Acta Entomology and Zoology

E-ISSN: 2708-0021
P-ISSN: 2708-0013
www.actajournal.com
AEZ 2024; 5(2): 202-212
Received: 17-08-2024
Accepted: 25-09-2024

Ballachanda Monnappa Nalini
Department of Zoology, Field Marshal K. M. Cariappa College, Madikeri, Kodagu District, Karnataka, India

S Basavarajappa
DOS in Zoology, University of Mysore, Manasagangotri, Mysuru, Karnataka, India

Corresponding Author:
S Basavarajappa
DOS in Zoology, University of Mysore, Manasagangotri, Mysuru, Karnataka, India

Floral source and pollen calendar of pollinating insects amidst agro-ecosystems of Kodagu district, Karnataka, India

Ballachanda Monnappa Nalini and S Basavarajappa

DOI: https://doi.org/10.33545/27080013.2024.v5.i2c.172

Abstract
Plants which bear flowers provide pollen and nectar to nourish varieties of insect species and in turn get reward in the form of pollination. The floral source, blooming period of flowering plants, pollen calendar, insect species benefiting from the flora during different seasons are ongoing mysterious events elucidates the true biological activity existing between plants and animals amidst every agro-ecosystems in the nature. To record such an amazing event amidst the Kodagu district (12.15[1]-12.45[1]N latitude, 75.25[1]-76.14[1]E longitude and altitude 390 to 5,627 ft) during 2021 to 2023 present investigation was conducted by following standard methods at randomly chosen 12 different agro-ecosystems. Results revealed that 120 plants which belong to 24 orders of 54 plant families provided floral source to various insect pollinators. Asteraceae family members were more predominant and it was followed by plant species belong to the family Fabaceae, Rubiaceae, Lamiaceae, Euphorbiaceae, Myrtaceae and Poaceae which were common in their occurrence with varied relative abundance. However, *Alternathera sessilis*, *Oryza sativa*, *Duranta rapens*, *Chrysanthnemum* sp., *Sphagneticola trilobata*, *Coffea cnephora*, *Cosmos sulphureus*, *Emilia sonchifolia* relative abundance was high (3.43 to 11.2). *Aster tataricus* and *Carica papaya* have provided floral source to insect pollinators throughout the year and remaining 118 flowering plant species which belong to different families have extended the floral source to the insect pollinators during different months in a year. The foraging value such as nectar (N) and pollen (P) source was more, moderate and less and accordingly designated them as N1, N2, N3 and P1, P2 and P3 plants, which provided considerable amount of floral source constantly and consistently to various insect pollinators at different agro-ecosystems. This kind of investigations help assess the insect pollinator's diversity and distribution amidst different agro-ecosystems based on the available floral source during different seasons. Such type of observations are beyond the limit of present study, however, attempts will be made to publish on insect pollinators elsewhere. Hence, present investigation provided an insight on the status of floral source and pollen calendar of pollinating insects of different agro-ecosystems of Kodagu district of Karnataka state.

Keywords: Pollinating insects, floral source, pollen calendar, agro-ecosystems

Introduction
Plants which bear flowers are essential to the life of several insect species for a variety of reasons. Many insect species rely heavily on flowering plants for their food, nourishment, nesting and breeding activities. In turn, flowering plants would get reward in the form of pollination by insects that could help conduct propagation in plants. Insect pollinators forage on variety of flowering plant species which grow differently amidst varied ecological conditions. Understanding the kinds of plants which attract different species of insect pollinators, when various flowering plant species bloom, how long they bloom and nutritional resources available to pollinators in terms of both space and time (Bhatta and Kumar, 2021) [6] is vital for the life of both plants and insect pollinators and thus it end up with mutualistic association.

Flowering plant types and their flowering duration differ from one place to another due to variation in prevailed physiography, geography and ecological conditions. Besides, source of nectar and pollen also vary among the different species of flowering plants. Nectar is the sweet liquid produced by plants as floral and extra floral resources and it is the main carbohydrate source for energy to insect pollinators, while pollen is protein source for insect pollinators in general and bees in particular (Abrol, 1997) [1]. Nectar, the carbohydrate source

sought by most insect pollinators, varies in composition from purely sucrose type as in the plant species belong to Ranunculaceae and Berberidaceae families, to hexose source found in the plant species belong to Brassicaceae, Apiaceae and Asteraceae families. However, flowering plants with an equal proportion of sucrose, fructose and glucose in the nectar is most preferred source of carbohydrate by many insect pollinators including bee species. Moreover, pollen of anemophilous plants is rich in carbohydrates (Suryanarayana, 1986) [37] which is used as main food of many insect species. However, entomophilous flowers have protein-rich pollen, while several bee flowers of Asteraceae and Brassicaceae plant families have with rich pollen that constitute proteins and lipids. The flowering plants which yield both carbohydrates and proteins are collectively referred as 'bee pastures. Many insect pollinators including bee species are generalists and collect pollen from different flowering plant species, which can greatly differ in chemical composition, quantity and quality of proteins, carbohydrates and other nutrients (Requier *et al.*, 2020) [30]. Therefore, understanding the floral source of insect pollinators including bee species is essential to restore the locally biodiversity that constitute both flowering plants and pollinators of every ecosystem. Bee forage plants includes the plants producing fruits, vegetables, ornamental flowers and they may be crops, medicinal plants, herbs, shrubs, bushes, trees, forest and weeds (Abrol, 1997; Kumar *et al.*, 2015) [1, 17]. Hence, the energetic food source to insect pollinators comes from diverse group of flora that act as significant part of local biodiversity and it help support locally existing insect pollinators including bee population as well. Finally, it could help influence crop pollination, beekeeping activity and bee hive productivity for the benefit of local populace.

In India, Deodikar *et al.* (1958) [10] have studied the nectar yielding plants of Mahabaleshwara Hills of Maharashtra. Later, significant work has been carried out on floral sources of insects in general and honeybees in particular by Ramanujam *et al.* (1992) [29], Sivaram (1995) [34], Tidke and Nagarkar (2010) [38], More *et al.* (2010) [22] and Waykar *et al.* (2015) [41], Shivaram (2001) [35], Raghunandan and Basavarajappa (2014) [27] at different parts of India. Locally available flora and their pollinators are greatly affected by various environmental factors (Kearns and Inouye 1993) [15]. Flower development, nectar secretion, anther dehiscence and seed development are depended on local temperature conditions. Moreover, in fragmented or natural resource-poor landscapes, reintroducing natural plant diversity through the establishment of native flowering plants within pollinators flight ranges could help provide required source of nectar, pollen and shelter during different seasons so as to help sustain the insect pollinators, wild bees including domesticated bee population (Isaacs *et al.*, 2009; Blaauw and Isaacs, 2014) [13, 8]. For this, in depth investigations on floral source of every agro-climatic region is essential. The abundance of flora is one of the most crucial requirements for pollinator's survival. Therefore, insect pollinator's flora is divided into three categories, namely: plants which provide more nectar, plants which provide more pollen and plants which provide both nectar and pollen (Waykar and Baviskar, 2015) [41]. Several flowering plant species which belong to different families do bloom at various times during different seasons of the year. The timing of blooming varies even for the same nectar plant, depending on edaphic factors (e.g. Soil), climatic conditions (e.g. Temperature) and locally available vegetation (Abrol, 2013) [2]. When floral resources are close to the insect pollinators at different landscapes it could help both plants which depend on insect species for pollination and insect pollinators would get food as reward from plants. Further, larger flower bearing plants can promote improved pollination of wild flora as well as increased insect pollinator's diversity and density (Blaauw and Isaacs, 2014) [8] it is due to evolutionary co-adaptation between flowers and their pollinators (Adhikari and Ranabhat, 2011) [4]. Further, every region has its own floral dearth periods, which would be with short or long duration. Therefore, it is essential to know about the floral dearth periods so as to manage the native pollinating insect species including honeybees. Since, floral dearth is characterized by the lack of availability of nectar and pollen source that is quantitatively and qualitatively less in turn, it affects the breeding activity of insect species including honeybees and their hive products (Waykar *et al.*, 2015) [41].

Further, floral calendar reveals the available floral source (both nectar and pollen) indicating the time and duration of the blossoming period during different months of a year in the ecosystem. Preparation of a floral calendar is a herculean task that requires complete observations of the seasonal changes in the vegetation patterns and/or agro-ecosystems of the area (Hosamani *et al*., 2018) [12]. Such in depth knowledge on floral source help in the effective management of locally existing insect pollinators which are disturbed by natural and man-made activities in Kodagu district. There is a need to record the foraging plants of insect pollinators in Kodagu district. There are no published reports on floral source and floral calendar. Hence, present study was conducted to record the flora, their relative abundance to prepare floral calendar in Kodagu district of Karnataka state. In recent years, the natural habitats amidst different agro-ecosystems of Kodagu district are disturbed due to frequently occurring natural calamities. Published reports on floral source available to local insect pollinators are not available. There is a need to evaluate the bee forage plants and their diversity. Hence this study was undertaken.

Materials and Methods

Study area: The Kodagu district experiences a malnad climate and lies at 12.15^{1}-12.45^{1}N latitude and 75.25^{1}-76.14^{1}E longitude with an altitude in between 390 to 5,627 ft (Figure 1). Moreover, the Kodagu district is a birth place of the holistic River Cauvery of south India, which drains in the greater part of Kodagu and created exceptional biodiversity (Kamath, 2001) [14]. The temperature ranges from 10.6 to 29.7°C and relative humidity varies between 39.0 to 81% with an annual rainfall on average 2,552 mm (Kamath, 2001) [14] *et al*. In Kodagu district, the agrarian economy is mainly depended on coffee plantation and other horticultural crops. The Kodagu district is characterized by red and gravel soil that supports various horticulture crops like Coffee (*Coffea Arabica* and *Coffea canephora*), Pepper (*Piper nigrum*), Ginger (*Zingiber officinale*), Areca nut (*Areca catechu*), Coconut (*Cocos nucifera*) and other forest plants. All these florae have provided rich floral resources to various insect pollinators.

Methodology: Twelve study sites were selected randomly at three geographically distinct taluks in Kodagu district. Field survey was conducted systematically for three years

i.e., from March, 2020 to February, 2023. The study sites were visited four times in a month and that represents three different seasons except July and August. During the full bloom period of the flowering plant species, the pollinators visit was observed by following standard methods. The variable width line transects (VWLT's) with length 50 to 450 meters were earmarked in the selected 12 study sites and pollinators were observed using visual count method (VC) and all-out search methods for a period of 10 to 15 minutes at every flowering plant as per Potts *et al*. (2006) [26], Blaauw and Isaacs (2014) [8] and O'Connor *et al.* (2019) [24] and Raghunandan and Basavarajappa (2014) [27]. The pollinators visited flowering plants were grouped into trees, shrubs, herbs and climbers etc. The per cent occurrence of flowering plants, their relative abundance and density was calculated as per Raghunandan and Basavarajappa (2014) [27]. The species richness and evenness were calculated as per Magurran (2005) [21]. The major foraging plants were further verified by direct observation. The seasonal abundance of flora was estimated as per (Pande and Ramkrushna, 2018) [25]. The nectar and pollen plants were grouped based on the activities performed by insect pollinators including honeybees on different flowers. The flowers, where the pollinators extended their proboscis into the deep region were considered as sources of nectar and the flowers on which the bees were observed with pollens on their hind legs were considered for sources of pollen as per Bista and Shivakoti (2001; Raghunandan and Basavarajappa, 2014) [7, 27]. Recorded flowering plants were identified in the Department of Botany, Field Marshal K. M. Cariappa College, Madikeri, Karnataka with the help of senior taxonomist and published reports of Keshavamurthy and Yoganarasimhan (1990) [16], Sivaram (2001) [35] and Waykar *et al.* (2015) [41] The status of floral source, abundance of flora and per cent occurrence and frequency of pollinators visit and flowering duration (Time of flower blooming to till wilt) of a plant species was carefully noted. Based on that the plant species were categorized into major (designated as N3P3), medium (N2P2) and minor (N1P1) sources of pollen and nectar plants depending upon their resource potentials (presence pollinators abundance on pollen, nectar and honeydew of plants). The collected data was compiled systematically for a period of three years to prepare floral calendar as per Raghunandan and Basavarajappa (2014) [27], Waykar and Baviskar (2015) [41], Pande and Ramkrushna (2018) [25].

Statistical Analysis: Collected data was systematically analyzed and compiled by following standard methods and compared using standard statistical tests as per Saha (2009) [32].

Results

Flowering plant species: Total 120 plants which belong to 24 orders of 54 plant families were recorded during the present investigation as major flowering plant species provided floral source to insect pollinators at different agro-climatic regions of Kodagu district (Table 1). The common name and scientific name of 120 flowering plant species, their relative abundance, flowering period and forage value is detailed in Table 1. Interestingly, Asteraceae family members belong to the order Asterales were more predominant (13 species) and it was followed by plant species belong to the family Fabaceae of the order Fables were more (7 species) in their occurrence at different agro-ecosystems of Kodagu district (Table 1). Moreover, Rubiaceae (Order: Gentianales), Lamiaceae (Order: Lamiales), Euphorbiaceae (Order: Malpighales), Myrtaceae (Order: Myrtales) and Poaceae (Order: Poales) family members (5 to 6 species) were common in their occurrence compared to other remaining flowering plant species (occurred less than 5 species) at different agro-ecosystems of Kodagu district (Table 1).

Relative abundance: Few plant species such as Honagone (*Alternathera sessilis*), Bhatta (*Oryza sativa*), Neelakantha (*Duranta rapens*), Sevanthige (*Chrysanthnemum* sp.), American weed (*Sphagneticola trilobata*), Robusta coffee (*Coffea cnephora*), Pathe hoo gida (*Cosmos sulphureus*), Kangressu gida (*Emilia sonchifolia*) relative abundance was high (3.43 to 11.2) and it was respectively 11.2, 8.2, 6.97, 6.47, 6.47, 3.70, 3.43 and 3.43 (Table 1). However, 17 flowering plant species which belong to different family's relative abundance was in between the range of 1 to 3 and remaining other flowering plant species relative abundance was less than one (Table 1). Detailed relative abundance of 120 flowering plant species which occurred at different agro-ecosystems of Kodagu district is given in Table 1.

Flowering Period: Only two flowering plant species namely Aster (*Aster tataricus*) and Parangi hannu gida (*Carica papaya*) belong to the family respectively Asteraceae and Caricaceae were provided floral source to insect pollinators throughout the year at different agro-ecosystems of Kodagu district (Table 1). However, remaining 118 flowering plant species which belong to different families have extended the floral source to the insect pollinators during different months at various agro-ecosystems of Kodagu district. Moreover, the blooming period of all these flowering plant species at different agro-ecosystems of Kodagu district is given in Table 1.

Forage value: The foraging value of different plant species in terms of their nectar (N) and pollen (P) source i.e., more, moderate and less respectively as N1, N2, N3 and P1, P2 and P3 are depicted in Table 1. Total 12, 8 and 1 flowering plants were enlisted as N1, N2 and N3 plant species (Table 1). Similarly, 15, 17 and 1 flowering plants were enlisted as P1, P2 and P3 plant species. However, remaining 66 flowering plant species were enlisted as P1N1 or P2N1 or P3N1 or P2N2 or P3N3 based on the presence of amount of nectar and pollen in the flowers of various plant species which grown at different agro-ecosystems of Kodagu district (Table 1). Further, in Table 2, the forage value of flowering plant species grown at different agro-ecosystems of Kodagu district is depicted. P2 plants (18 species) have provided high pollen source (15%) and it was followed by P1 plants (15 species) have provided more source of pollen (12.5%) and N1 plants (12 species) have provided more source of nectar (10%), N2 plants (9 species) have provided moderate source of nectar (7.5%) to insect pollinators at different agro-ecosystems of Kodagu district (Table 2). Moreover, P1N1, P2N2, P1N2 and P2N1 plant species respectively provided 15.8, 11.7, 8.3 and 19.2% both pollen and nectar source to various insect pollinators at different agro-ecosystems of Kodagu district (Tables 2 and 3).

Floral calendar: Based on the available pollen and nectar plants, which grown at different agro-ecosystems of Kodagu district during different months i.e., from January to December, floral calendar is prepared. Figure 2 shows the source of flora available at various pollinating insect species

amidst different agro-ecosystems of Kodagu district. Total 11 plant species grown at different agro-ecosystems have provided 9.1% floral source to the insect pollinators from January to December. From February to June, 11 plant species have provided 9.1% floral source to the insect pollinators (Table 1). From March to June, 11 plant species have provided 9.2% floral source to the insect pollinators. Similarly, from April to December (9 plant species), May to December (8 plant species), June to October (5 plant species), July to January (2 plant species), August to November 3 plant species), September to May (10 plant species), October to May (23 plant species), November to May (17 plant species) and December to August (10 plant species) have provided floral source respectively 7.5, 6.7, 4.2, 1.7, 2.5, 8.3, 19.2,14.2 and 8.3% to various insect pollinators at different agro-ecosystems of Kodagu district (Figures 1). Figure 3 shows the distribution of different flowering plant species during different months in Kodagu district.

Discussion

During the present study, 120 flowering plant species which provided foraging source to various insect pollinator species at different agro-ecosystems of Kodagu district of Karnataka state, India. The flowering plants belongs to Asteraceae, Fabaceae, Rubiaceae and Lamiaceae wore more predominant and they were followed by Poaceae, Euphorbiaceae and Myrtaceae family members compared to other plant families which were less in their occurrence at different agro-ecosystems. Moreover, collected data indicated that Kodagu district has hosted good floral sources which produce considerable amount of pollen, nectar and both pollen and nectar during different months throughout the year. This enabled various insect pollinators to avail the required amount of pollen and nectar throughout the year. Various researchers have identified and recorded several flowering plants and their usefulness to insects and to the mankind at various ecosystems. Suryanarayana (1966) [36] have provided the list of flora of Coorg and emphasized their usefulness in beekeeping. However, detailed floral source to other than honeybee species was not provided. During the present investigation, floral source available to insect pollinators at different agro-ecosystems of Kodagu district indicated the good floral source. Similar type of observations was made by Zamarlicki, Rai *et al.* (2002) [28], Kumar *et al*. (2005) [18], Harugade and Chaphalkar (2013) [11], Venkatachalapathi *et al.* (2015) [40], Singh *et al.* (2016) [33] in Burma, Shimoga, Bichpuri (Uttar Pradesh), Baramati (Maharashtra) Walayar Valley of Coimbatore District (Western Ghats) and Nagaland.

Pollinators (e.g. Bees) use specific strategies while seeking pollen and nectar from different plant species (Varadharajan, 2002) [39]. Accordingly, certain bee species (e.g. *Apis dorsata*) have specific foraging plants (Neupane *et al.* (2006) [23]. *Apis* species are depended on sunflower *Helianthus annuus* (Ali *et al*., 2015) [5] in Pakistan. Sometimes, weed plants like *Parthenium hysterophorus* is used during foraging by certain bee (e.g. *Apis mellifera*) species (Dalio, 2013) [9]. Therefore, any flowering plant species which is grown at different agro-ecosystems, one on the other way useful to the pollinators (e.g. *Apis* species) use pollen to feed developing brood (More *et al*., 2010) [22]. Therefore, for any insect pollinator species, both pollen and nectar are vital for their growth, development and survival. During the present investigation, monthly occurrence of various flowering plant species identification help knows their relative abundance, decide the blooming periods and foraging value to prepare floral calendar. Many plant species bloom for several months, while others do so throughout the year. However, July and August months, there was a heavy rainfall in Kodagu district. Although good number of flowering plants available at different agro-ecosystems during rainy season, the cold conditions and rainy weather perhaps suppressed the pollinators including bee's activity (Kearns and Inouye, 1993; Adhikari 2010) [15, 3]. On the other hand, several plant species such as Orchids, *Dahlia*, *Ligustrum*, *Ricinus* species bloom during the winter. Hence, availability of plants which provide pollen or nectar during rainy or winter seasons is vital for the viability/survival of insect pollinators and conservatory beekeeping (Hosamani *et al*., 2018) [12]. However, many flowering plant species do bloom during spring and summer seasons. Provide plentiful pollen and nectar sources to many insect pollinators that could help grow, develop and survive the pollinators including honeybees and their activity. It would help develop strong, healthy colonies and in turn beekeepers would get good honey yield. Therefore, beekeepers should also be aware of locally existing forage plants which help restore local pollinators and honeybees to improve the hive health and in turn increasing their honey productivity.

Similar type of observations was made by Sivaram (2001) [35] between 1993 and 1999 by identifying 192 plant species in southern Karnataka. Similarly, Waykar and Baviskar (2015) [41] have identified 63 plant species, which served as good bee-foraging plants, of which majority were nectar and pollen producing plant species. Moreover, Adhikari and Ranabhat (2011) [4] have identified 158 plant species, of which both pollen and nectar plants constituted 65.2%. Williams *et al.* (2019) [20] have reported the occurrence of more wild bees on native wild flowering plants than on control flower plots in the USA and observed that wildflower mixes attracted diverse communities of wild bee species at different regions. Raghunandan and Basavarajappa (2014) [27] have identified 252 plant species which were visited by *Apis* species (e.g. *A. dorsata*) for their pollen and nectar at various regions of southern Karnataka. Further, Kumar *et al.* (2013) [19], Lundin *et al.* (2019) [20], and Rowe *et al.* (2020) [31] have also identified quite a good number of flowering plants including weeds and wild fruits producing plants, which provided pollen and nectar to both wild and domesticated bee species and other insect pollinators. However, reports on the foraging value of different plant species in terms of their nectar (N) and pollen (P) source is remained unattended in many published reports. During the present investigation, based on nectar and pollen source, plants were designated as N1, N2, N3 and P1, P2 and P3 and number of these plants available to insect pollinators during different months was critically analyzed and prepared the floral calendar. This information becomes a ready reckoner for a beekeeper and conservationist to undertake protective measures to restore the existing flora and fauna of the region. Regarding the identification of floral source and preparation of pollen calendar, our observations are on par with the observations of Zamarlicki (1984) [28], Rai *et al.* (2002) [28] Kumar *et al*. (2005) [18] Harugade and Chaphalkar (2013) [11], Raghunandan and Basavarajappa (2014) [27 Venkatachalapathi *et al.* (2015) [40] and Singh *et al*. (2016) [33].

Table 1: Floral source of insect pollinators, their relative abundance, flowering period and forage value in Kodagu.

Sl. No.	Order	Sl. No.	Family	Sl. No.	Common name	Scientific name	Relative Abundance	Flowering period	Forage value
1.	Apiales	1.	Araliaceae	1.	Bethu mara	*Schefflera arboricola*	0.16	Apr-June	P2N1
				2.	Bethu mara/balli	*Schefflera venulosa*	0.05	Apr-June	P2N2
2.	Arecales	2.	Arecaceae	3.	Baine mara	*Caryota urens*	1.10	Nov, Apr	P1
				4.	Thengina mara	*Cocos nucifera*	0.16	Oct-Mar	P1N1
3.	Asperagales	3.	Amaryllidaceae	5.	Neeru lily	*Zephyranthes rosea*	0.27	Apr-May	N1
		4.	Iridaceae	6.	Gladiola	*Gladiolus dalenii*	0.22	Dec-June	N1
		5.	Orchidaceae	7.	Rattlesnake orchid	*Pholidota imbricata*	0.22	April-July	N2
		6.	Orchidaceae	8.	Seetale	*Rhynchostylis retusa*	0.11	June-July	P1N2
4.	Asterales	7.	Asteraceae	9.	Oorala gida	*Ageratum conyzoides*	0.27	Jan-Apr	P2
				10.	Aster	*Aster tataricus*	0.39	Jan-Dec	P1N1
				11.	Spanish needles	*Bidens pilosa*	0.60	July-Jan	P2N1
				12.	Devilweed	*Chromolaena odorata*	0.49	May- Dec	P1
				13.	Sevanthige	*Chrysanthemum* sp.	6.47	Nov- Jan	P2
				14.	Pathe hoo gida	*Cosmos sulphureus*	3.43	Nov-Mar	P2
				15.	Dere/dahlia hoo	*Dahlia* sp.	0.83	Nov-May	P2
				16.	Ili kivi gida	*Emilia sonchifolia*	0.44	Nov-May	N2
				17.	Kamgressu gida	*Parthenium hysterophorus*	3.70	Oct/Feb	P2N2
				18.	American weed	*Sphagneticola trilobata*	6.47	Oct-Dec	P1N2
				19.	Chendu hoo gida	*Tagetes patula*	2.49	Oct-Jan	P1
				20.	Mara suryakanthi	*Tithonia diversifolia*	0.22	Oct-Mar	P1N2
				21.	Zinnia	*Zinnia* sp.	0.72	Sept-Nov	P2
		8.	Campanulaceae	22.	Kaaduhogesoppu	*Lobelia nicotianifolia*	0.30	Oct-Feb	P1N2
5.	Brassicales	9.	Brassicaceae	23.	Mustard	*Brassica juncea*	0.61	Oct-Dec	P1N2
		10.	Caricaceae	24.	Parangi hannu gida	*Carica papaya*	0.16	Jan-Dec	P1N1
		11.	Moringaceae	25.	Nugge soppu	*Moringa oleifera*	0.22	Feb-May	P2N1
		12.	Tropaeolaceae	26.	Garden nasturtium	*Tropaeolum majus*	0.39	May-Aug	P2N1
6.	Caryophyllales	13.	Amaranthaceae	27.	Uttarani	*Achyranthus aspera*	0.11	Dec-April	P1
				28.	Honagone	*Alternathera sessilis*	11.2	Dec-May	P2N2
				29.	Spiny pigweed	*Amaranthus spinosus*	1.8	Oct-Dec	P1
		14.	Nyctaginaceae	30.	Sanje mallige	*Mirabilis jalapa*	0.33	Oct-Nov	P1N1
		15.	Polygonaceae	31.	Coral vine	*Antigonon leptopus*	0.11	Dec-June	P1N2
		16.	Portulacaceae	32.	Moss rose	*Portulaca grandiflora*	1.30	Jan-May	P2
7.	Colchicaceae	17.	Colchicaceae	33.	Thok/gowri hoo	*Gloriosa superba*	0.05	Aug-Oct	P1
8.	Cucurbitales	18.	Cucurbitaceae	34.	Cucumber	*Cucumis sativus*	0.05	Oct-Apr	P2
				35.	Kumbala balli	*Cucurbita maxima*	0.61	Oct-Nov	P1
9.	Ericales	19.	Balsaminaceae	36.	Garden Balsam	*Impatiens balsamina*	0.33	Sept- Jan	P2N2
		20.	Sapotaceae	37.	Sapota gida	*Manilkara zapota*	0.22	Feb-Mar	N1
10.	Fabales	21.	Caesalpiniaceae	38.	Thathe gida	*Cassia tora*	0.16	April-Dec	P2
		22.	Fabaceae	39.	Baage mara	*Albizia lebbeck*	0.05	Apr-May	P1N1
				40.	Muthuga	*Butea monosperma*	0.05	Apr-May	P2N1
				41.	Kadu senabu	*Crotolaria* sp.	0.11	Feb- May	N1
				42.	Honge mara	*Millettia pinnata*	0.16	May-July	P2N1
				43.	Copperpod	*Peltophorum pterocarpum*	0.55	Nov-Feb	N3
				44.	Common bean	*Phaseolus vulgaris*	0.33	Nov-Jan	P2
				45.	Kaadu seege	*Senegalia caesia*	0.33	Sept-Feb	N1
		23.	Mimosaceae	46.	Kadira mara	*Leucaena leucocephala*	0.44	June-Oct	P2
				47.	Muttidare muni	*Mimosa pudica*	2.9	Sept-Nov	P1N2
		24.	Papilionaceae	48.	Pongare	*Erythrina lithosperma*	1.60	Mar-April	N2
11.	Gentianales	25.	Apocyanaceae	49.	Gowri hoo	*Thevetia peruviana*	0.05	Dec-Mar	P1
				50.	Haale mara	*Alstonia scholaris*	0.11	Jan-April	N1
				51.	Yekkada gida	*Calotropis gigantea*	0.16	Oct-Mar	N1
		26.	Rubiaceae	52.	Arabic coffee	*Coffea arabica*	1.33	Feb-June	N1
				53.	Robusta coffee	*Coffea canephora*	3.43	Feb-Mar	P2N2
				54.	Scarlet bush	*Hamelia patens*	1.88	Feb-Mar	P2N2
				55.	Kepala hoo gida	*Ixora coccinea*	0.16	Jan-Feb	P2N2
				56.	Star cluster	*Pentas lanceolata*	0.4	Oct- May	N2
				57.	Amme hannu mara	*Psydrax umbellata*	1.33	Sept-may	P1N1
12.	Lamiales	27.	Acanthaceae	58.	Gorate hoo gida	*Barleria cristata*	0.33	Dec-Mar	N2
				59.	Adusoge	*Justicia adhatoda*	0.3	Oct-May	P2N2
		28.	Bignoniaceae	60.	Pink trumpet vine	*Podranea ricasoliana*	0.16	Mar-May	N1
				61.	Jalebi balli	*Pyrostegia venusta*	0.3	Nov-Mar	P2N1
		29.	Lamiaceae	62.	Chinese cup saucer	*Holmskioldia sanguinea*	0.3	Nov-April	P2N1
				63.	Tumbe gida	*Leucas aspera*	0.83	Nov-Mar	P2N1
				64.	Krishna Thulasi	*Ocimum basilicum*	0.72	Nov-Mar	P1N1

				65.	Thulasi gida	*Ocimum tenuiflorum*	1.05	Oct-Feb	P2N2
				66.	Salvia plant	*Salvia* sp.	0.16	Oct-May	P1N2
				67.	Lakki gida	*Vitex negundo*	0.05	Sept-Nov	P2N2
		30.	Oleaceae	68.	Koli mara	*Ligustrum ovalifolium*	0.11	June-July	N1
		31.	Verbanaceae	69.	Bakale	*Citharexylum spinosum*	0.11	Dec-May	N1
				70.	Neelakantha	*Duranta rapens*	6.97	Mar-May	P1N1
				71.	Chitrangi	*Lantana camara*	2.32	Sept-Apr	N1
13.	Laurales	32.	Lauraceae	72.	Lavanga mara	*Cinnamomum sulphuratum*	0.22	Dec-Mar	P3
				73.	Pattu thali	*Litsea floribunda*	0.16	Feb-Mar	P2N1
				74.	Benne hannu mara	*Persea macrantha*	0.16	Jan-Mar	P2
14	Magnoliales	33.	Magnoliaceae	75.	Sampige mara	*Magnolia champaca*	0.05	Mar-June	P1
15.	Malpighiales	34.	Euphorbiaceae	76.	Croton plant	*Codiaeum variegatum*	0.22	June-Sept	P1
				77.	Asthma weed	*Euphorbia hirta*	0.16	June-Sept	P2N2
				78.	Poinsettia gida	*Euphorbia pulcherrima*	0.99	May-Sept	P2N1
				79.	Kachi gida	*Jatropha curcas*	1.55	Nov-Jan	P1N1
				80.	Haralu gida	*Ricinus communis*	0.5	Sept-May	P1N1
		35.	Garciniaceae	81.	Punarpuli	*Garcinia gummi-gutta*	0.16	Jan-Apr	P1
16.	Malvales	36.	Bixaceae	82.	Rangumale	*Bixa orellana*	0.05	Sept-Oct	P1N1
		37.	Malvaceae	83.	Dombeya gida	*Dombeya spectabilis*	0.83	Aug-Nov	P2
				84.	Hatti mara	*Gossypium* sp.	0.22	Jan-Mar	P2N2
				85.	Mullu gogu	*Hibiscus surattensis*	0.94	Oct-Mar	P2N1
				86.	Broom weed	*Sida acuta*	0.16	Oct-Mar	P2
17.	Myrtales	38.	Combretaceae	87.	Hole mathi	*Terminalia arjuna*	0.05	July-Nov	P2
				88.	Mathi mara	*Terminalia paniculata*	0.05	Mar-May	P2N1
		39.	Lythraceae	89.	Mexican heather	*Cuphea floriglory*	0.22	Dec-May	P1N1
				90.	Nandi mara	*Lagerstroemia* sp.	0.05	Mar-April	P2N1
		40.	Melastomataceae	91.	Nekkare	*Melastoma malabathricum*	0.11	Dec-Aug	P1
		41.	Myrtaceae	92.	bottlebrush	*Callistemon* sp.	0.3	Apr- May	P2N1
				93.	Neelagiri mara	*Eucalyptus* sp.	0.16	Feb-May	N2
				94.	Seebe Kaayi mara	*Psidium guajava*	0.16	Jan-Mar	P2N1
				95.	Nerale hannu mara	*Syzygium cumini*	0.66	Mar-April	P2N1
				96.	Jumbu nerale mara	*Syzygium jambos*	0.66	Mar-April	P2N1
18.	Oxalidales	42.	Elaeocarpaceae	97.	Rudrakshi mara	*Elaeocarpus tuberculatus*	0.11	Oct-Jan	P1N1
19.	Poales	43.	Poaceae	98.	Kaadu ragi hullu	*Dactyloctenium aegyptium*	1.33	Nov-Jan	P1N2
				99.	Doddakki hullu	*Digitaria sanguinalis*	1.3	Nov-Jan	P1
				100.	Goosegrass	*Eleusine indica*	1.1	Oct-Dec	P1N1
				101.	Bhatta	*Oryza sativa*	8.2	Oct-Nov	P2
				102.	Aane hullu	*Pennisetum polystachion*	0.61	Sept-Jan	P1
20.	Proteales	44.	Nelumbonaceae	103.	Thavare gida	*Nelumbo nucifera*	0.05	Mar-June	P2
		45.	Proteaceae	104.	Silver mara	*Grevillea robusta*	0.16	May-June	N2
21.	Rosales	46.	Rhamnaceae	105.	Kotte hannu gida	*Ziziphus rugosa*	0.16	Feb-Mar	P2N1
		47.	Rosaceae	106.	Bili gulabi gida	*Rosa alba*	0.16	May-July	P1N1
				107.	Nukkatte hannu gida	*Rubus indicus*	0.22	Oct-May	P2N1
22.	Sapindales	48.	Anacardiaceae	108.	Cashew tree	*Anacardium occidentale*	0.22	Feb-Apr	P2N2
				109.	Maavina mara	*Mangifera indica*	0.4	Feb-April	P2N1
		49.	Rutaceae	110.	Kahi huli mara	*Citrus aurantium*	0.11	7May	P2N1
				111.	Nimbe hannu gida	*Citrus limon*	0.16	Apr-June	N1P1
				112.	Karibevina gida	*Murraya koenigii*	0.11	Jan-Feb	N1P1
		50.	Sapindaceae	113.	Lichi plant	*Lychee chinensis*	0.05	Aug-Oct	P2N1
23.	Solanales	51.	Solanaceae	114.	Datura	*Brugmansia arborea*	0.11	Mar-May	P1
				115.	Chikka Gummate	*Physalis minima*	0.3	Nov-Apr	P2
				116.	Kudanekayi gida	*Solanum torvum*	0.11	Nov-Feb	P1N1
24.	Zingiberales	52.	Cannaceae	117.	Canna hoo	*Canna indica*	0.4	Feb-May	P1N1
		53.	Musaceae	118.	Baale gida	*Musa paradisiaca*	1.11	Mar-June	P2N2
		54.	Zingiberaceae	119.	Elakki gida	*Elattaria cardamomum*	0.11	May-June	N2
				120.	Shunti/Ginger	*Zingiber officinale*	1.1	Nov-Feb	P1N2
Total							100	-	-

Table 2: Forage value of flowering plant species in Kodagu district.

Sl. No.	Blooming Period	Forage value							
		P1	P2	N1	N2	P1N1	P2N2	P1N2	P2N1
1.	Jan-Feb	-	-	-	-	1	1	-	-
2.	Jan-March	-	1	-	-	-	1	-	1
3.	Jan-April	1	1	1	-	-	-	-	-
4.	Jan-May	-	1	-	-	-	-	-	-
5.	Jan-Dec	-	-	-	-	2	-	-	-
6.	Feb-March	-	-	1	-	-	2	-	2
7.	Feb-April	-	-	-	-	-	1	-	1
8.	Feb-May	-	-	1	1	1	-	-	1
9.	Feb-June	-	-	1	-	-	-	-	-
10.	March-April	-	-	-	1	-	-	-	3
11.	March-May	1	-	1	-	1	-	-	1
12.	March-June	1	1	-	-	-	1	-	-
13.	April-June	-	-	-	-	1	1	-	1
14.	April-May	-	-	1	-	1	-	-	2
15.	April-July	-	-	-	1	-	-	-	-
16.	April-Dec	-	1	-	-	-	-	-	-
17.	May-Dec	1	-	-	-	-	-	-	-
18.	May-Aug	-	-	-	-	-	-	-	1
19.	May-July	-	-	-	-	1	-	-	1
20.	May-Sept	-	-	-	-	-	-	-	1
21.	May only	-	-	-	-	-	-	-	1
22.	May-June	-	-	-	2	-	-	-	-
23.	June-July	-	-	1	-	-	-	1	-
24.	June-Oct	-	1	-	-	-	-	-	-
25.	June-Sept	1	-	-	-	-	1	-	-
26.	July-Jan	-	-	-	-	-	-	-	1
27.	July-Nov	-	1	-	-	-	-	-	-
28.	Aug-Oct	1	-	-	-	-	-	-	1
29.	Aug-Nov	-	1	-	-	-	-	-	-
30.	Sept-Nov	-	1	-	-	-	1	1	-
31.	Sept-Jan	1	-	-	-	-	1	-	-
-32.	Sept-Feb	-	-	1	-	-	-	-	-
33.	Sept-May	-	-	-	-	2	-	-	-
34.	Sept-April	-	-	1	-	-	-	-	-
35.	Sept-Oct	-	-	-	-	1	-	-	-
36.	Oct-March	-	1	1	-	1	-	1	1
37.	Oct-Feb	-	-	-	-	-	2	1	-
38.	Oct-Dec	1	-	-	-	1	-	2	-
39.	Oct-Jan	1	-	-	-	1	-	-	-
40.	Oct-Nov	1	1	-	-	1	-	-	-
41.	Oct-May	-	1	-	1	-	1	1	1
42.	Nov-April	1	1	-	-	-	-	-	1
43.	Nov-Jan	1	2	-	-	1	-	1	-
44.	Nov-May	-	1	-	1	-	-	-	-
45.	Nov-Feb	-	-	-	1	1	-	1	-
46.	Nov-Mar	-	1	-	-	1	-	-	2
47.	Dec-June	-	-	1	-	-	-	1	-
48.	Dec-April	-	-	-	-	-	1	-	-
49.	Dec-May	1	-	1	-	1	-	-	-
50.	Dec-Mar	1	1	-	1	-	-	-	-
51.	Dec-Aug	1	-	-	-	-	-	-	-
No. of plant species		15	18	12	9	19	14	10	23
% Contribution		12.5	15.0	10.0	7.5	15.8	11.7	8.3	19.2

Table 3: Per cent occurrence of nectar and pollen plants recorded in Kodagu district

Sl. No.	Plant type	No. of plant species	% Occurrence
1.	N1	12	10.0
2.	N2	9	7.5
3.	P1	15	12.5
4.	P2	14	11.7
5.	P3	4	3.33
6.	P1N1	19	15.8
7.	P1N2	12	10.0
8.	P2N1	21	17.5
9.	P2N2	12	10
10.	P3N1	2	1.7
Total		120	100.0

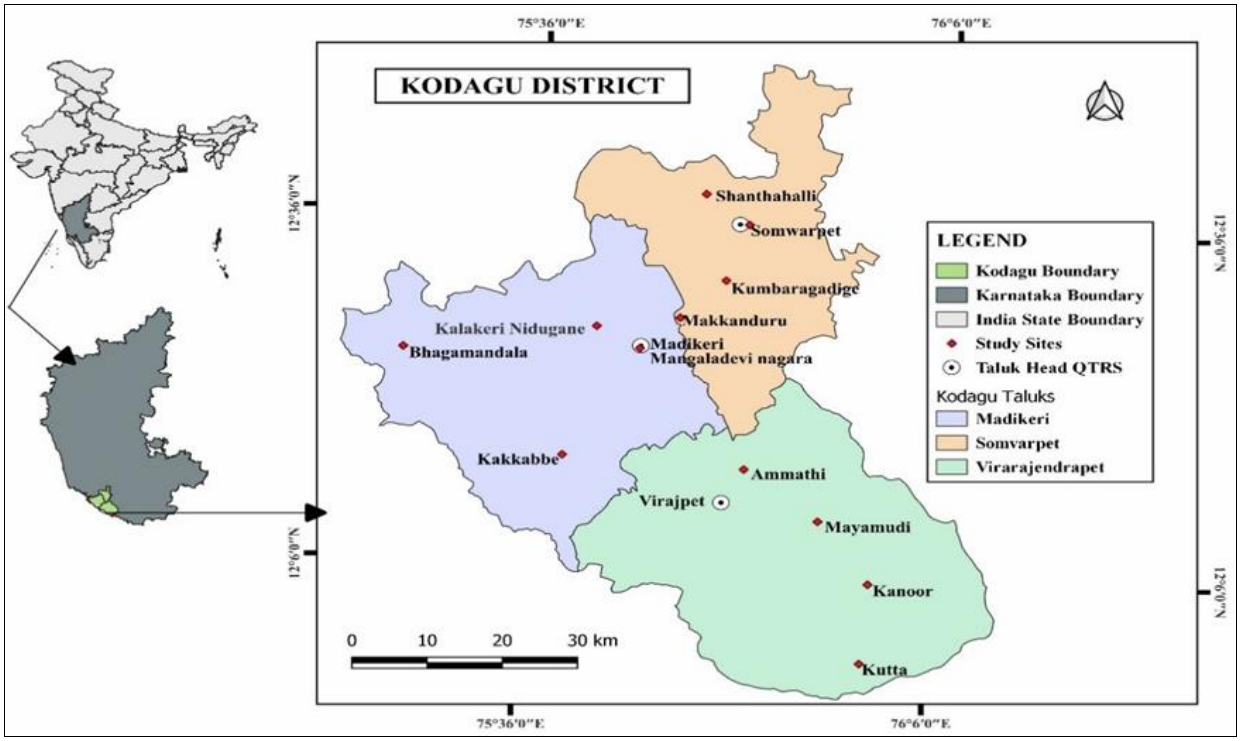

Fig 1: Map showing all the study sites in Kodagu district.

Fig 2: Source of flora available to various pollinating insect species in Kodagu District

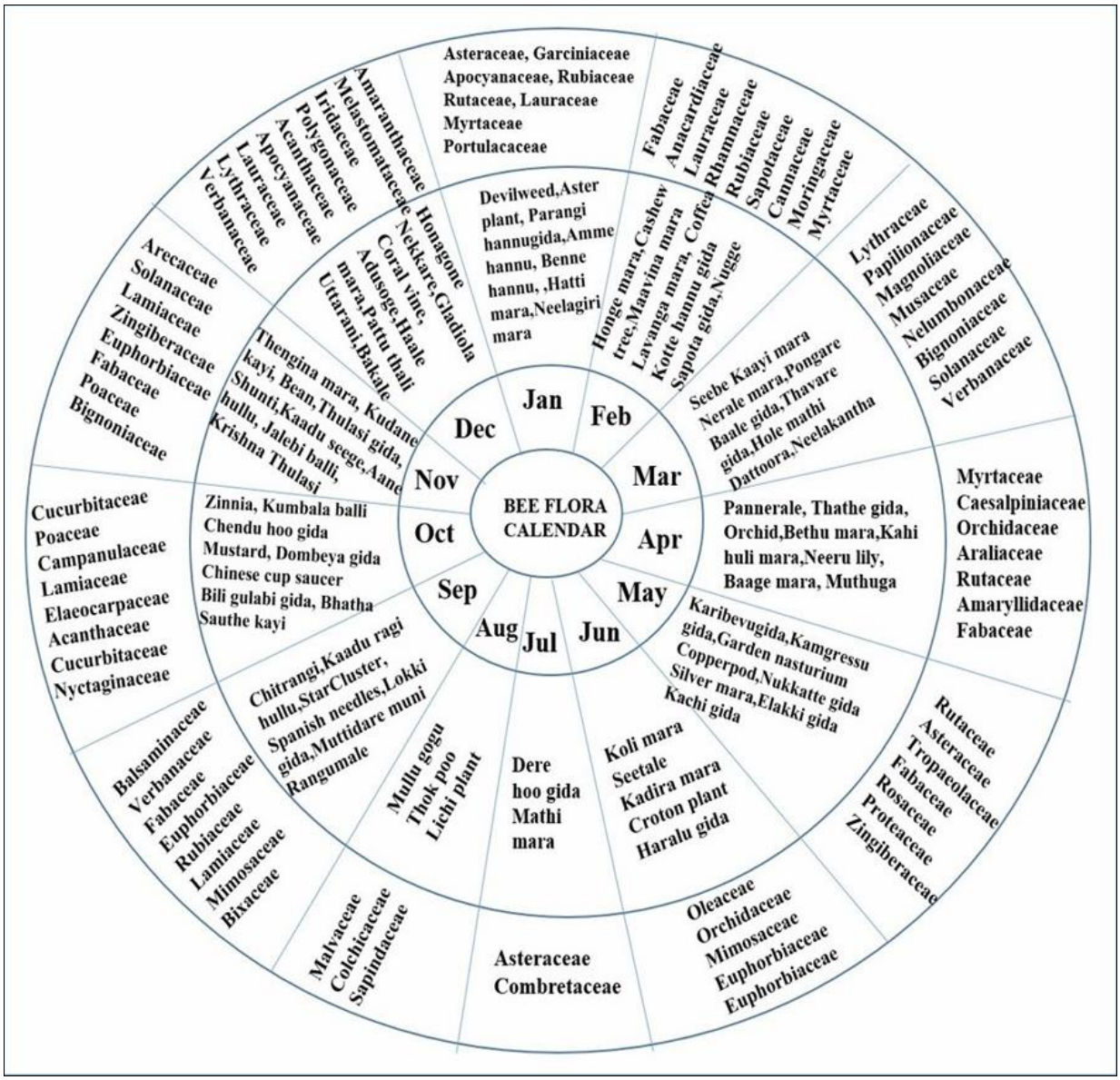

Fig 3: Floral calendar of insect pollinators in Kodagu district.

Conclusion

The present study revealed that the Kodagu district hosted abundantly grow diverse group of flowering plant species, which bloom during different months in a year amidst various agro-ecosystems. Locally grown flowering plant species provide considerable amount of pollen, nectar and both pollen and nectar to the diverse group of insect pollinators during different months in a year and even during dearth periods and inclement weather conditions in rainy season also. Due to the prolonged flowering period of many plant species which belong to different plant family's help encouraged the survival of many insect pollinators amidst various agro-ecosystems. The scientific knowledge of forage plants of insect pollinators, forage plants nutritive resources (i.e., pollen, nectar and both pollen and nectar), blooming period and their relative abundance help reveal the local biodiversity that comprise both plants and animals. Besides, it is possible to assess the insect pollinator's diversity and distribution amidst different agro-ecosystems of Kodagu district. Such type of observations is beyond the limit of this research paper; however, attempts will be made to publish on insect pollinators of Kodagu district elsewhere. Thus, present investigation provided an insight on the status of floral source of different agro-ecosystems of Kodagu district.

Acknowledgements

Author (BMN) thankful to the Principal, Field Marshal K. M. Cariappa College, Madikeri for the cooperation. Authors also thankful to the taxonomists who have helped while identifying the plant species and farmers for their assistance. Authors thank the Chairman, Research Scholars, Apidology Laboratory, DOS in Zoology, University of Mysore, Manasagangotri, Mysore for laboratory facilities.

References

1. Abrol DP. Bees and Beekeeping in India. 1st ed. New Delhi: Kalyani Publishers; c1997. p. 110-130.
2. Abrol DP. Asiatic Honey bee *Apis cerana*: Biodiversity Conservation and Agricultural Production. Dordrecht: Springer; c2013. p. 1-10.
3. Adhikari S. Floral phenology and pollination ecology of *Punica granatum* L. in Kathmandu, Nepal. Nepal J Sci Technol. 2010;11:115-124.

4. Adhikari S, Ranabhat NB. Bee flora in mid hills of Central Nepal. Botanic Orient J Plant Sci. 2011;8:45-56.
5. Ali H, Ayman AO, Khan KA, Abdulaziz SA. Insect visitors and abundance of four species of Apis on sunflower *Helianthus annuus* L., in Pakistan. Acta Zool. 2015;67(2):235-240.
6. Bhatta VR, Kumar AN. Survey of bee-friendly flowering plants and bee-plant interaction in an urban green space in Bengaluru, India. J Environ Biol. 2021;42:1330-1337.
7. Bista S, Shivakoti CP. Honey bee flora at Kabre, Dolakha District. Nepal Agric Res J. 2001;4(5):18-25.
8. Blaauw BR, Isaacs R. Flower plantings increase wild bee abundance and the pollination services provided to a pollination-dependent crop. J Appl Ecol. 2014;51:890-898.
9. Dalio JS. Foraging activity of Apis mellifera on *Parthenium hysterophorus*. ISOR J Pharm Biol Sci. 2013;7(5):1-4.
10. Deodikar GB, Shah PN, Thakar CV, Salvi SR. Morphological characterization of pollen grains of some of the major bee plants from Mahabaleswar hills. In: Proceedings of the 17th International Bee Keeping Congress; c1958 Oct 12-17; Bologna & Rome. p. 214-217.
11. Harugade S, Chaphalkar S. Floristic studies with reference to Honey bees of Baramati, Pune District. Int J Adv Res Technol. 2013;2(8):178-187.
12. Hosamani V, Kattimani KN, Rajeshwari N, Gangadharappa PM, *et al*. Diversity of nectariferous and polleniferous bee flora and floral calendar of honey bees in dryland regions of Koppal District. J Pharmacogn Phytochem. 2018;SP3:362-366.
13. Isaacs R, Tuell J, Fiedler A, Gardiner M, Landis D. Maximizing arthropod mediated ecosystem services in agricultural landscapes: the role of native plants. Front Ecol Environ. 2009;7(4):196-203.
14. Kamath SU. Karnataka State Gazetteer. Bangalore: Government Press; c2001. p. 1-49.
15. Kearns CA, Inouye DW. Techniques for Pollination Biologists. Niwot: University Press of Colorado; c1993.
16. Keshava Murthy KR, Yoganarasimhan SN. Flora of Coorg (Kodagu). Vimsat Publishers; c1990. p. 189, 212, 250-359.
17. Kumar D, Vineeta, Sharma U, Bharti. Mapping of medicinal flora as honey bees forage. J Entomol Zool Stud. 2015;3(6):235-238.
18. Kumar MA, Singh PK, Singh J. Floral calendar for beekeeping at Bichpuri, Agra. Indian Bee J. 2005;67(3-4):156-160.
19. Kumar RG, Rajput RC, Mishra O, Agrawal OP. A study on assessment of duration of dearth period for honey bees in Haryana, India. Munis Entomol Zool. 2013;8(1):434-437.
20. Lundin O, Ward KL, Williams NM. Identifying native plants for coordinated habitat management of arthropod pollinators, herbivores and natural enemies. J Appl Ecol. 2019;56(3):665-676.
21. Magurran AE. Species abundance distributions: Pattern or process? Funct Ecol. 2005;19(1):177-181.
22. More S, Ghori N, Bera SK. Study on the selection of some local pollen plants in West Bengal, India as pollen brood feed in *Apis cerana* F. larvae by worker bees, through Meconia analysis and community ordination method of recovered pollen taxa. Proc Zool Soc. 2010;63(1):39-44.
23. Neupane KR, Dhakal DD, Thapa RB, Gautham DM. Foraging preference of giant honeybee, *Apis dorsata* F. to selected horticultural crops. J Inst Agric Anim Sci. 2006;27:87-92.
24. O'Connor RS, Williams E, Kunin MP, Garatt SG, Potts SG, *et al*. Monitoring insect pollinators and flower visitation: The effectiveness and feasibility of different survey methods. Methods Ecol Evol. 2019;10(12):2129-2140.
25. Pande R, Ramkrushna GI. Diversification of honey bees' flora and bee flora calendar for Nagpur and Wardha districts of Maharashtra, India. J Entomol Zool Stud. 2018;6(2):3102-3110.
26. Potts SG, Theodora P, Stuart R, Chris O, Toole AH, Willmer P. Plant-pollinator biodiversity and pollination services in a complex Mediterranean landscape. Biol Conserv. 2006;129:519-529.
27. Raghunandan KS, Basavarajappa S. Floral hosts and pollen calendar of Asian giant honeybee, *Apis dorsata* F., at southern Karnataka, India. J Ecol Nat Environ. 2014;6(9):321-330.
28. Rai SP, Ramachandra YL, Reddy CC, Kumar AM. Bee foraging plant and seasonal activity of *Apis cerena* F. at Shimogga, Karnataka State. Proc 6th AAA Int Conf World Apiexpo; Bangalore, India; c2002 Jan 23-27. p. 95.
29. Ramanujam CGK, Kalpana TP, Fatima K. Mellittopalynology and recognition of major nectar and pollen sources for honeybee in some districts of Andhra Pradesh. Geophytology. 1992;22:261-271.
30. Requier F, Kim K, Jowanowitsch K, Steffan-Dewenter I. Limitation of complementary resources affects colony growth, foraging behaviour and reproduction in bumble bees. Ecology. 2020;101(3):e0294.
31. Rowe L, Daniel G, Christie AB, Bahlai J, Gibbs DA, Landis D, *et al*. Flower traits associated with the visitation patterns of bees. Oecologia. 2020;193:511-522.
32. Saha TK. Biostatistics in Theory and Practice. India: Emkay Publications; c2009. p. 5-104.
33. Singh AK, Jaiswal DK, Singh HK, Thakur RK. Diversity of bees' flora and floral calendar of native honeybees in Nagaland, India. Adv Life Sci. 2016;5(6):2285-2292.
34. Sivaram V. Bee flora, honey flow and beekeeping in the plains of Karnataka. Ph.D. Thesis, Bangalore University, Bangalore; c1995. p. 1-100.
35. Sivaram V. Honeybee flora and beekeeping in Karnataka State, India. In: Proceedings of the 37th International Apicultural Congress; 2001 Aug 19-24; Durban, South Africa. p. 1-7.
36. Suryanarayana MC. Studies on flora of Coorg with emphasis on beekeeping forage plants, ecological and botanical features. Indian Bee J. 1966;28:59-75.
37. Suryanarayana MC. Honey bee-flower relationship. Bull Bot Surv India. 1986;28(1-4):55-62.
38. Tidke JA, Nagarkar SS. Honey as a regional bee floral indicator: Apalynological assessment. J Indian Bot Soc. 2010;89(3&4):324-333.
39. Varadharajan M. Foraging strategies of the Indian honeybee, *Apis cerena* indica, with reference to pollen

preferences and nectar collection under central-place foraging and risk-sensitive foraging in artificial nectaries. Ph.D. Thesis, Bharatidasan University, Mannampandal, Tamil Nadu; c2002. p. 2-100.
40. Venkatachalapathi A, Subbaiyan B, Jagathes KS, Aravindhan V, Paulsamy S. Study on diversity of social bees foraging medicinal plants in Walayar Valley of Coimbatore District, Western Ghats, India. Acad J Entomol. 2015;8(2):84-91.
41. Waykar B, Baviskar RK. Diversity of bee foraging flora and floral calendar of Paithan taluka of Aurangabad district, Maharashtra, India. Int J Entomol Res. 2015;4(1):66-69.
42. Zhang L, Liu X, Wang Y, Liu Y. Floral calendar and diversity of honeybee flora in Beijing, China. Acta Entomol Sinica. 2012;55(10):1153-1160.