12.8 bees at 1600 hr and maximum of 35.6 bees per 5 min. at 0700 hr.

Table 2: Comparative variation in the outgoing bees of yellow and black colour morphs of *Apis cerana* during summer season of 2008-09

Sl. No.	Time (hours)	February		March		April		May	
		Yellow	Black	Yellow	Black	Yellow	Black	Yellow	Black
Number of bees for every five minutes									
1	0600	34.8i	35.6j	72.4c	74.6c	65.8d	55.0e	55.0d	63.8e
2	0700	47.0g	51.8g	77.0b	76.8b	76.2c	77.2b	66.0c	67.6d
3	0800	76.2c	77.2d	82.2a	85.8a	82.2a	76.2b	74.2b	76.2a
4	0900	86.4b	86.0b	76.6b	76.8b	77.8b	83.4a	85.2a	74.0b
5	1000	97.6a	93.4a	58.0e	63.2e	65.8d	63.2d	56.0d	44.8g
6	1100	77.0c	80.6c	52.0f	52.0g	54.6e	44.8g	42.2f	23.2j
7	1200	65.8d	57.0e	45.0g	44.8h	36.4g	47.0f	25.2h	34.4h
8	1300	56.8f	53.2fg	31.6i	24.6k	24.4j	24.8j	23.2i	22.6j
9	1400	35.4i	31.0k	22.4k	22.4l	22.4k	26.2j	24.0hi	28.0i
10	1500	43.0h	42.4i	25.0j	27.4j	28.2i	31.6i	32.8g	35.0h
11	1600	45.4g	41.2i	42.6h	42.8i	34.0h	42.8h	45.6e	42.8g
12	1700	56.2f	46.2h	53.2f	54.4f	46.4i	56.2e	56.0d	55.2f
13	1800	59.4e	54.8f	66.6d	65.8d	65.6d	66.2c	72.8b	69.8c
	SEm \pm	0.68	0.66	0.58	0.56	0.51	0.63	0.64	0.76
	CD at 5%	1.92	1.87	1.64	1.59	1.45	1.79	1.83	2.15

Each value is average of 5 replications. Figures followed by same letters in the column do not differ significantly by DMRT.

Table 3: Comparative variation in the pollen foragers of yellow and black colour morphs of *Apis cerana* during winter season of 2008-09

Sl. No.	Time (hours)	October		November		December		January	
		Yellow	Black	Yellow	Black	Yellow	Black	Yellow	Black
Number of bees for every five minutes									
1	0600	8.8i	8.2h	7.6h	11.8g	5.8f	8.2h	9.6h	10.8h
2	0700	16.6f	18.4f	14.8f	27.0b	14.4e	14.0g	14.0g	15.4g
3	0800	28.0b	24.8c	27.2d	18.4d	27.0a	24.8d	14.8fg	24.8cde
4	0900	35.8a	35.2a	33.6c	40.8a	27.0a	35.8a	14.8fg	30.0ab
5	1000	24.8c	21.8d	45.2a	26.2b	21.8bcd	21.8e	21.2d	27.8abc
6	1100	19.2e	27.6b	35.8b	26.4b	26.4a	27.8b	27.0b	31.6a
7	1200	14.6g	20.2e	14.6f	13.8fg	20.4d	20.2e	20.8d	10.6h
8	1300	7.6ij	14.0g	16.2f	11.8g	14.4e	17.0f	24.4c	15.2g
9	1400	12.4h	21.4de	12.4g	6.8h	21.0cd	21.4e	21.2d	18.8fg
10	1500	7.0j	13.2g	15.0f	16.4de	23.4b	26.4bc	16.0f	23.0de
11	1600	14.8g	24.8c	14.8f	15.0ef	22.8bc	24.8cd	32.8a	28.2abc
12	1700	22.4d	28.6b	27.0d	24.0c	27.6a	27.0b	19.0e	26.6bcd
13	1800	11.0h	18.0f	24.4e	13.4fg	21.8bcd	26.4bc	13.8g	21.0ef
	SEm \pm	0.57	0.50	0.68	0.73	0.65	0.62	0.52	1.40
	CD at 5%	1.62	1.43	1.94	2.08	1.84	1.77	1.48	3.97

Each value is average of 5 replications. Figures followed by same letters in the column do not differ significantly by DMRT.

Table 4: Comparative variation in the pollen foragers of yellow and black colour morphs of *Apis cerana* during summer season of 2008-09

Sl. No.	Time (hours)	February		March		April		May	
		Yellow	Black	Yellow	Black	Yellow	Black	Yellow	Black
Number of bees for every five minutes									
1	0600	25.6e	26.2e	48.0b	52.8b	27.2h	33.8c	27.2d	23.6d
2	0700	38.0b	35.0b	56.4a	64.0a	35.4f	35.8b	35.0a	35.6a
3	0800	45.4a	35.4b	34.8d	39.2c	34.8c	42.8a	34.8b	32.4b
4	0900	33.6d	44.0a	37.0c	36.4d	31.6a	36.2b	25.0e	27.6c
5	1000	35.6c	32.4c	17.6f	28.8e	27.2bc	28.8d	23.0g	32.8b
6	1100	26.4e	21.6f	17.6f	17.0fg	16.4bc	17.0fg	15.2d	25.2d
7	1200	11.6i	20.2g	7.2h	12.8i	15.8e	12.8h	13.0i	17.6f
8	1300	14.0h	13.6j	13.6g	14.4h	10.4ef	8.4i	12.8jk	13.0gh
9	1400	21.2f	8.4k	6.8h	6.8j	6.8ef	11.8h	12.8jk	14.0gh
10	1500	15.0h	15.6i	15.0g	12.0i	11.0g	18.2f	14.8h	15.0g
11	1600	22.4f	18.6h	17.2f	15.8gh	36.4a	15.8g	24.0f	12.8h
12	1700	17.6g	25.0e	14.4g	18.4f	23.0d	23.4e	27.0d	21.0e
13	1800	25.0e	28.2d	25.0e	28.2e	25.0g	28.2d	27.6c	28.2c
	SEm \pm	0.66	0.46	0.66	0.53	0.63	0.63	27.2d	0.67
	cd	1.87	1.30	1.88	1.51	1.80	1.79	35.0a	1.91

Each value is average of 5 replications. Figures followed by same letters in the column do not differ significantly by DMRT.

4.1.3 Nectar gathering activity

Nectar gathering activity of both yellow and black colour morphs has been observed in 5 colonies of each colour morph are averaged and presented in Table 5 for winter season and in Table 6 for summer season months.

In October month, Nectar gatherers of yellow colour morph bees ranges from 16.0 bees per 5 min. at 1500 hr to 46.6 bees per 5 min. at 0900 hr. In black bees nectar gatherers ranges from 21.2 bees per 5 min. at 1700 hr and 44.6 bees per 5 min. at 0900 hr.

During November month, the highest number of nectar gatherers of 46.2 and 36.2 bees per 5 min. at 0900 hr in both yellow and black colour morphs was recorded respectively. The lowest number of nectar gatherers of 11.8 bees was recorded during 1400 hr in both yellow and black colour morphs.

In December, the highest number of nectar gatherers of 43.4 and 48.0 bees per 5 min. at 1000 hr in the yellow and black colour morphs respectively was noticed. The lowest number of nectar gatherers of 17.2 and 15.0 bees per 5 min. at 0600 hr in yellow and black colour morphs respectively was observed.

In January, the highest number of nectar gatherers of 35.8 yellow bees was recorded for 5 min. at 1200 hr of the day and lowest number of 11.2 nectar gatherers was recorded at 0800 hr. In black bees highest number of nectar gatherers of 26.6 bees for 5 min. at 1100 hr and lowest of 8.4 bees per 5 min. at 0800 hr of the day was recorded.

In February, the nectar gatherers of yellow bees ranged from 15.2 bees per 5 min. at 1300 and 1400 hr to 37.0 bees per 5 min. at 0800 hr of the day. In black bees it ranged from 7.8 bees at 1300 hr to 33.0 bees per 5 min. at 0800 hr of the day.

In March, the highest number of nectar gatherers of 36.2 bees per 5 min. at 1800 hr and 31.6 bees per 5 min. at 1700 and 1800 hr of the day in yellow and black colour morphs respectively was noticed. The lowest number of 9.0 nectar gatherers was recorded bees per 5 min. at 1500 hr and 7.6 bees per 5 min. at 1200 hr of the day in yellow and black colour morphs respectively.

In April month, highest number of 38.8 and 35.4 nectar gatherers was recorded of for 5 min. at 0800 hr in yellow and black colour morphs respectively. The lowest number of 13.0 and 16.6 nectar gatherers was recorded per 5 min. at 1200 hr of the day in yellow and black colour morphs respectively.

In the month of May, the nectar gatherers ranged from 14.2 to 38.0 bees and 13.6 to 45.2 bees per 5 min. in yellow and black colour morphs respectively. The highest number of nectar gatherers of yellow and black colour morphs was recorded at 0800 hr and 0900 hr of the day and lowest was found at 1200 hr of the day respectively.

4.2 Brood rearing activity

Brood rearing activity of two colour morphs of *A. cerana* was studied from October 2008 to May 2009 and data obtained is presented in Table 7.

4.2.1 Brood area

Initial brood area of yellow and black colonies was 226.50 and 236.50 cm² per colony respectively. Observations taken at every fortnight interval revealed that, there was constant increase in brood area of both the colour morphs and reached 1029.50 and 1054.00 cm² per colony.

Table 5: Comparative variation in the nectar foragers of yellow and black colour morphs of *Apis cerana* during winter season of 2008-09

Sl. No.	Time (hours)	October		November		December		January	
		Yellow	Black	Yellow	Black	Yellow	Black	Yellow	Black
Number of bees for every five minutes									
1	0600	26.8e	23.0ij	23.8g	22.2c	17.2h	15.0k	14.6fg	15.0de
2	0700	33.6cd	27.4f	30.0d	25.2b	24.2fg	24.6h	16.6e	13.2ef
3	0800	36.4b	37.6d	35.2c	26.8b	35.0cd	40.8b	11.2h	8.4h
4	0900	46.6a	44.6b	46.2a	36.2a	39.2b	34.6d	26.6c	22.0b
5	1000	34.4bc	50.2a	41.8b	36.0a	43.4a	48.0a	31.4b	26.4a
6	1100	26.8e	32.4e	25.2fg	16.0d	24.0fg	32.4e	22.2d	26.6a
7	1200	36.4b	39.6c	36.4c	26.8b	22.2g	40.8b	35.8a	15.6cd
8	1300	32.2d	25.2gh	14.4h	15.2d	31.8e	27.8f	13.2g	11.8fg
9	1400	22.0f	24.0hi	11.8i	11.8e	34.4cd	25.2gh	15.0efg	13.4def
10	1500	16.0g	27.0fg	14.4h	14.8d	34.6cd	16.6j	13.2g	9.6gh
11	1600	24.0f	22.0j	24.0g	24.8b	24.6f	36.6c	15.2ef	11.2fg
12	1700	26.6e	21.2j	26.8ef	26.6b	33.4de	26.6fg	22.0d	14.8de
13	1800	28.6e	25.4gh	28.6de	25.2b	35.6c	22.4i	25.2c	17.4c
	SEm \pm	0.72	0.62	0.64	0.66	0.68	0.55	0.65	0.76
	CD at 5%	2.04	1.76	1.82	1.86	1.93	1.57	1.83	2.15

Each value is average of 5 replications. Figures followed by same letters in the column do not differ significantly by DMRT.

Table 6: Comparative variation in the nectar foragers of yellow and black colour morphs of *Apis cerana* during summer season of 2008-09

Sl. No.	Time (hours)	February		March		April		May	
		Yellow	Black	Yellow	Black	Yellow	Black	Yellow	Black
Number of bees for every five minutes									
1	0600	25.2d	20.2c	20.8f	22.4c	22.2e	22.4f	22.2e	22.4f
2	0700	31.6b	27.6b	33.6bc	26.8b	35.2bc	32.8bc	34.8b	35.2c
3	0800	37.0a	33.4a	24.2e	26.0b	38.8a	35.4a	38.0a	37.6b
4	0900	32.4b	28.6b	26.6d	17.2d	26.4d	28.2d	35.4b	45.2a
5	1000	27.4c	27.8b	21.2f	16.6d	23.4e	23.2f	34.8b	23.8f
6	1100	23.8de	17.4d	13.2h	10.8f	16.4fg	18.4g	15.6g	17.8g
7	1200	17.4f	12.8e	9.0i	9.0g	13.0h	16.6h	14.2g	13.6h
8	1300	15.2g	7.8f	12.4h	13.2e	15.2g	18.8g	18.8f	16.4g
9	1400	15.2g	12.2e	13.2h	14.8e	17.2f	25.8e	20.8e	23.0f
10	1500	22.2e	18.8cd	17.0g	7.6g	23.8e	28.0d	24.0d	26.4e
11	1600	35.2a	29.0b	32.4c	25.8h	27.4d	25.8e	27.6c	32.8d
12	1700	33.0b	32.4a	35.0ab	31.6a	33.8c	34.0ab	34.0b	43.0a
13	1800	33.2b	31.6a	36.2a	31.6a	36.2b	31.6c	33.8b	36.8bc
	SEm \pm	0.69	0.71	0.60	0.57	0.66	0.59	0.62	0.78
	CD at 5%	1.96	2.02	1.70	1.63	1.87	1.69	1.76	2.22

Each value is average of 5 replications. Figures followed by same letters in the column do not differ significantly by DMRT.

Table 7: Brood rearing activity of yellow and black colour morphs of *Apis cerana* at Sirsi during 2008-09

Date of observation	Brood area (cm ²)	
	Yellow colour morphs	Black colour morphs
October 1	226.50 ± 2.85	236.50 ± 2.24
October 15	240.00 ± 3.95	247.50 ± 2.50
October 29	242.50 ± 2.50	252.00 ± 2.09
November 12	265.50 ± 2.09	273.00 ± 2.09
November 26	272.50 ± 2.50	284.50 ± 2.07
December 10	323.00 ± 2.09	341.50 ± 2.24
December 24	339.00 ± 2.85	353.00 ± 2.09
January 7	377.50 ± 3.95	390.00 ± 3.95
January 21	404.00 ± 2.85	417.50 ± 2.50
February 4	460.50 ± 4.47	477.50 ± 2.50
February 18	553.00 ± 2.09	589.00 ± 2.25
March 4	650.00 ± 3.85	650.00 ± 2.86
March 18	777.10 ± 2.66	815.00 ± 3.95
April 1	790.00 ± 3.85	850.5 ± 2.07
April 15	816.50 ± 3.35	876.50 ± 2.24
April 29	850.50 ± 3.95	885.50 ± 2.07
May 13	900.50 ± 2.85	905.00 ± 2.85
May 27	1029.50 ± 3.75	1054.00 ± 2.85
SEm±	1.21	1.03
CD at 5%	3.40	2.91

Mean ± SD. of 5 observations (from 5 colonies)

Difference in brood area of two colour morphs: non significant (p = 0.05, t-test)

Table 8: Stored pollen area in the colonies of yellow and black colour morphs of *Apis cerana* at Sirsi during 2008-09

Date of observation	pollen area (cm ²)	
	Yellow colour morphs	Black colour morphs
October 1	21.50 ± 2.85	33.00 ± 2.09
October 15	32.00 ± 3.26	33.50 ± 2.09
October 29	33.00 ± 3.26	34.50 ± 2.09
November 12	38.00 ± 3.26	43.50 ± 2.24
November 26	42.50 ± 3.06	45.00 ± 2.50
December 10	43.50 ± 2.09	46.00 ± 2.85
December 24	51.50 ± 2.85	54.00 ± 2.85
January 7	53.50 ± 2.24	62.00 ± 2.09
January 21	60.00 ± 3.95	66.00 ± 1.37
February 4	68.50 ± 2.85	74.00 ± 2.85
February 18	90.00 ± 3.95	100.00 ± 2.85
March 4	105.50 ± 3.26	115.00 ± 1.77
March 18	117.50 ± 2.85	121.50 ± 2.85
April 1	132.50 ± 2.85	135.00 ± 3.86
April 15	135.00 ± 3.26	145.50 ± 3.71
April 29	147.50 ± 3.86	155.00 ± 4.81
May 13	152.50 ± 4.56	165.00 ± 3.86
May 27	167.00 ± 2.09	175.00 ± 4.50
SEm±	1.18	1.10
CD at 5%	3.34	3.10

Mean ± SD. of 5 observations (from 5 colonies)

Difference in brood area of two colour morphs: non significant (p = 0.05, t-test)

Table 9: Stored Honey area of yellow and black colour morphs of *Apis cerana* at Sirsi during 2008-09

Date of observation	Honey area (cm ²)	
	Yellow race	Black race
October 1	13.00 ± 2.85	12.00 ± 2.09
October 15	22.50 ± 1.77	14.00 ± 2.85
October 29	24.50 ± 3.26	19.00 ± 2.85
November 12	26.00 ± 2.85	21.50 ± 1.37
November 26	24.50 ± 3.26	19.00 ± 2.85
December 10	26.00 ± 2.85	21.50 ± 1.37
December 24	24.10 ± 2.61	22.50 ± 2.50
January 7	30.00 ± 3.06	31.50 ± 2.24
January 21	35.50 ± 2.09	32.50 ± 1.77
February 4	47.00 ± 2.09	43.00 ± 2.09
February 18	54.00 ± 2.85	50.00 ± 1.77
March 4	67.00 ± 2.09	63.50 ± 2.85
March 18	93.00 ± 3.26	74.50 ± 1.12
April 1	124.00 ± 2.85	116.50 ± 4.87
April 15	175.00 ± 5.30	158.50 ± 3.35
April 29	253.50 ± 3.35	203.50 ± 4.18
May 13	404.50 ± 3.26	427.00 ± 2.09
May 27	426.00 ± 2.85	447.00 ± 2.09
SEm±	1.21	1.21
CD at 5%	3.41	3.40

Mean ± SD. of 5 observations (from 5 colonies).

Difference in honey area of two colour morphs: non significant (p = 0.05, t-test)

Table 10: List of Pollen and nectar sources of yellow and black colour morphs of *Apis cerana* in Sirsi taluk

Sl. No.	Botanical name and Family	Common name in English	Local name	Flowering period	Pollen /nectar/ both
1	<i>Acacia auriculiformis</i> (Fabaceae)	Earleaf acacia	Sabu gida	May to October	P
2	<i>Acacia catechu</i> (Fabaceae)	Cutch tree	Kachu	May to October	P
3	<i>Acacia concinna</i> (Fabaceae)	Soap pod	Sige	September to November	P and N
4	<i>Ailanthus triphysa</i> (Simarubaceae)	Stink tree	Maddi dhoopa	February to March	P and N
5	<i>Allophylus cobbe</i> (Sapindaceae)	Sidisale	Moorele balli	April to June	N
6	<i>Alseodaphne semicarpifolia</i> (Lauraceae)	Karuvadi	Mashe	March to July	N
7	<i>Alstonia scholaris</i> (Apocynaceae)	Dita bark tree	Maddale	March to April	N
8	<i>Anacardium occidentale</i> (Anacardiaceae)	Cashew nut	Geru mara	December to January	N
9	<i>Anthocephalus cadamba</i> (Rubiaceae)	Kadamba tree	Kadamba vruksha/ apathina mara	April to June	N
10	<i>Aporosa lindleyana</i> (oleaceae)	Indian olive	Salle mara	January to March	P
11	<i>Archidendron monadelphum</i> (Fabaceae)	Kachlora	Kan karinje / Nuggikar	January to February	N
12	<i>Areca catechu</i> (Arecaceae)	Betel nut	Adike	May to December	N
13	<i>Artocarpus heterophyllus</i> (Moraceae)	Jack fruit	Halasina mara	January to March	P
14	<i>Artocarpus hirsute</i> (Moraceae)	Wild jack fruit	Hebbalasu	December to March	P
15	<i>Artocarpus lakoocha</i> (Moraceae)	Lakooch	Naate huli mara	January to February	P
16	<i>Bombax ceiba</i> (Bombaceae)	Yellow Silk Cotton Tree	Boorala	January to March	P and N
17	<i>Butea monosperma</i> (Fabaceae)	Flame of the forest	Muttaga	February to March	N
18	<i>Calophyllum apetalum</i> (Clusiaceae)	coachwood	Babbi	October to November	P
19	<i>Canarium strictum</i> (burseraceae)	Black dammer tree	Kayi dhoopa	January to March	P and N
20	<i>Canthium dicoccum</i> (Rubiaceae)	Kumar chikni	Hanigere	April to August	N
21	<i>Carallia brachiata</i> (Rhizophoraceae)	Indian oak	Andi/ anda murugals	December to February	N
23	<i>Careya arborea</i> (Melastomataceae)	Ceylon oak	Kavalu	February to April	P and N
24	<i>Caryota urens</i> (Arecaceae)	Indian sago palm	Baine	January to December	P

Contd.....

Sl. No.	Botanical name and Family	Common name in English	Local name	Flowering period	Pollen /nectar/ both
25	<i>Cassine glauca</i> (Celastraceae)	Marble tree	Kannur mara /Gotadike mara	February to June	P
26	<i>Celtis philippensis</i> (Ulmaceae)	Sugar hackberry	Peenari /Hetari mara	January	N
27	<i>Chionanthus malabarica</i> (Oleaceae)	Malabar Fringe Tree	Akkerakalu	January to February	N
28	<i>Chrysobalanus roxburghii</i> (Sapotaceae)	The star Apple	Hale mara	April to May	P and N
29	<i>Cinnamomum malabathrum</i> (Lauraceae)	Lavangada yele	Neeshne	January to June	N
30	<i>Cinnamomum zeylanicum</i> (Lauraceae)	Wild cinnamon tree	Dalchinni	December to March	N
31	<i>Cocos nucifera</i> (Pandanaeae)	Coconut	Tengina mara	January to December	P
32	<i>Cordia dichotoma</i> (Boraginaceae)	Sebsten plum	Challe kayi	March to April	P
33	<i>Dalbergia latifolia</i> (Fabaceae)	Indian rose wood	Beete / Sisam	January to March	N
34	<i>Dillenia pentagyna</i> (Dilleniaceae)	Karmal	Gudde kanagila	January to March	P and N
35	<i>Diospyros malabarica</i> (Ebenaceae)	Gaub tree	Antina mara	March to May	N
36	<i>Diospyros melanoxylon</i> (Ebanaceae)	Coromandelebony	Tumari	April to May	P
37	<i>Diospyros microphylla</i> (Ebanaceae)	Gaub	Sannale mara	January to March	N
38	<i>Diospyros montana</i> (Ebanaceae)	Mountain ebony	Bala gane	April to May	N
39	<i>Emblica officinalis</i> (Euphorbiaceae)	The emblic Myrabolan	Nelli	February to March	P and N
40	<i>Eucalyptus citriodora</i> (Myrtaceae)	Eucalyptus	Niligeri mara	October to February	P and N
41	<i>Flacourtia montana</i> (Flacourtiaceae)	Mountain Sweet Thorn	Sampige hannu	November to January	P
42	<i>Garcinia gummigutta</i> (Clusiaceae)	Malabar gamboges	Uppage	February to March	N
43	<i>Garcinia indica</i> (Clusiaceae)	Indian gamboges	Murugalu	April to August	N
44	<i>Grewia tiliaefolia</i> (Tiliaceae)	Dhaman	Dadasalu mara	February to April	N
45	<i>Holigarna arnottiana</i> (Anacardiaceae)	Jungle marking nut	Holageru	January to February	P and N
46	<i>Holigarna beddomei</i> (Anacardiaceae)	Beddomes black varnish	Doddale holegeru	January to February	P and N
47	<i>Holigarna ferruginea</i> (Anacardiaceae)	-	Holegeru	March to May	P and N
48	<i>Hopea ponga</i> (Dipterocarpaceae)	-	Haiga	March to April	N

Contd.....

Sl. No.	Botanical name and Family	Common name in English	Local name	Flowering period	Pollen /nectar/ both
49	<i>Ixora brachiata</i> (Rubiaceae)	Gorbale	Gorbale	November to January	P and N
50	<i>Lagerstroemia lanceolata</i> (Lythaceae)	Ben tree	Nandi mara	March to May	P and N
51	<i>Mammea suriga</i> (Clusiaceae)	Surangi	Suragi mara	March	P and N
52	<i>Mangifera indica</i> (Anacardiaceae)	Mango tree	Mavina mara	January to March	N
53	<i>Mitragyna parvifolia</i> (Rubiaceae)	Kaim	Etagalu mara	May to July	P and N
54	<i>Moringa oleifera</i> (Moringaceae)	Drum stick	Nugge gida	February	P
55	<i>Murraya koenigii</i> (Rutaceae)	Curry leaf tree	Curry leaf plant	March to May	N
56	<i>Musa paradisiacal</i> (Musaceae)	Banana	Bale	January to December	P and N
57	<i>Nothopogia racemosa</i> (Anacardiaceae)	—	Gandu holegeru	April to May	P and N
58	<i>Peltoforum ferrugenium</i> (Fabaceae)	Copper pod	Tamra gida	March to July	P
59	<i>Phoenix sylvestris</i> (Arecaceae)	Wild date palm	Echalu mara	February to May	P
60	<i>Phyllanthus emblica</i> (Euphorbiaceae)	The emblic myrabolan	Nelli	February to March	P and N
61	<i>Pongamia pinnata</i> (Faboideae)	Indian beech tree	Honge mara	March to May	N
62	<i>Randia dumetorum</i> (Rubiaceae)	Bush randia	Khare mara	April to June	P
63	<i>Samanea saman</i> (Fabaceae)	Rain tree	Male mara	April to May	P
64	<i>Santalum album</i> (Euphorbiaceae)	Sandal wood tree	Chandana / Shri gandha	May to June	N
65	<i>Sapindus emerginatus</i> (Sapindaceae)	Soap nut	Antuvala	November to February	P and N
66	<i>Schleichera oleosa</i> (Sapindaceae)	Ceylon oak	Sagadi mara	February to March	N
67	<i>Strychnos nuxtovomica</i> (LOganiaceae)	Snake wood	Kasarka	February to April	P and N
68	<i>Syzygium caryophyllaeum</i> (Myrtaceae)	-	Kunta neralu	February to June	P and N
69	<i>S;zygium cumini</i> (Myrtaceae)	Indian cherry	Nerale	February to May	P and N
70	<i>Syzygium gardneri</i> (Myrtaceae)		Henneralu	March to April	P and N
71	<i>Terminalia bellerica</i> (Combretaceae)	Behera	Tari mara	February to April	N
72	<i>Terminalia chebula</i> (Combretaceae)	Gall nut	Andle kayi	March to April	N

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Sl. No.	Botanical name and Family	Common name in English	Local name	Flowering period	Pollen /nectar/ both
73	<i>Terminalia paniculata</i> (Combretaceae)	Flowering murdah	Honagalu	July to December	P and N
74	<i>Terminalia tomentosa</i> (Combretaceae)	Laurel	Matti mara	May	P and N
75	<i>Xylia xylocarpa</i> (Rosaceae)	Burma iron wood	Jambe mara	March to April	P
76	<i>Zanthoxylum rhetsa</i> (Simarubaceae)	Indian prickly ash	Jammaana kayi	June to November	N
77	<i>Ziziphus rugosa</i> (Phamnaceae)	Wild jujuba	Bile mullu hannu	January – April	N
	Herbs and shrubs				
1	<i>Anisomeles indica</i> (Lamiaceae)	Indian catmint	Karithumbi	November to January	P and N
2	<i>Antigonon leptopus</i> (Polygonaceae)	Coral creeper	Antigonum	January to December	N
3	<i>Chromolaena odorata</i> (Euphorbiaceae)	Communist weed	Durge soppu	November to February	N
4	<i>Cleome chelidonii</i> (Capparaceae)	Celandine spider flower	Habbu balli	June to October	P and N
5	<i>Hyptis suaveolens</i> (Lamiaceae)	American mint		September to November	P and N
6	<i>Mimosa pudica</i> (Mimosaceae)	Touch me not	Muttidare muni	January to December	P and N
7	<i>Ocimum americanum</i> (Lamiaceae)	Hoary basil	Jangli tulsi	August to October	P and N
8	<i>Ocimum basilicum</i> (Lamiaceae)	Basil	Tulsi	August to October	P and N
9	<i>Tribulus terrestris</i> (Zygophyllaceae)	Puncture wine	Negil-mullu	January to December	P and N
10	<i>Tridax procumbens</i> (Asteraceae)	Tridax daisy	Gabbu shaavanthi	January to December	P and N

P- Pollen source, N – Nectar source, P, N – Both Pollen and Nectar source



1. Pollen of coconut



2. Pollen of Areca catechu



3. Pollen of Acacia



4. Pollen of copper pod

4.2.2 Pollen store

Pollen collected by both yellow and black colonies was measured and the data is summarised in Table 8.

Average pollen store in the beginning of study was 21.50 and 33.00 cm² per colony for yellow and black colour morphs respectively. Pollen stored at the end of January 60.00 cm² per colony of yellow colour morphs and 66.00 cm² per colony of black colour morphs. The pollen area in colonies of both yellow and black colour morphs steadily increased and by the end of May month pollen area were 167.00 and 175.00 cm² per colony of yellow and black colour morphs respectively.

4.2.3 Honey store

Honey storing capacity of two colour morphs of *A. cerana* was studied in both yellow and black colour morphs. Data obtained by measuring honey store area in the combs of both yellow and black colour morphs at every fortnight interval is presented in Table 9.

In the beginning of this study honey stored area of yellow bee colonies was 13.00 cm² per colony and of black colonies was 12.00 cm² per colony. Later in January honey area in a yellow colony was 35.5 cm² per colony and honey area in black colonies was 32.50 cm² per colony. In May month, honey area in colonies of both the colour morphs increased and it was 426.00 and 447.00 cm² per colony for yellow and black colour morphs respectively.

4.3 Important pollen and nectar sources of yellow and black colour morphs of *A. cerana* in Sirsi taluk

To identify the important pollen and nectar sources of yellow and black colour morphs of *Apis cerana* a survey was conducted from October 2008 to May 2009 in Sirsi in the experimental area. The flora found during survey as either pollen or nectar and/or both sources are listed in Table 10. In this table, the floral sources were noted for their botanical name, local names common names in English and their flowering period.

Pollen analysis revealed that 19 tree species out of 77 were pollen yielding flora (Table 10). Of these 19 trees species, 11 were observed to be major pollen yielders, five were secondary pollen source and remaining three was identified as minor pollen yielders. Out of the 10 species of herbs and shrubs, two were identified as nectar sources and another eight species were both pollen and nectar sources.

The results of melissopalynological studies conducted revealed that *Sapindus emarginatus*, *Areca catechu*, *Canthium dicoccum*, *Careya arborea*, *Embllica officinalis*, *Canarium strictum*, *Syzygium caryophyllaeum*, *Terminalia bellerica* and *Terminalia tomentosa* were the predominant sources of honey in both yellow and black morphs of *A. cerana* in Sirsi from November 2008 to May of 2009.



Flowers of coral creeper (*Antigonon leptopus*)



Flowers of Banana (*Musa paradisiaca*)



Flowers of Gorbale (*Ixora brachiata*)

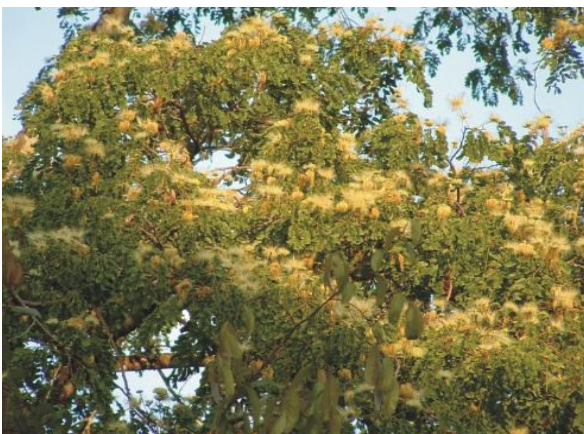
Plate.5 Contd....



Flowers of sale (*Aporosa lindleyana*)



Flowers of soap nut (*Sapindus emarginatus*)



Flowers of rain tree (*Samanea saman*)

Plate.5.Contd.....



Flowers of Gurige (*Strobilanthes* spp)



Flowers of Kuntnerale (*Syzygium caryophyllaeum*)



Flowers of Touch me not (*Mimosa pudica*)

5. DISCUSSION

Results obtained from the comparative studies on performance of two colour morphs viz; Yellow (Plain morph) and Black (Hill morph) colour morphs at Sirsi, Uttara Kannada district are discussed in this chapter. The Indian bee, *Apis cerana* Fabricius exhibits geographical variations in many parts of the world. In china *Apis cerana* can be grouped into 5 geographical colour morphs, including the Hainan, Eastern, Southern Yunnan, Aba and Xizang (Tibet) colour morphs (Peng *et al.* 1989). In Indonesia, two distinct cavity nesting morphs of bees were found. Morphometric analysis indicate that the smaller, darker morph corresponds to *Apis cerana*. The larger morph, with yellowish clypeus and legs are referred to as *Apis nigrocincta* F. (Hadisoesilo *et al.* 1995). Takahashi *et al.* (2007) reported that genetic variation among *Apis cerana japonica* isolates from Japan. In Philippines Genetic variation was estimated by restriction and sequence analysis of PCR-amplified fragments of the tRNA leu-COII region. (De La Rua *et al.*, 2000). Like this in Karnataka also, *Apis cerana* exhibits variation, which comprises two colour morphs which are geographically separated each other (Oldroyd *et al.* 2006). The yellow 'plain' type and black 'hill' type are the two geographic populations considered for the present study. These two colour morphs were compared for their performance with respect to following parameters. The parameters include (i) Foraging behaviour (ii) brood rearing activity (iii) Identification of pollen and nectar sources of yellow and black colour morphs in Sirsi taluk. The investigations carried out include foraging behaviour, brood rearing activity, pollen and nectar sources of yellow and black colour morphs of *A. cerana*.

5.1 Foraging behaviour

The variation in the foraging activity of *A. cerana* was studied for a period of eight months from October, 2008 to May 2009. The results of the study revealed that workers of yellow and black colour morphs of *A. cerana* gathered pollen and nectar throughout the year irrespective of climatic and floral conditions. The present observations are in agreement with the findings of Bisth and Pant (1968) and Verma (1983). *A. cerana* gathered pollen pellets throughout the year. The highest pollen gathering activity was recorded during January to March, where as May to June were the periods of lesser activity. The foraging activity of honey bees depends mainly on availability of bee pasturage on one hand and environmental factors like rainfall, temperature, sunshine, relative humidity and wind velocity on the other hand. In the present investigations there were marked variations in the pollen and nectar gathering activity during different seasons and even during different months in a season. Similar views were also expressed by Muttu and Verma (1985).

5.1.1 Foraging behaviour of outgoing bees in winter season

Foraging behaviour during winter season was similar for both the colour morphs and there was no significant difference statistically. The foraging activity was noticed throughout the day from morning 0600 hr to evening 1800 hr. similar foraging activity of *A. cerana* throughout the day was also noticed by Bisht and Pant (1968), Singh (1980) and Virakthamath (1990). oing bees were low in early morning at 0600 hr (18.4 bees per 5 min.) which increased grad

In October, the outg ually and reached peak at 1200 hr (84.8 bees per 5 min) and decreased gradually thereafter. But in black colour morphs, the outgoing bees were low in the late evening, at 1800 hr (22.0 bees per 5 min.) and reached peak at 1000 hr (81.0 bees per 5 min.) and decreased gradually thereafter. Similar trend was observed during November with peak at 1100 hr in black colour morphs.

But in December, the outgoing bees of yellow and black colour morphs were low in the early morning at 0600 hr (21.2 and 23.4 bees per 5 min respectively), which increased gradually and reached peak at 1000 hr (81.0 and 78.4 bees per 5 min respectively) and decreased gradually thereafter. Similar trend was observed during January with peak at 1100 hr and 1000 hr in yellow and black colour morphs respectively. The variation in the temperature in winter months probably reduced the number of outgoing bees in morning

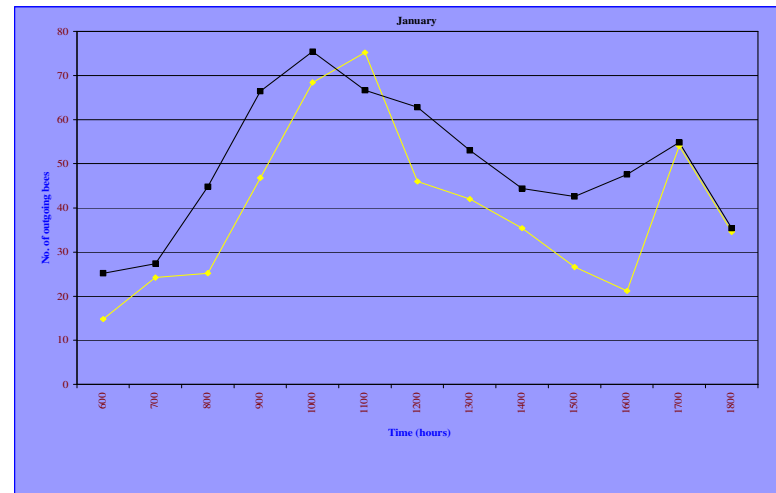
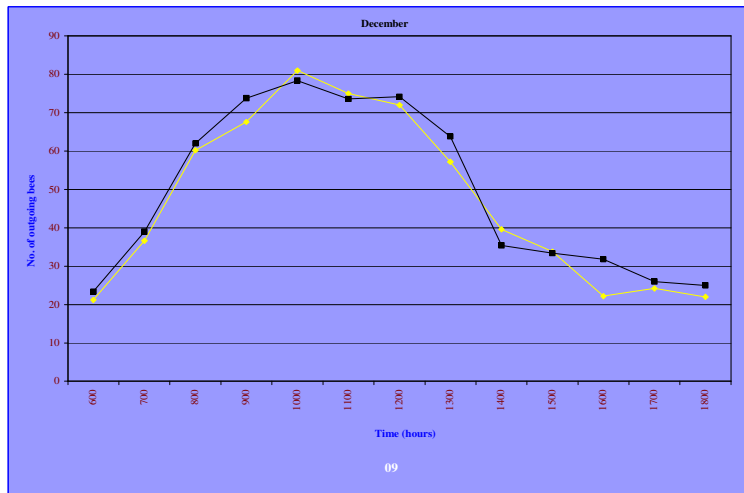
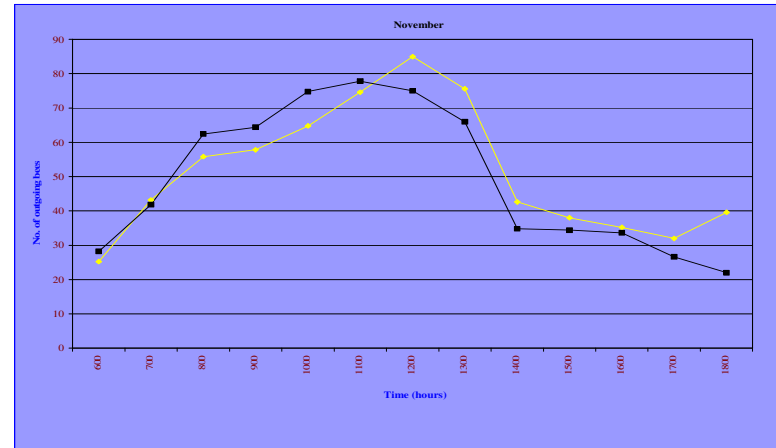
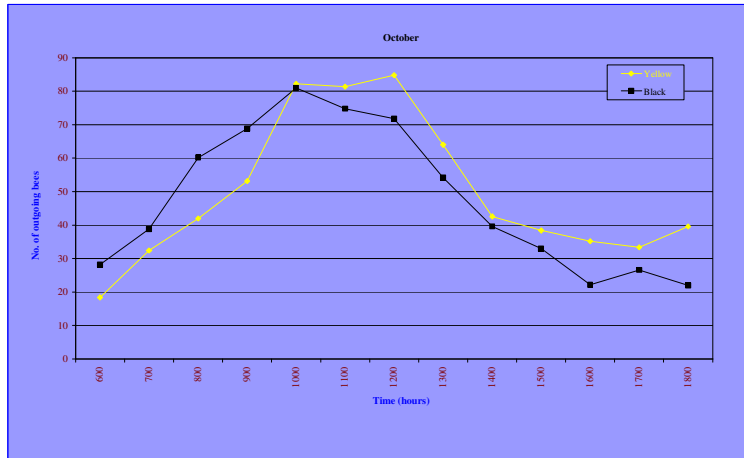


Fig. 2: Activity of out going bees of yellow and black colour morphs of *A. cerana* during winter season of 2008-09

hours significantly. This delayed the foraging activity in morning hours in both the colour morphs.

5.1.2 Foraging behaviour of outgoing bees in summer season

In yellow and black colour morphs of *Apis cerana* workers foraged throughout the summer season irrespective of climate and floral conditions. In February, the number of outgoing bees of yellow and black colour morphs was low in the morning at 0600 hr (34.8 and 35.6 bees per 5 min. respectively), which increased gradually and reached peak at 1000 hr (97.6 and 93.4 bees per 5 min. respectively) in yellow and black colour morphs.

In March, the number of outgoing bees of yellow and black colour morphs was very low at 1400 hr (22.4 bees per 5 min.) in both the colour morphs. But peak activity was observed at 0800 hr with 82.2 and 85.8 bees per 5 min. in yellow and black colour morphs respectively. Similar trend was observed in the month of April with peak at 0800 hr and 0900 hr (82.2 and 83.4 bees per 5 min. respectively)

In the month of May, the number of outgoing bees of yellow and black colour morphs was very low at 1300 hr (23.2 and 22.6 bees per 5 min. respectively). With a peak at 0900 hr (85.2 bees per 5 min) in yellow colour morphs and at 0800 hr (76.2 bees per 5 min.) in black colour morphs.

Although, there is no significant difference between yellow and black colour morphs for number of outgoing bees. But black bees start their foraging work earlier than yellow bees. Yellow bees start going out later to black counterpart, but continue to work for longer time as day progressed.

During summer months the number of outgoing workers was higher in both yellow and black colour morphs. Temperature in early morning hours in summer induced the foragers to start work early and continued till six o'clock in the evening. However, there was no significant difference between yellow and black bees which go out for foraging only during afternoon hours recorded less number of outgoing bees as compared to morning and evening hours. Temperature played a major role in deciding the outgoing foragers activity. Till the end of May bee activity of both the colour morphs was higher in comparison with winter months.

There were no studies on the comparison of yellow and black colour morphs of *A. cerana* in India. Verma and Dulta (1986) compared the foraging behaviour of *A. mellifera* and *A. cerana* on apple flowers. *Apis cerana* workers started their activity significantly earlier in the morning than *A. mellifera* and their activity ceased late in the evening hours.

5.1.3 Pollen foragers of yellow and black colour morphs in winter season

The pollen foragers during all the four months of winter season also followed similar pattern as that of outgoing bees. In present study the peak activity of pollen foragers was noticed at 0900 hr (35.8 and 35.2 bees per 5 min. respectively) in yellow and black colour morphs in the month of October (Table 3).

In the month of November, December and January the peak activity of pollen foragers noticed at 1000 hr and 0900hr, 0900 hr and 0900 hr and 1600 hr and 1100 hr in yellow and black colour morphs respectively.

The increase and decrease in the peaks of pollen foragers were of smaller magnitude. This variations in the peak pollen foraging activity periods in winter months might be due to changes in the weather factors mainly temperature and relative humidity during different months. Holi and virakthamath (1997) have also arrived at similar conclusion.

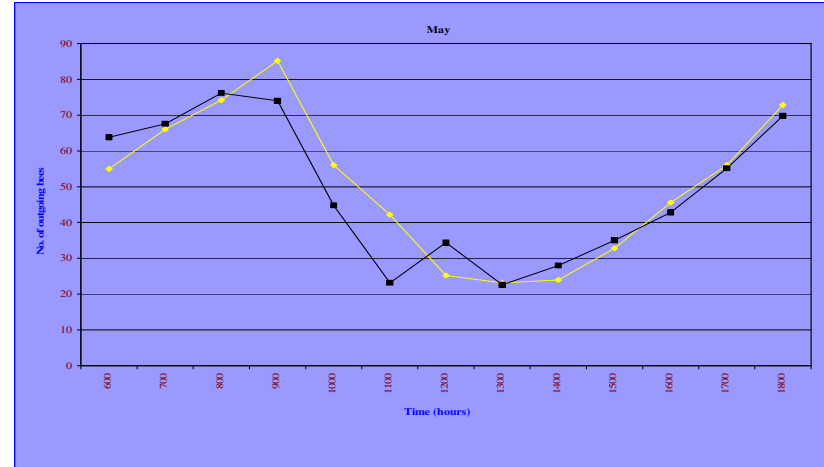
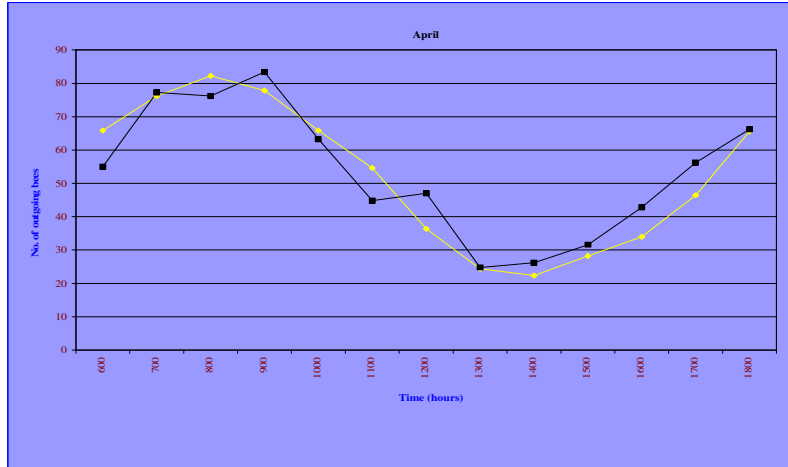
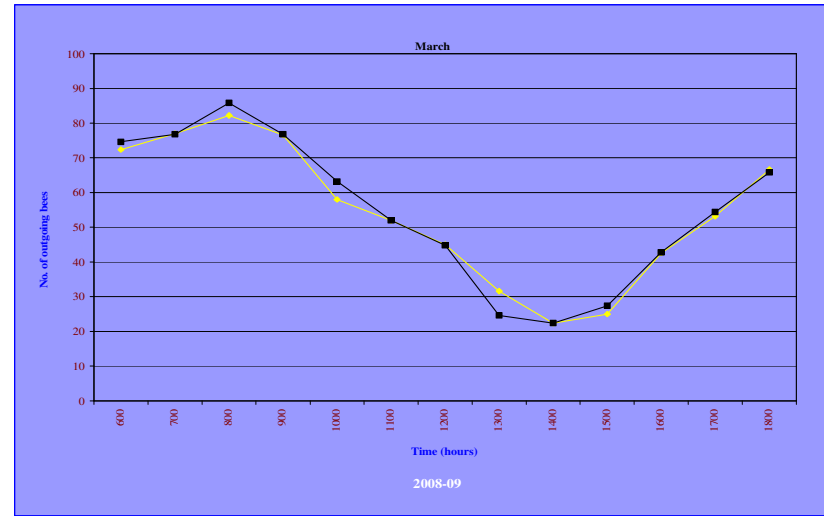
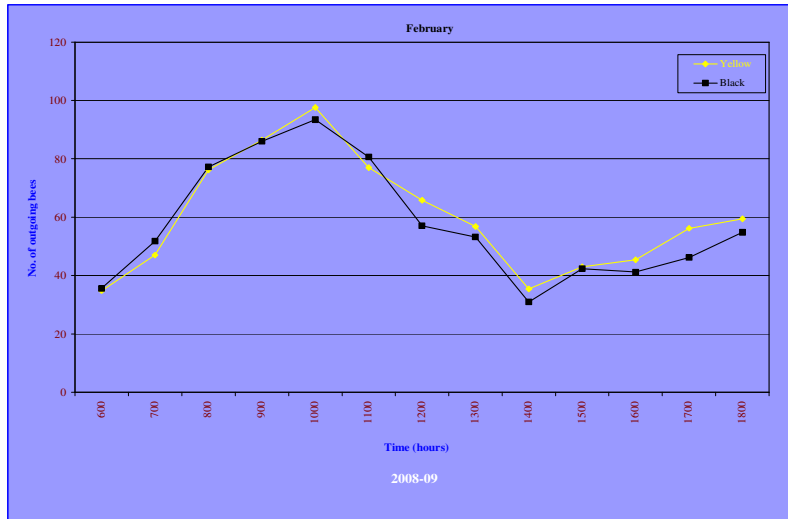


Fig. 3: Activity of outgoing bees of yellow and black colour morphs of *A. cerana* during summer season of 2008-09

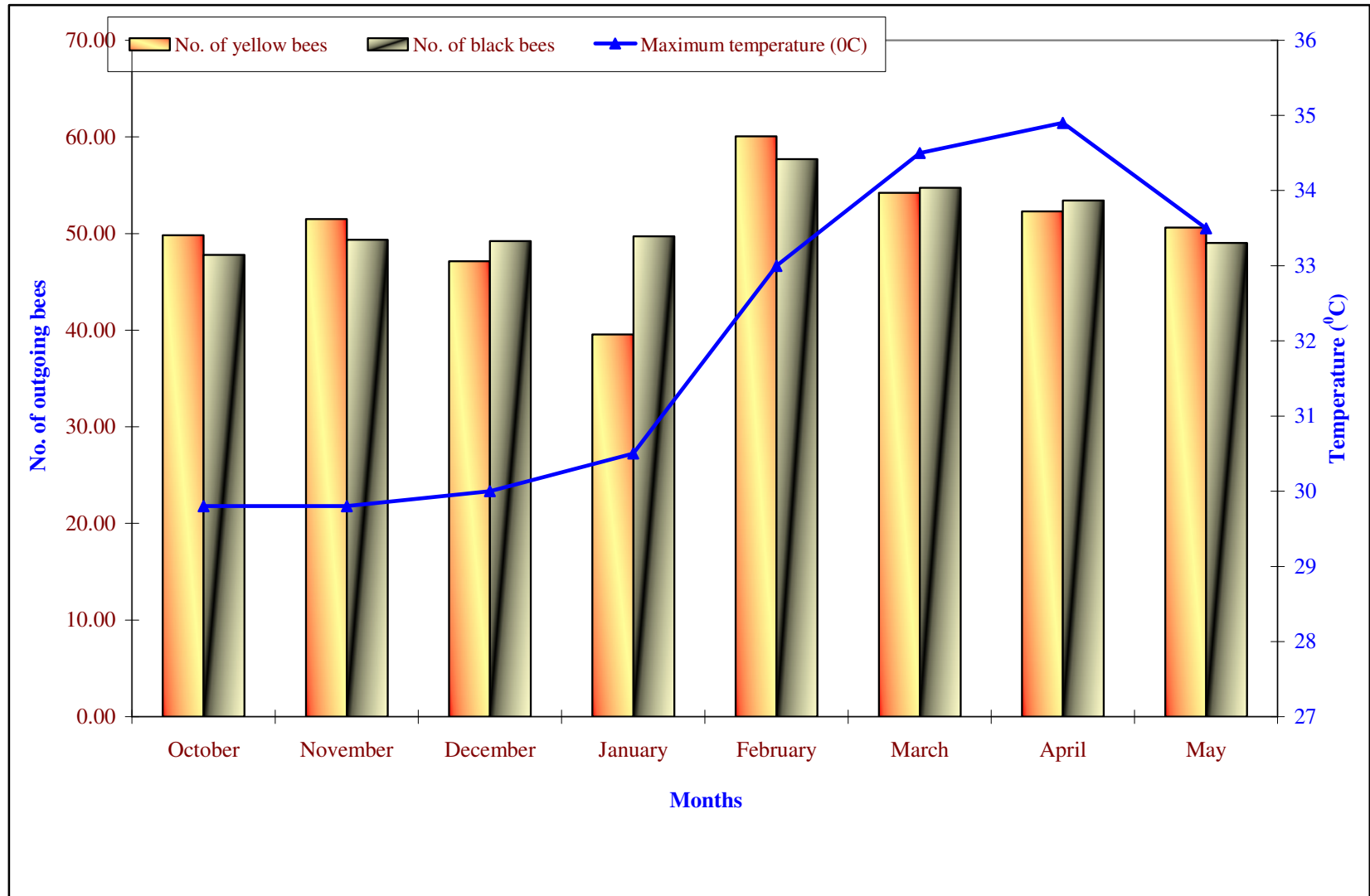


Fig. 4: Influence of temperature on outgoing bees of yellow and black colour morphs

5.1.4 Pollen foragers of yellow and black colour morphs in summer season

In summer February, March, April and May, the peak pollen activity at 0800 hr and 0900 hr, 0700 hr and 0700 hr, 1600 hr and 0800 hr and 0700 hr and 0700 hr in both yellow and black colour morphs of *A. cerana* respectively. The low activity of all the pollen foragers during noon was mainly due to prevailing high temperature in Table 3 and 4.

Pollen gathering activity of both the colour morphs was found on par with each other. Both the bees performed in a similar manner with the number of pollen gatherers activity of yellow colour morphs bees as compared to black bees.

Pollen gathering activity was significantly less during afternoon hours and high in morning and evening sessions. This phenomenon applied equally for both colour morphs.

During summer months of February, March, April and May pollen gathering activity was higher as compared to winter months. Pollen gathering activity of both the colour morphs increased with the increase in day temperature. Pollen gathering activity reduced in afternoon hours from 1200 to 1500 hr and high in morning and evening sessions.

The results of the present investigations are in the agreement with the finding of Mattu and Verma (1985), Holi and Virakthamath (1997) and Sattigi and Lingappa (1993) who also observed two peaks of pollen foraging activity during summer.

There were no reports on the comparative studies on yellow and black colour morphs of *Apis cerana*. However, Rahman and Rahman (1993) revealed that stored pollen area in colonies of *A. c. indica* is more than *A. mellifera* colonies.

5.1.5 Nectar foragers of yellow and black colour morphs in winter season

The data on nectar collector indicates that, the nectar foragers were always more than the pollen foragers during winter season in both yellow and black colour morphs of *A. cerana*. This is because the pollen availability was maximum during morning and decreased in the afternoon, consequently some pollen foragers shifted to nectar collection and they resumed pollen collection the next day morning. The results of the present study revealed that, nectar foragers of yellow bees comparatively more than the black colour morphs of *A. cerana*. But they are not significantly differing each other throughout the season.

5.1.6 Nectar forgers of yellow and black colour morphs in summer season

In the summer season also the data revealed that, the nectar foragers were always more than the pollen foragers in both yellow and black colour morphs of *A. cerana*. Probably, this increased activity of nectar gatherers may be due to coinciding of flowering activity of plants having more of nectar than pollen.

Nectar gathering activity of both yellow and black colour morphs was observed in winter and summer months. There was no significant difference for the number of nectar gathering workers in both the season, throughout the study for both colour morphs. Variation seen was only in the day temperature which influenced the number of nectar gatherers. There was higher forager activity in morning and evening as compared to afternoon hours. Nectar gatherers increased constantly and reached highest towards the end of summer season.

5.2 Brood rearing activity of yellow and black colour morphs of *A. cerana*

The brood rearing activity was studied from October 2008 to May 2009 in both yellow and black colour morphs of *A. cerana*.

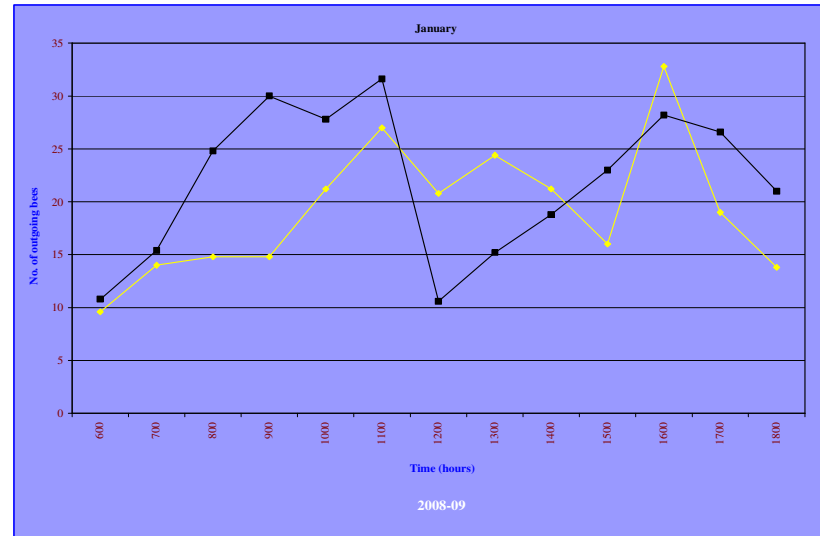
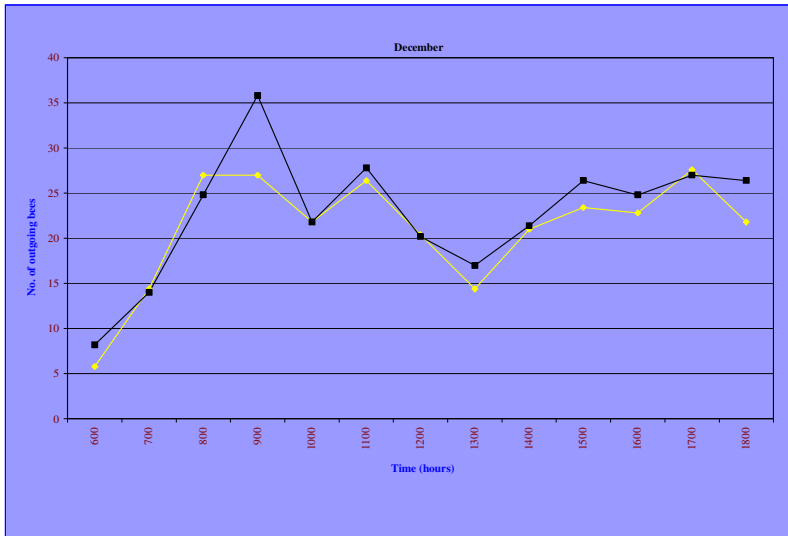
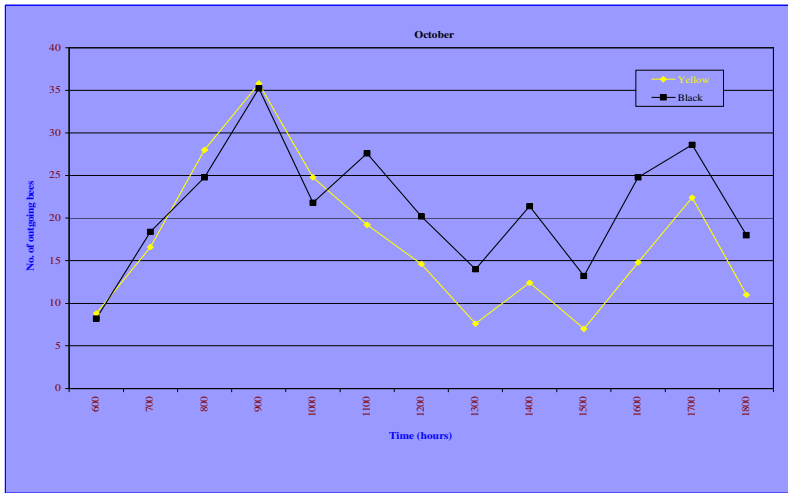


Fig.5. Activity of pollen foragers of yellow and black colour morphs of *A. cerana* during winter season of 2008-09

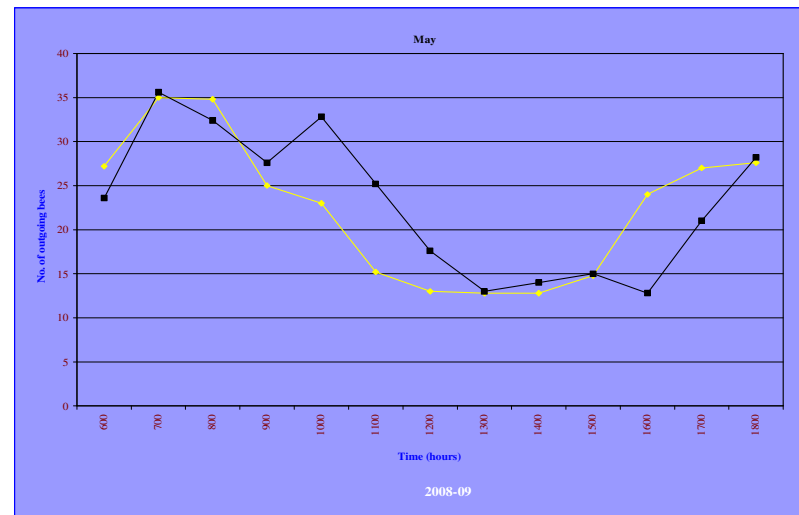
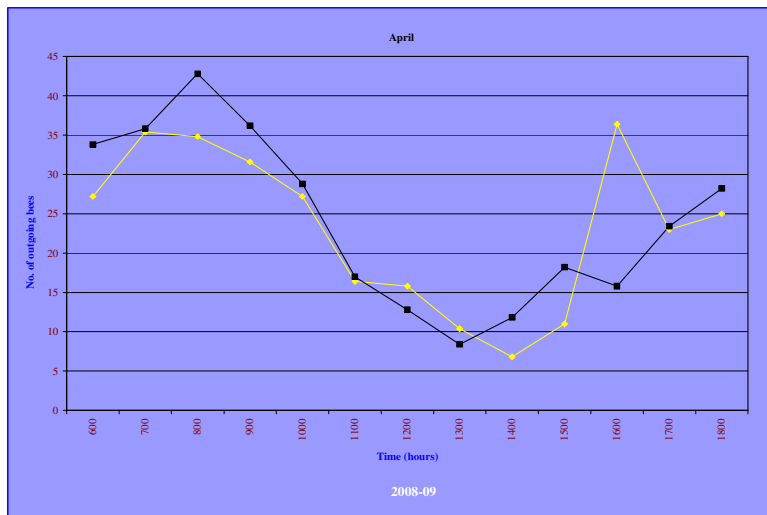
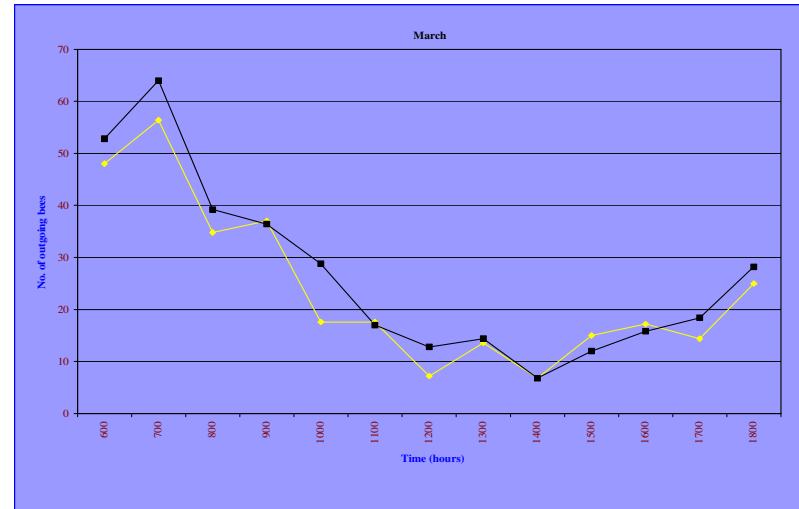
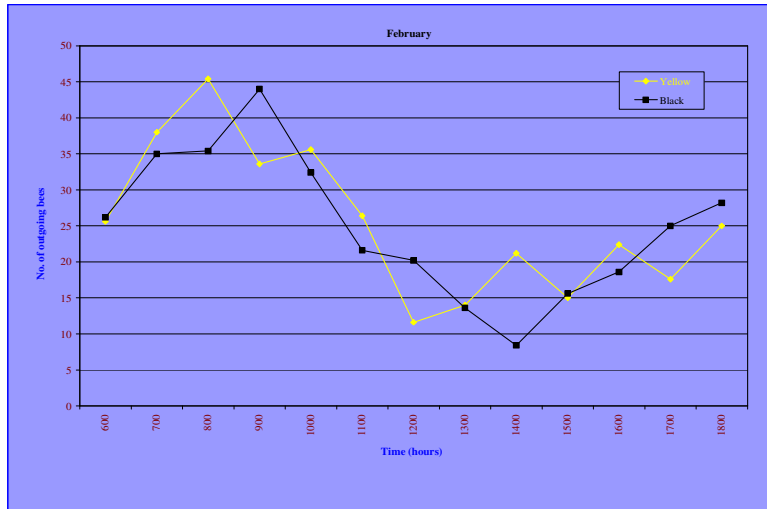


Fig. 6: Activity of pollen foragers of yellow and black colour morphs of *A. cerana* during summer season of 2008-09

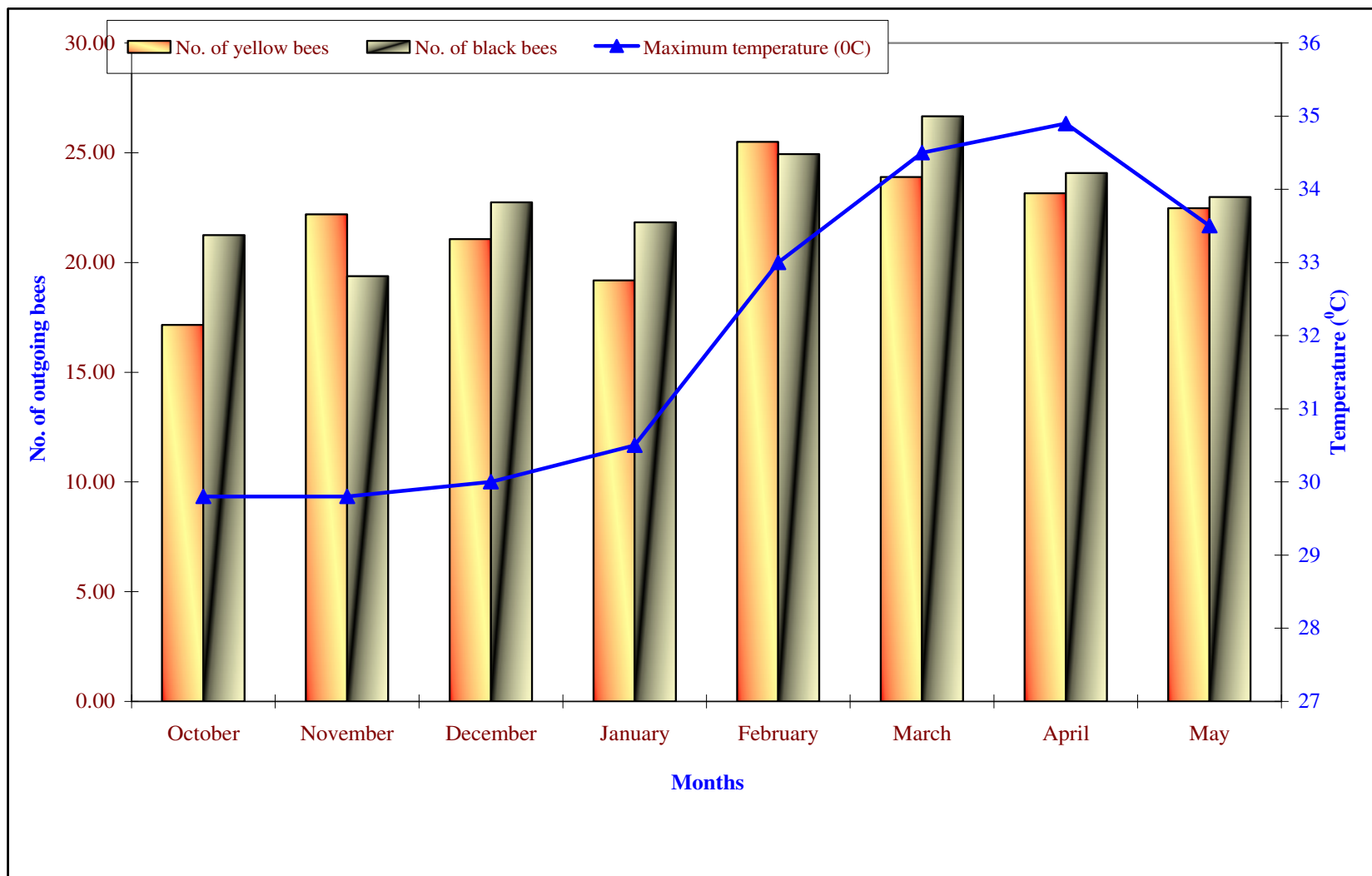


Fig. 7: Influence of temperature on pollen foragers of yellow and black colour morphs

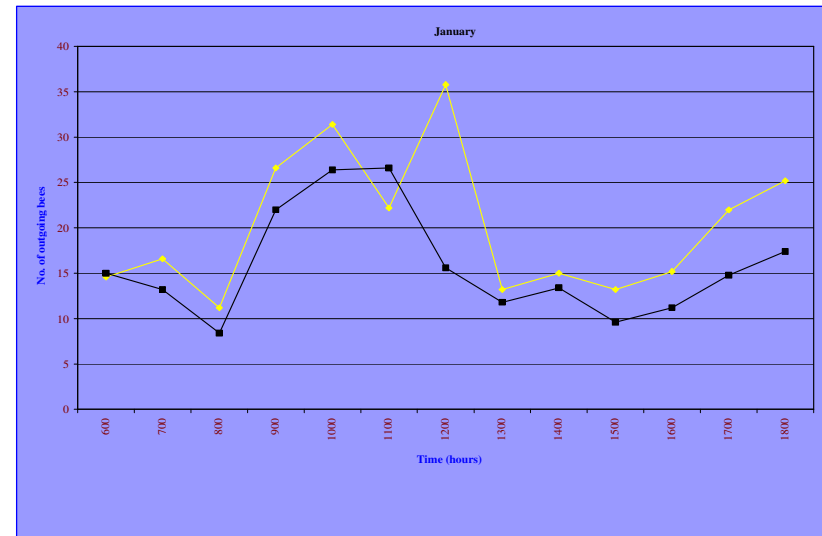
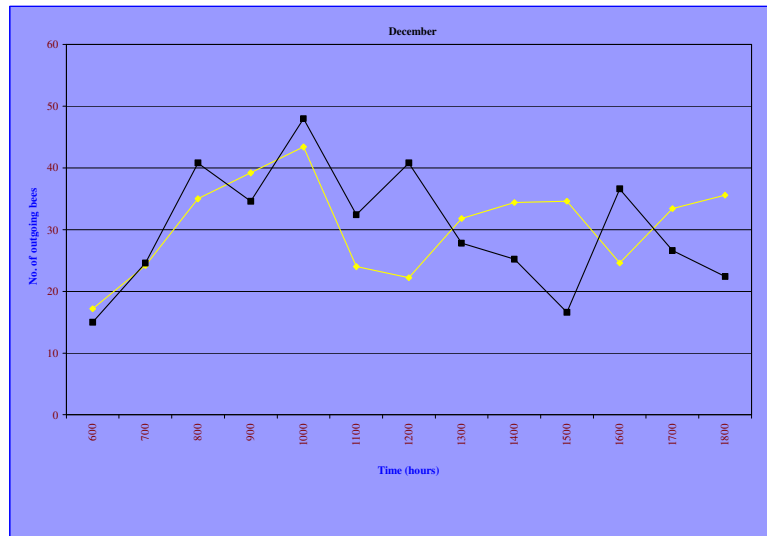
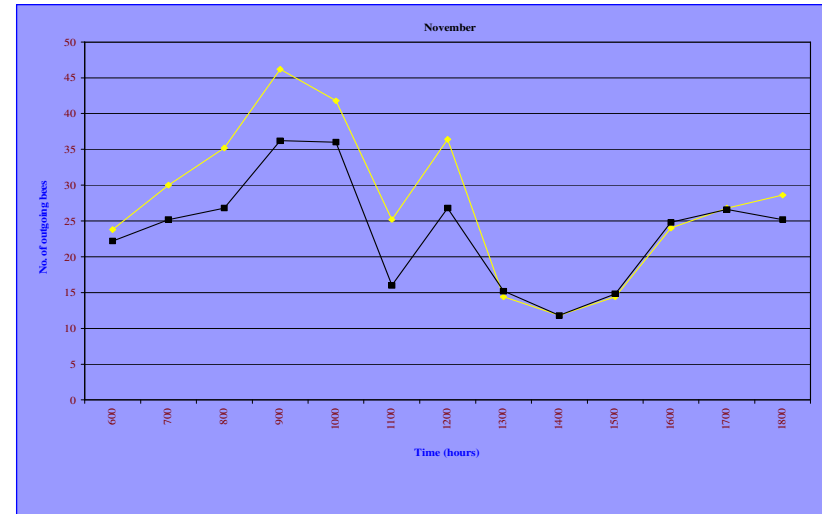
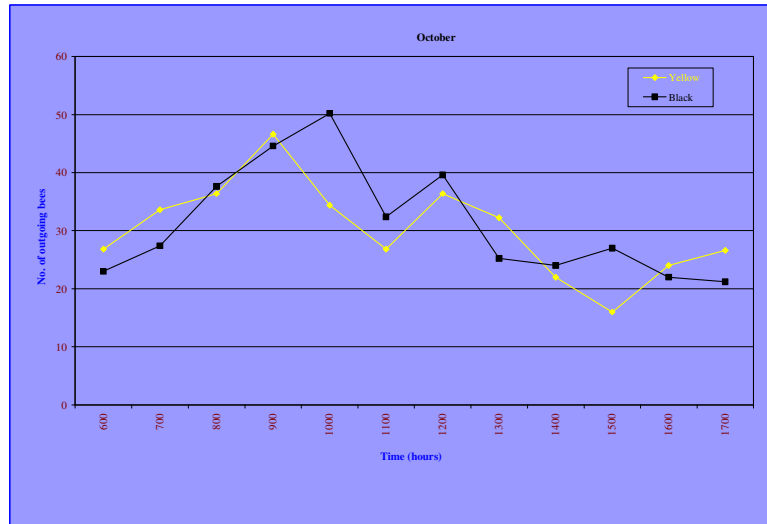


Fig. 8: Activity of nectar foragers of yellow and black colour morphs of *A. cerana* during winter season of 2008-09

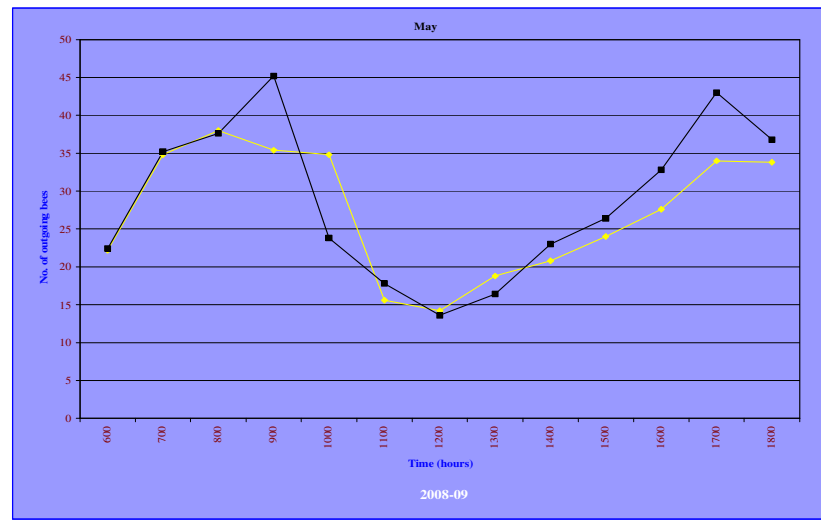
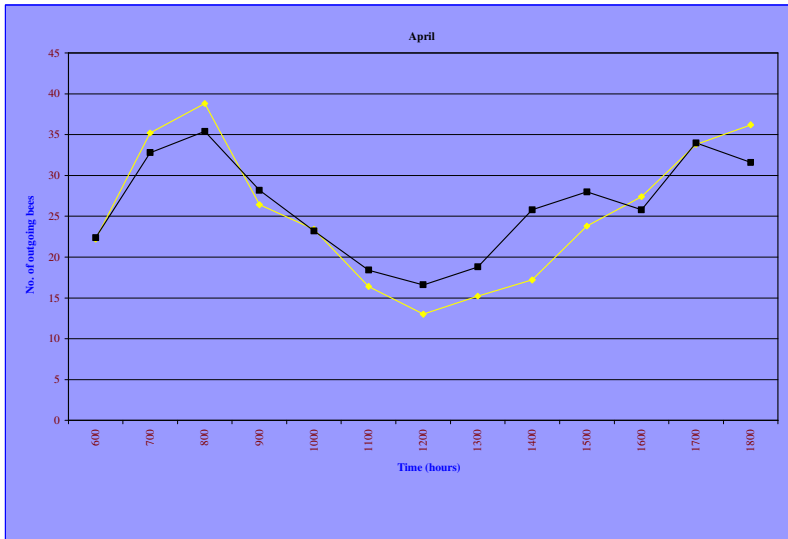
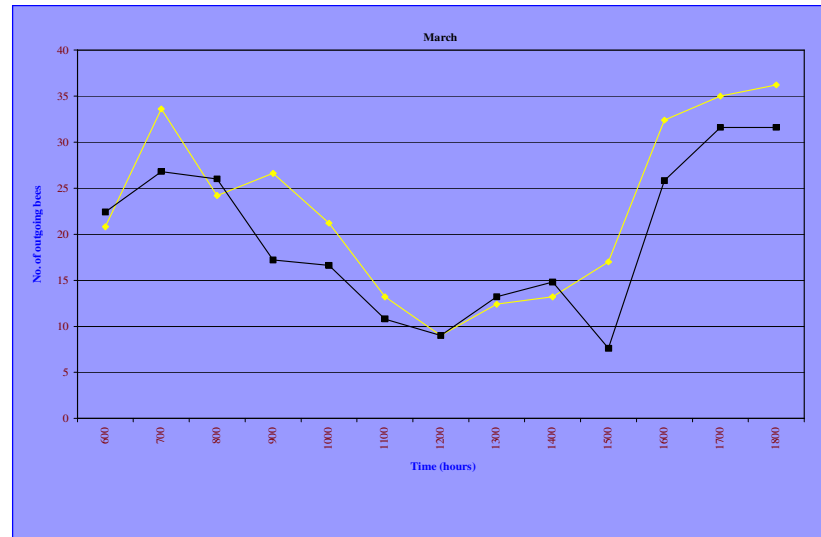
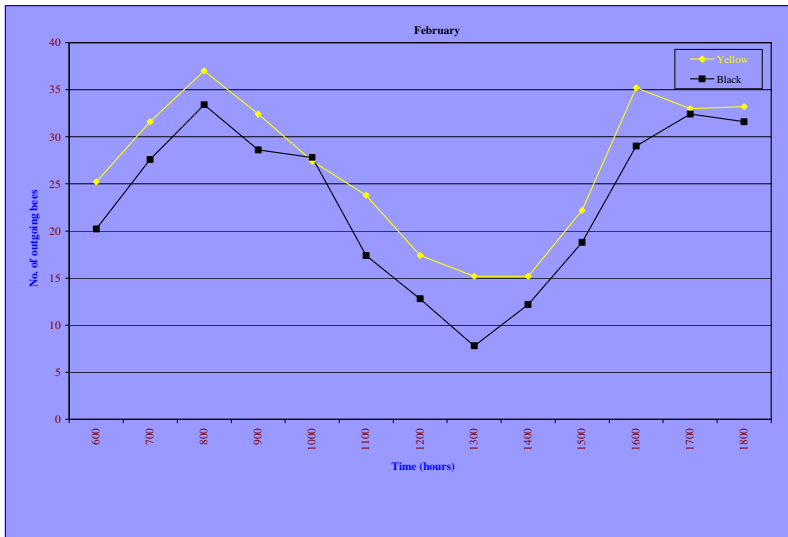


Fig. 9: Activity of nectar foragers of yellow and black colour morphs of *A. cerana* during summer season of 2008-09

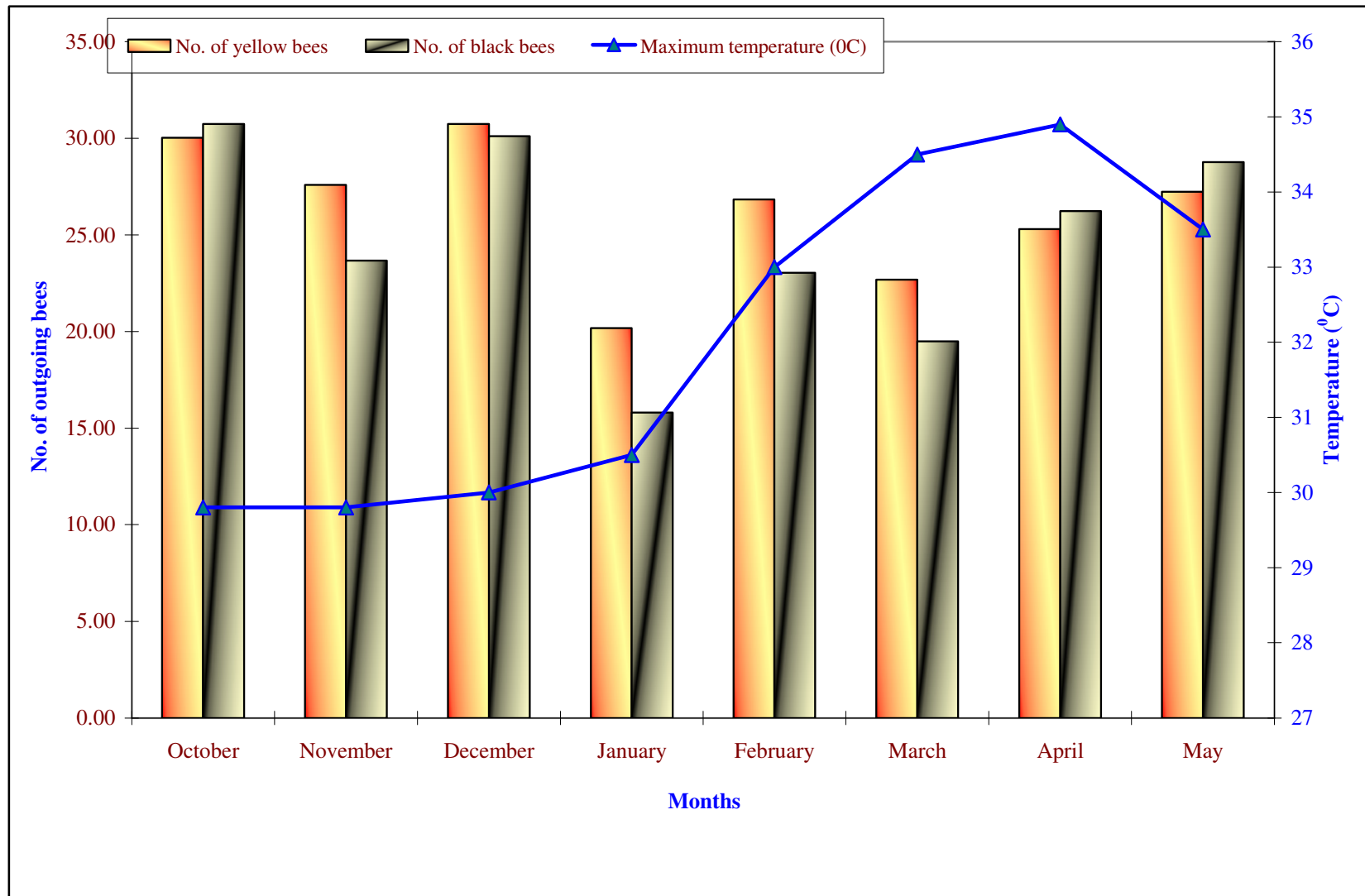


Fig. 10: Influence of temperature on nectar foragers of yellow and black colour morphs

5.2.1 Brood area

During October 2008, the colonies having a brood area of $226.50 \pm 2.85 \text{ cm}^2$ and $236.50 \pm 2.24 \text{ cm}^2$ in yellow and black colour morphs respectively. The frames with brood increased gradually till May 2009, and reaches upto $1029.50 \pm 3.75 \text{ cm}^2$ and $1054.00 \pm 2.85 \text{ cm}^2$ in yellow and black colour morphs respectively. This shows that there a gradually increases in both the colour morphs. Brood area developed in each colony of both yellow and black colour morphs was no significant and both colour morphs performed equally exhibiting similar brood growth. However, brood development varied with temperature and season. Brood development increased constantly with season advancement starting from winter months of October and reached maximum brood growth at the end of May in summer. Verma (1998) revealed that the average brood area was maximum in October followed by March, April, November and September; this shows that the brood area was directly related to the availability of pollen grains.

Shah and Shah (1981) compared the egg-laying capacity of *Apis cerana* in Kashmir higher than exotic *Apis mellifera*. Maximum brood rearing was reported in May and it was minimum in January. Rana and Goyal (1994) compared the brood rearing activity of *A. mellifera* and *A. cerana* and observed that Indian honey bees reared more brood as compared to that of exotic species, but in overall performance latter bee showed a lesser brood rearing activity. But like this there were no studies on the yellow and black colour morphs of *A. cerana*.

5.2.2 Pollen area

In October 2008, the pollen area of the colony was $21.50 \pm 2.85 \text{ cm}^2$ and $33.00 \pm 2.09 \text{ cm}^2$ for yellow and black colour morphs respectively. The frames with pollen increased gradually and reached $167.00 \pm 2.09 \text{ cm}^2$ and $175.00 \pm 4.50 \text{ cm}^2$ in yellow and black colour morphs in May 2009.

Comparative performance of pollen gathering activity in terms of pollen area in colonies of both yellow and black colour morphs exhibited no significant difference. Both the colour morphs performed in similar way in increasing the pollen store area.

However, pollen store area increased to the maximum level at the end of summer season in May month. Pollen store depended mainly on availability of pollen and that coincided with flowering season of different pollen source plants. There was continues availability of pollen in summer months as compare to winter months. So higher the pollen store area in colony exhibited higher the brood development. This phenomenon was similar in both the colour morphs. Similarly trend was seen in Coimbatore, *Apis cerana indica* stored greater amount of honey and pollen in February and April months (Ramachandran and Mahadevan, 1950). Bisht *et al.* (1982) revealed that brood rearing of *Apis cerana* was highest in February – May with a minimum in December. Pollen storage was highest in April – July under Delhi conditions.

5.2.3 Honey area

Honey area also increased gradually like in pollen area in both the yellow and black colour morphs of *Apis cerana*. But in black colour morphs there is a sudden increase in the honey area as compared to yellow colour morphs in May month. In May month honey area was 426.00 ± 2.85 and $447.00 \pm 2.09 \text{ cm}^2$ in yellow and black colour morphs.

Comparative performance of nectar gathering activity in terms of honey area in colonies of both yellow and black colour morphs exhibited no significant difference. Both the colour morphs performed in similar way in increasing the honey store area.

However, honey store area increased to the maximum level at the end of summer season in May month. Honey store depended mainly on availability of nectar and that coincided with flowering season of different nectar source plants. There was continues

availability of nectar in summer months as compare to winter months. Higher the honey store area in colony was coupled with higher brood development. This phenomenon was similar in both the colour morphs. Present investigations are in line with the findings of Naim and Phadke (1976) reported maximum honey storing activity of *Apis cerana* during March – April at Pusa (Bihar).

5.3 Pollen sources

The floral sources of Sirsi taluk was surveyed from October 2008 to May 2009 and identified the plants as either pollen or nectar sources and some as both nectar and pollen sources.

The bee plants identified (Table 10) included 77 tree species, 10 shrubs and herbs. There were 19 number of plants which served as only pollen sources. Out of this 19 trees species recorded, 11 were catagorised as major, five secondary and three minor sources of pollen. The plants like *Aporosa lindleyana*, *Ailanthus triphysa*, *Cocos nucifera*, *Careya arborea*, *Flacourtia montana*, *Peltoforum ferrugenium*, *Sapindus emerginatus*, *Syzygium caryophyllaeum*, *Syzygium cumini*, *Tridax procumbens* and *Terminalia tomentosa*. *Artimisia* sp, *Guizotia abyssinica* Cass, *Brassica nigra* Koach, *Mimosa pudica* L. and *Tridax procumbens* L. were recorded as major pollen sources of *A. cerana* by Agashe and Scinthia (1997) in Bangalore. Similar study by Holi and Virakthamath (1997) revealed that 38 species as pollen sources of *A. cerana* in dharwad.

The herbs and shrubs are identified as both pollen and nectar sources of yellow and black colour morphs of *Apis cerana*.

5.4 Nectar sources

Pollen analytical studies on honey samples of *A. cerana* revealed that seven samples were unifloral and three were multifloral. Similar studies were conducted at Himachal Pradesh by Muttu *et al.* (1997) indicated that out of 30 samples 13 were unifloral and 17 were multifloral.

The studies on nectar source also indicated that *Sapindus emerginatus* was the predominant pollen type during November. In December and January, *Areca catechu*, and *Canthium dicocum* were the predominant pollen type. But in February, *Areca catechu*, *Embllica officinalis*, and *Careya arborea* was the predominant pollen type. *Areca catechu*, *Canarium strictum*, *Syzygium caryophyllaeum* and *Terminalia bellerica* were the predominant sources of pollen type in March month. *Syzygium caryophyllaeum* and *Terminalia tomentosa* are the predominant sources of pollen type in April and May period.

Similar studies on 13 honey samples collected from Uttar Pradesh revealed the presence of Euphorbiaceae, Myrtaceae, Liliaceae, Rosaceae, Meliaceae, Brassicaceae and *Rumax* sp as dominant sporomorphs in honey (Sharma and Nair, 1965). Holi and Virakthamath (1997) identified that *Eucalyptus* spp, *Bignonia venusta* Miq., *Bauhinia purpurea* L., *Filicum decipens*, *Moringa oleifera* Lam., *Azadirachta indica* Juss. and *Pithecollobium dulce* Benth. were predominant pollen type in the Dharwad region.

6. SUMMARY AND CONCLUSION

The Asian honey bee, *Apis cerana* Fabr. is a predominant one in Karnataka among other species such as *A. dorsata*, *A. florea*, *Trigona*, *A. mellifera*. The *A. cerana* population in Karnataka is composed of two distinct colour morphs: the yellow 'plain' morph and the black 'hill' morph (Oldroyd *et al.*, 2006). A study was undertaken to know the comparative performance of these two colour morphs which are geographically separated in Karnataka state. Performance of two populations was compared with respect to parameters like foraging behaviour, brood rearing activity. There was also a study to identify the bee plants of both the colour morphs. The geographical variation among the populations of *A. cerana* in other parts of the world revealed major and important groups of Indian bees. The Indian bee, *A. cerana* species possess a distinct variability between geographical populations of Japan has been established and proved through DNA sequences of the mitochondrial DNA non-coding region (Takahashi *et al.* 2007). Geographical races of *A. cerana* in china have been reviewed by Peng *et al.* (1989). In India also the geographic variations of *A. cerana* has been shown by Oldroyd *et al.* 2006. According to Oldroyd *et al.*, in South India there are two geographically separated distinct populations of *A. cerana* and they differ at molecular level. The two populations are called as 'hill morph' which are black in colour and restricted to higher elevations and seen in western ghats ecosystem, and the other as 'plain morph' which are yellow in colour and restricted to plain areas of lower elevation. These two distinct populations were studied at Agricultural research station, Sirsi in Uttara Kannada district of Karnataka. Present investigation was aimed at comparing the performance are (i) foraging behavior (ii) brood rearing activity and (iii) identifying the pollen and nectar sources of two colour morphs in Sirsi taluk.

The results of comparison study showed that the black hill morph and yellow plain morph performed on par with each other with respect to all parameters like Foraging activities, and brood rearing activities. There was no significant difference when stastically analysed for number of outgoing bees, number of pollen gatherers and number of nectar gatherers activity for both the colour morphs.

The brood rearing activity of both the colour morphs was on par with each other. The two colour morphs behaved similarly in brood rearing activity.

The pollen and nectar area also exhibited non significant difference between two colour morphs.

A total of 77 tree species and 10 shrubs and herbs were identified as the bee plants. The major pollen sources identified in Sirsi include *Aporosa lindleyana*, *Ailanthus triphysa*, *Cocos nucifera*, *Careya arborea*, *Flacourtia Montana*, *peltorum ferrugenum*, *Sapindus emerginatus*, *Syzygium caryophyllaeum*, *Syzygium cumini*, *Tridax procumbens* and *Terminalia tomentosa*. Nineteen plants served only as pollen sources. The number of plants identified as only nectar source was 30 species and 27 number of plants was identified as both nectar and pollen source. Majority of bee plants identified had the flowering period from January to May. Among the 10 shrubs and herbs 2 are nectar yielders and 8 species are both pollen and nectar yielders

Conclusions

Based on observations on foraging behaviour, brood rearing activities and the floral sources identified for both the colour morphs of *A. cerana* Fabricius of Karnataka, it is clearly showed that there is no significant difference in the performance of both the colour morphs when studied under Sirsi conditions. Although, there exists a mitochondrial DNA variation and reproductive isolation for both the geographical populations of Karnataka, they have similarity in foraging and brood rearing behaviour. Hence, the yellow 'plain' colour morph can be successfully introduced to 'hill' conditions in Western Ghats region of Uttara Kannada, where there is assured flora availability for pollen and nectar. Also, based on results of long term study conducted Agricultural Research station, Sirsi on introduction of yellow bees to hill areas of Sirsi, the two colour morphs are identical in foraging and brood rearing activities.

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Appendix

Appendix I: Weather data for the year 2008-09

Months	Rainfall (mm)	Relative humidity (%)	Maximum temperature (°C)	Minimum temperature (°C)
October 08	40.1	86.0	29.8	19.3
November 08	19.4	80.4	29.8	15.7
December08	9.1	77.6	30.0	14.8
January 09	0.0	14.0	30.5	14.0
February 09	0.0	79.8	33.0	15.3
March 09	32.3	89.0	34.5	19.2
April 09	9.9	84.0	34.9	20.5
May 09	51.7	81.0	33.5	21.9
Total	162.5			

COMPARATIVE STUDIES ON THE PERFORMANCE OF YELLOW AND BLACK COLOUR MORPHS OF *Apis cerana indica* F. AT SIRSI, KARNATAKA

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2009

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ABSTRACT

A. cerana population in Karnataka is composed of two distinct colour morphs: the yellow morph and the black morph. The two populations are called as 'hill morph' which are black in colour and restricted to higher elevations and seen in Western Ghats ecosystem, and the other as 'plain morph' which are yellow in colour and restricted to plain areas of lower elevation.

The results of comparison study showed that the black hill morph and yellow morph performed on par with each other with respect to all parameters of foraging activities and brood rearing activities. There was no significant difference between both colour morphs when statistically analysed for number of outgoing bees, number of pollen gatherers and number of nectar gatherers activity. The brood rearing activity of both colour morphs was on par. Brood rearing parameters like pollen area and nectar area exhibited no significant difference between two colour morphs.

The bee plants identified in Sirsi include *Aporosa lindleyana*, *Ailanthus triphysa*, *Cocos nucifera*, *Careya arborea*, *Flacourtia Montana*, *Peltoforum ferrugenium*, *Sapindus emerginatus*, *Syzygium caryophyllaeum*, *Syzygium cumini*, *Tridax procumbens* and *Terminalia tomentosa* among 77 tree species, 10 shrubs and herbs. There were 19 species of plants which served as only pollen sources. The number of plants identified as only nectar source was 30 tree species and 27 number of plants was identified as both nectar and pollen source. Majority of bee plants identified had the flowering period from January to May. Among the 10 shrubs and herbs 2 are nectar yielders and 8 species are both pollen and nectar yielders.

On par performance of yellow colour morph with local black colour morph at Sirsi indicated that yellow colour morph can be successfully introduced to hill conditions in Western Ghat region of Uttara Kannada, where there are assured flora sources for pollen and nectar.