Melittopalynological studies of *Apis dorsata* honey samples from Kolar District, Karnataka, India

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Abstract
Honeybees, while foraging for nectar on flowers, also gather some pollen which retains in the honey even after extraction. Pollen grains are the essential tools in the analysis of honey. The aim of the present report was to find the *Apis dorsata* honey floral resources in Kolar district state Karnataka. In the present study, the pollen content of 28 *A. dorsata* honey samples were collected from 5 different locations of Kolar district, Karnataka, India. Samples were subjected to Melittopalynological studies to identify their honey plant resources and colour, optic density and collection places were documented. A wide variety of pollen types represent their plant sources and their frequency classes were recognized in each honey sample. Among 28 honey samples analysed, 10 samples were identified as multifloral, 18 unifloral with predominant pollen types such as *Syzygium cumini*, *Pongamia pinnata*, *Eucalyptus sp.*, *Guizotia abyssinica*, *Psidium guajava* and *Coriandrum sativum*, each count was found above 45%. Pollen spectra indicated a total of 56 pollen types belonging to 27 plant families. Fabaceae was represented as the largest family with 14 species contributing honey production. Among the habitat, tree was dominant with 51.78%, followed by herbs (32.14%) and shrubs (16.07%). The economic importance of identified plants with apiculture importance was categorized as medicinal, ornamental, vegetable, timber and oil yielding, weeds, fruits and nuts. *A. dorsata* depends on wild trees and cultivated plants bloom throughout the year as pollen and nectar source. From the results, it is evident that there is a lot of potential in establishing beekeeping industries in the study area.

Keywords: *Apis dorsata*, Kolar district, Melittopalynology, Multifloral, Unifloral

INTRODUCTION
Melittopalynology is an applied branch of Palynology deals with the microscopic analysis of pollen grains in honey. Honeybees depend on plants for pollen and nectar. In turn bees provide pollination services to a wide variety of flowering plants. Honey contains pollen grains, which are collected by honeybees while foraging the flowers for nectar. The microscopic analysis of pollen is a standard method to identify the abundance of nectar sources, distribution, geographical and botanical origin, and honey adulteration in a given area (Silva and Santos, 2014). Knowledge of floral diversity of apicultural importance is a prerequisite for beekeepers to undertake migratory beekeeping to increasing honey production and pollination (Singh et al., 2016). Beekeeping provides self-employment to the farmers and tribes to generate income. Honeybees naturally produce honey from the nectar of plants. It is widely consumed as a health food product worldwide, but adulteration and the false labelling of honey are common problems in many countries (Sajwani et al., 2007; Louveaux et al., 1978). In this context, Melittopalynology plays an important role in ascertaining honey’s botanical and geographical origins by studying the pollen contained in the honey (Anklam, 1998; Oliveira et al., 2010; Ramirez-Arriaga et al., 2011; Upadhyay and Bera, 2012).

In the growth and development of honey bees, nectar is the source of carbohydrates and proteins are provided by pollen (Turner, 1984; Lin et al., 1993). Pollen analyses of honey and bee loads are used to learn honey bee foraging ecology, the habitat and vegetation, habitat composition, changes in honey bee food sources and the geographical region of the hive location (Ramanho and Kleint-Giovannini, 1986; Feller-Demalsy et al., 1989; Barth, 1990; Diaz-Losada et al., 1998; Terrab et al., 2004). Pollen contents of honey samples offer dependable evidence on floral resources of honey along with the relative predilections of bees.
amongst the varied assemblies of plant species flower-
ing synchronously (Deodikar and Thakar, 1953; Deodi-
kar, 1961; Garg, 2006). Melittopalynological study was introduced over a hun-
dred years ago by several scientists from different part
of the world (Maurizio, 1975; Lieux, 1980; Agwu and
Akanbi, 1985; Moar, 1985; Deodikar, 1961; Alves and
Santos, 2014; Jesus et al., 2015; Majid et al., 2020). In
India, the earliest contribution in this field was by Deodi-
kar and Thakar (1953), Sen and Banerjee (1956) and
Novais et al. (2009) characterized pollen in honey
samples of Mahabaleshwar hills of Maharashtra State
and from West Bengal, respectively. Later, Vishnu-
Mitter (1958) analyzed the pollen content of honey from
Nepal, Kashmir and Lucknow. Recently, several scient-
ists reported the botanical origin of honey in many
places of India (Shubharani et al., 2012; Raghunandan
and Basavarajappa, 2014; Neha Singh and Chaturvedi,
2016; Manju Sahney et al., 2018). However, no study
has been reported from Kolar district, Karnataka. The
present study aimed to identify the floral diversity of
apicultural importance by melittopalynological studies
of A. dorsata honey of Kolar district, Karnataka state.

MATERIALS AND METHODS

Study area
The Kolar district is situated in the southeastern part of
Karnataka state and called the land of gold, silk and
milk. The district lies almost in the central part of penin-
sular India, which has an immense bearing on its geo-
climatic conditions and experiences tropical climatic
condition throughout the year. The district is situated
between 12° 46’ and 13° 58’ north latitude and 77° 21’
and 78° 35’ east longitude between Eastern and West-
ern coast and is bound on the West by Bangalore and
Tumkur districts, South by North Arcot and Dharmapuri
districts of Tamilnadu, East and North by Chittor district
of Andhra Pradesh. The district has an area of 8,233 sq
km and occupies 12th place in the state, having 11 Ta-
luk viz., Bagepalli, Bangarpet, Chikballapur, Chin-
tamani, Gudibande, Gauribidanur, Kolar, Malur, Mulb-
agal, Siddlagatta and Srinivasapura (Fig. 1). The district
is endowed with a number of hills with peaks of varying
heights, particularly in the northern part. Kolar district falls in the eastern dry agro climatic zone. It experiences a semi-arid climate, characterized by
typical monsoon tropical weather with hot summer and
mild winter. The average rainfall is around 850 mm with
55-65 rainy days in Kolar district and the greater portion
of the rainfall is from September to November. District
experience scanty and erratic rainfall with uneven dis-
tribution during monsoon. The large variation in rainfall
was noticed from year to year and amongst talk to a
larger extent. The main occupation of the people of this
district is agriculture; 5% of the total area in the district
is covered by forest, 46% under cultivation and 28% is
uncultivated area.

Preparation of honey samples
In the present study, 28 honey samples were collected
from the hives of A. dorsata from 5 different locations of
Kolar district such as Kolar, Srinivasapura, Mulbagal,
Malur and Bangarpet during 2017-2019. The Honey
samples collected details are documented in Table 1.

Melittopalynological analysis
The collected honey samples were subjected to pollen
analysis to characterize and identify the floral origin,
according to the guidelines of Erdtman (1960), Louveaux et al. (1978) and Moore et al. (1991). Ten grams of crude honey sample was dissolved in 20
ml of warm (40 °C) distilled water and then centrifuged
for 10 min at 2500 rpm. The sediment was treated with
acetolysis mixture, centrifuged and the supernatant
was decanted. The sediment was washed twice with
distilled water to remove the debris. A drop of glycerine
was added to prevent the sample from drying and
gently heated. Five different slides were prepared
from each honey sample by adding 50 µl of treated
sample and cover with a coverslip. The slides were
subjected to microscopic study to identify the pollen
type by using a Leica DM2500 light microscope. The
pollen types present in honey samples were identified
by comparison with reference slides and pollen photo-
micrographs. The pollen types and their number were
counted by using Haemocytometer. Based on the per-
centage of pollen type and its distribution frequency,
the honey was categorised into unifloral (one pollen
type represented >45%) or multifloral (no pollen type
>45%) and also classified to different groups like pre-

Fig. 1. Map of Kolar district of Karnataka showing honey
samples collected areas.
dominant pollen (>45%), secondary pollen (16-45%), important minor pollen (3-15%) and minor pollen (<3%) by constructing pollen spectrum (Louveaux et al., 1978; White, 2005). Furthermore, the pollen morphology of the identified pollen from the honey samples was also documented.

RESULTS AND DISCUSSION

Kolar district has established beekeeping centres, maintained by the Department of Industries and Commerce of Apiculture wing. The present study identified the bee foraging plants of apiculture importance with particular reference to floral fidelity. The giant bee, A. dorsata is a widely distributed wild bee and is one of the important natural pollinators with high foraging potential (Neupane et al., 2006). Twenty-eight honey samples collected from 5 different regions in the study area were subjected to Melittopalynological studies to identify its honey plant resources. The colour, Optic density and place of the collection are documented in Table 1. The colour of the collected honey samples varied from light yellow to dark red. This variation may be due to floral source or exposure of honey to high temperature (Matos and Santos, 2016). The colour classification of honey is very important for commercial purpose. The optical density of the honey samples ranged from 0.208-0.996. Melittopalynological analysis is one of the main tools to determine the honey's botanical origin and differentiate the type of honey as unifloral or multifloral (Rodopoulou et al., 2018). A wide variety of pollen types representing their plant sources and their frequency classes were recognized in each honey samples and listed in Table 2. Among 28 honey samples analysed, 10 samples were identified as multifloral, whereas 18 were unifloral with predominant pollen types such as S. cumini, P. pinnata, Eucalyptus sp, G. abyssinica, P. guajava and C. sativum. Each count was found to be above 45% (Table 2).

The pollen type of Eucalyptus sp. was identified in 8 honey samples collected from the study area. The two different species, E. globules and E. citriodora have been known to occur in this region, has a significant role in providing nectar and pollen to A. dorsata. Bees
**Table 2.** Pollen spectrum of honey samples collected from Kolar District.

| Honey sample | Predominant pollen types 45% & above | Secondary pollen types (16-45%) | Important minor pollen types (3-15%) | Minor pollen types (Less than 3%) | Honey types |
|--------------|-------------------------------------|---------------------------------|--------------------------------------|-----------------------------------|------------|
| ADH-1        | S. cumini                           | Eucalyptus                      | C. equisetofolia, C. sativum, C. nucifera | D. regia, M. pudica, Poaceae, H. auriculata, Amaranthaceae, Fabaceae, C. bonplandianum, C. lemon | Unifloral |
| ADH-2        | P. pinnata                           | Eucalyptus, A. catechu, A. lebeck | M. pudica, C. nucifera, P. pterocarpum, Poaceae, E. alsinoides | M. pudica, Asteraceae, D. metal, E. alsinoides, A. catechu, Poaceae, C. sativum. | Unifloral |
| ADH-3        | P. guajava                           | Asteraceae, M. pucica, A. indica | C. nucifera, S. jambosa, Amaranthaceae sp., Cassia sp., O. sanctum, C. lemon. | | Multifloral |
| ADH-4        | Eucalyptus                           |                                 | H. auriculata, M. pudica, C. nucifera, O. sanctum, C. benghalensis. | P. nigrum, Poaceae, H. auriculata, A. catechu, C. benghalensis, R. indica. | Unifloral |
| ADH-5        | G. abyssinica                        | C. nucifera                     | Asteraceae, D. metal, C. lemon. | C. argentea, Poaceae, T. angustata, O. sanctum. | Unifloral |
| ADH-6        | Eucalyptus                           |                                 | M. pudica, B. nigrum, C. nucifera, Asteraceae, C. nucifera, C. benghalensis. | H. auriculata, M. alba, O. sanctum, Poaceae, C. sativum. | Unifloral |
| ADH-7        | Eucalyptus                           |                                 | A. catechu, Poaceae, H. auriculata, C. benghalensis, R. indica. | | Multifloral |
| ADH-8        | Asteraceae, Eucalyptus               | C. nucifera                     | Asteraceae, M. pudica, O. sanctum. | B. nigra, A. catechu, C. benghalensis, H. auriculata, C. lemon, Solanaceae, R. communis. | Unifloral |
| ADH-9        | Eucalyptus                           | M. pudica                       | Asteraceae, C. nucifera, O. sanctum. | A. catechu, Fabaceae, B. nigra, Poaceae, C. benghalensis. | Multifloral |
| ADH-10       | Eucalyptus                           | M. pudica                       | Asteraceae, C. nucifera, O. sanctum. | Amaranthaceae sp., H. auriculata, C. sativum, C. nucifera, D. metal, T. terestris | Unifloral |
| ADH-11       | Eucalyptus                           |                                 | Asteraceae, M. pudica, O. sanctum | M. pudica, Solanaceae, P. sylvestris, C. lemon, O. sanctum. | Unifloral |
| ADH-12       | Eucalyptus                           |                                 | H. auriculata, C. nucifera, C. sativum. | | Unifloral |
| ADH-13       | Eucalyptus                           | H. auriculata                   | Asteraceae, C. sativum, C. nucifera. | Amaranthaceae sp., O. sanctum, B. nigrum, M. pudica. | Unifloral |
| ADH-14       | Eucalyptus, Bignoniaceae            | Asteraceae, C. sativum, G. sepium | Asteraceae, C. nucifera, O. sanctum. | P. sylvestris, Poaceae, Asteraceae, C. nucifera, Citrus sp., M. pudica, Solanaceae, Acacia sp. | Multifloral |
| ADH-15       | Asteraceae, Eucalyptus               | C. sativum                      | C. nucifera, O. sanctum, H. auriculata, M. pudica, C. nucifera. | T. argentea, P. sylvestris, Fabaceae, Acacia sp. Amaranthaceae sp. C. bonplandianum, D. metal, Poaceae. | Multifloral |
| ADH-16       | Eucalyptus, Bignoniaceae            | Asteraceae, C. nucifera         | Asteraceae, C. nucifera, O. sanctum. | A. catechu, Acacia sp., Poaceae, M. pudica, R. communis, C. sativum, A. lebeck. | Multifloral |
| ADH-17       | P. guajava                           | Asteraceae, Eucalyptus          | P. pinnata, C. nucifera, Citrus sp., A. indica, Poaceae, C. bonplandianum, P. sylvestris, D. regia. | C. nucifera, Citrus sp., A. indica, Poaceae, C. bonplandianum, P. sylvestris, D. regia. | Unifloral |
| ADH-18       | Eucalyptus, Syzygium sp., M. pudica | C. nucifera                    | P. pinnata, Poaceae, P. guajava, P. sylvestris, Fabaceae, C. bonplandianum. | | Multifloral |

Contd....
ADH-19  *Eucalyptus*  sp., *Asteraceae*  
P. guajava, *M. pudica*, *C. commelina*, *C. nucifera*, *H. auriculata*, *A. marmelos*, *C. sativum*, *P. poaeceae*, *S. cumini*, *V. negundo*  
Unifloral

ADH-20  *Eucalyptus*, *M. pudica*  
*Asteraceae*, *S. sativum*, *V. laurinifolius*  
Multifloral

ADH-21  *P. guajava*  
*Asteraceae*, *S. syzygium*, *E. sp., I. opomea*  
Unifloral

ADH-22  *P. guajava*  
*Asteraceae*, *S. nucifera*, *E. sp., O. sanctum*  
Unifloral

ADH-23  *Eucalyptus*  
*Asteraceae*, *M. pudica*  
*P. guajava*, *M. sativum*, *B. nigra*  
Unifloral

ADH-24  *Eucalyptus*  
*C. nucifera*, *T. indicus*  
*Asteraceae*, *M. pudica*, *J. simplex*  
Unifloral

ADH-25  *C. sativum*  
*Eucalyptus*, *Asteraceae*  
*C. nucifera*, *B. hispida*, *C. inerme*  
Unifloral

ADH-26  *Eucalyptus*, *C. nucifera*  
*Asteraceae*, *M. pudica*, *C. sativum*, *M. indica*  
Multifloral

ADH-27  *Syzygium sp.*  
*Eucalyptus*, *C. nucifera*, *H. auriculata*  
Unifloral

ADH-28  *P. pinnata*  
*Eucalyptus*, *Asteraceae*  
*F. elephantum*, *E. alsinoides*  
Unifloral

Table 2. Contd……..

| S. cumini (ADH-1 and 27) and P. pinnata (ADH-2 and 28) | Pollen type were found in 2 samples each. S. cumini is a large evergreen tree found all along the avenues and around the forest area. It is an important source of nectar and pollen for honeybees because the tree flowers from February and continues to bloom till the end of April (Abou-Shaara, 2014). Eucalyptus, C. eqisetofolia, C. sativum, C. nucifera, D. regia, M. pudica, H. auriculata, C. lemon, C. bonplandianum and O. sanctum pollen types were associated with this unifloral honey. Whereas P. pinnata, a much branched bushy tree, widely cultivated medicinal application. A non-timber tree flowers profusely during the onset of summer month, it closes before the early monsoon. The Pongamia honey associated with Eucalyptus sp., A. catechu, M. pudica, C. nucifera, Peltophorum pterocarpum, Evolups alsinoides, Ferronia elephantum, Grevillea robusta and Delonix regia. Further, pollen spectrum revealed the association of Guizotia abyssinica unifloral honey sample (ADH-5) was Eucalyptus Sp., Hygrophila auriculata, M. pudica, Commelina benghalensis, C. nucifera, O. sanctum, P. hysterophorus, B. nigra, Justicia simplex and Typha angustata. Guizotia abyssinica is an annual erect herb to a height of 3 feet. It is cultivated as a minor crop along with ragi or groundnut which flowers during August to December. Coriander pollen occurs as dominant pollen in the sam-
| Sl. No. | Plant species                        | Family             | Habit   | Flowering period          | Economic importance          |
|--------|--------------------------------------|--------------------|---------|---------------------------|------------------------------|
| 1      | Acacia catechu (L.f.) Willd.         | Fabaceae           | Tree    | June-October              | Medicinal                    |
| 2      | Acacia chundra (Roxb. ex Rottler)    | Fabaceae           | Tree    | April-August              | Medicinal                    |
| 3      | Albizia lebbeck (L.) Willd.          | Fabaceae           | Tree    | July-November             | Timber                       |
| 4      | Amaranthus spinosus L.               | Amaranthaceae      | Herb    | July-October              | Vegetable                    |
| 5      | Areca catechu L.                     | Arecaceae          | Tree    | January-March             | Nut                          |
| 6      | Azadirachta indica Juss.             | Meliaceae          | Tree    | March-April               | Medicinal                    |
| 7      | Bauhinia purpurea L.                 | Fabaceae           | Tree    | August-November           | Ornamental                   |
| 8      | Boronia hispida (L.) Schum.          | Rubiaceae          | Herb    | January-December          | Medicinal                    |
| 9      | Bororia stricta (L.f.) Schum.        | Rubiaceae          | Herb    | January-December          | Medicinal                    |
| 10     | Brassica nigra (L.) Koch.            | Brassicaceae       | Tree    | March-June                | Oil Yielding                 |
| 11     | Caesalpinia pulcherrima (L.) Swart.  | Fabaceae           | Tree    | January-December          | Ornamental                   |
| 12     | Cassia mimosaoides L.                | Fabaceae           | Tree    | August-October            | Ornamental                   |
| 13     | Casuarina equisetifolia J.R.and G.forst. | Casuarinaceae    | Tree    | February-September       | Timber                       |
| 14     | Celosia argentea L.                  | Acanthaceae        | Herb    | June-September            | Vegetable                    |
| 15     | Chrysanthemum indicum L.             | Asteraceae         | Tree    | January-December          | Ornamental                   |
| 16     | Citrus aurantium L.                  | Rutaceae           | Tree    | April-May                 | Fruit                        |
| 17     | Citrus medica L.                     | Rutaceae           | Tree    | April-May                 | Fruit                        |
| 18     | Clerodendrum inerme                   | Lamiaceae          | Shrub   | October-March             | Medicinal                    |
| 19     | Coccos nucifera L.                   | Arecaceae          | Tree    | January-December          | Oil Yielding                 |
| 20     | Commelina benghalensis L.            | Commelinaceae      | Shrub   | June-October              | Medicinal                    |
| 21     | Coriandrum sativum L.                | Apiaceae           | Herb    | June-July                 | Vegetable                    |
| 22     | Croton bonplandianum Baill.          | Fabaceae           | Shrub   | January-December          | Medicinal                    |
| 23     | Cyperus Sp                      | Cyperaceae         | Herb    | May-June                  | Medicinal                    |
| 24     | Datura metala L.                     | Solanaceae         | Shrub   | January-June              | Weed                         |
| 25     | Delonix rega (Boj.ex.) Raf.          | Fabaceae           | Tree    | June-June                 | Ornamental                   |
| 26     | Eucalyptus Sp                      | Myrtaceae          | Tree    | March-June                | Timber                       |
| 27     | Evolvulus alsinoides L.              | Convolvulaceae     | Shrub   | February-June             | Medicinal                    |
| 28     | Feronia elephantum Correa           | Rutaceae           | Shrub   | January-December          | Fruit                        |
| 29     | Gillicidia sepium (Jacq) Kunth ex. Steud. | Fabaceae      | Tree    | November-March            | Medicinal                    |
| 30     | Grevillea robust A. Cunn             | Proteaceae         | Tree    | January-December          | Timber                       |
| 31     | Guizotia abyssinica Cass.            | Asteraceae         | Herb    | May-October               | Oil yielding                 |
| 32     | Helianthus annus L.                  | Asteraceae         | Shrub   | July-October              | Oil Yielding                 |
| 33     | Hygrophila auriculata (Schum) Heine. | Acanthaceae        | Herb    | October-April             | Medicinal                    |
| 34     | Ipomoea sp. L.                      | Convolvulaceae     | Herb    | January-December          | Weed                         |
| 35     | Justicio simplex Don.               | Acanthaceae        | Herb    | October-December          | Weed                         |
| 36     | Mangifera indica L.                 | Anacardiaceae      | Tree    | March-April               | Fruit                        |
| 37     | Mimosa pudica L.                    | Fabaceae           | Herb    | January-December          | Weed                         |
| 38     | Morus alba L.                        | Moraceae           | Tree    | May-June                  | Silk Production              |
| 39     | Ocimum sanctum L.                    | Lamiaceae          | Herb    | January-December          | Medicinal                    |
| 40     | Parthenium hysterophorus L.          | Acanthaceae        | Herb    | January-December          | Weed                         |
| 41     | Peltophorum pterocarpum (DC) Baker. | Fabaceae           | Tree    | March-April               | Ornamental                   |
| 42     | Phoenix sylvestris (L.) Roxb.        | Arecaceae          | Tree    | June-August               | Fruit                        |
| 43     | Pongamia pinnata Vent.               | Fabaceae           | Tree    | April-June                | Oil Yielding                 |
| 44     | Prosopis julifera D.C.               | Fabaceae           | Tree    | August-Feb                | Medicinal                    |
| 45     | Psidium guajava L.                   | Myrtaceae          | Tree    | February-April            | Medicinal                    |
| 46     | Ricinus communis L.                  | Euphorbiaceae      | Tree    | March-April               | Oil Yielding                 |
| 47     | Rosa indica L.                      | Rosaceae           | Shrub   | January-December          | Ornamental                   |
| 48     | Sapindus laurifolius Vahl.           | Sapindaceae        | Tree    | February-April            | Medicinal                    |
| 49     | Syzygium cumini (L.) Skeels.          | Myrtaceae          | Tree    | March-April               | Fruit                        |
| 50     | Tabebuia argentina (R & S) Brit.     | Bignoniaceae       | Tree    | August-September          | Ornamental                   |
| 51     | Tamarindus indicus L.                | Fabaceae           | Tree    | March-May                 | Fruit                        |
| 52     | Toddalia asiatica (L.) Lamk.         | Rutaceae           | Herb    | March-September           | Medicinal                    |
| 53     | Tribulus terrestris L.               | Zygophyllaceae     | Herb    | March-May                 | Weed                         |
| 54     | Typha angustata L.                   | Typhaceae          | Herb    | May-July                  | Medicinal                    |
| 55     | Vitex negundo Mill.                  | Lamiaceae          | Shrub   | July-August               | Medicinal                    |
| 56     | Ziziphus oenoplia (L.) Mill.         | Rhamnaceae         | Tree    | July-November             | Fruit                        |
Table 4. Floral calendar of bee forage plants of Kolar district during 2017-2019.

| Sl. No. | Taxonomical Name of the Plant                  | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---------|------------------------------------------------|-----|-----|-------|-------|-----|------|------|-----|------|-----|-----|-----|
| 1       | *Acacia catechu* (L.f.) Willd.                  |     |     |       |       |     |      |      |     |      |     |     |     |
| 2       | *Acacia chundra* (Roxb. ex Rottler)            |     |     |       |       |     |      |      |     |      |     |     |     |
| 3       | *Albizia lebbeck* (L.) Wild                    |     |     |       |       |     |      |      |     |      |     |     |     |
| 4       | *Amaranthus spinosus* L.                       |     |     |       |       |     |      |      |     |      |     |     |     |
| 5       | *Areca catechu* L.                             |     |     |       |       |     |      |      |     |      |     |     |     |
| 6       | *Azadirachta indica* Juss.                    |     |     |       |       |     |      |      |     |      |     |     |     |
| 7       | *Bauhinia purpurea* L.                         |     |     |       |       |     |      |      |     |      |     |     |     |
| 8       | *Borreria hispida* (L.) Schum.                 |     |     |       |       |     |      |      |     |      |     |     |     |
| 9       | *Borreria stricta* (L.f.) Schum.               |     |     |       |       |     |      |      |     |      |     |     |     |
| 10      | *Brassica nigra* (L.) Koch.                    |     |     |       |       |     |      |      |     |      |     |     |     |
| 11      | *Caesalpinia pulcherrima* (L.) Swart.          |     |     |       |       |     |      |      |     |      |     |     |     |
| 12      | *Cassia mimosoides* L.                         |     |     |       |       |     |      |      |     |      |     |     |     |
| 13      | *Casuarina equisetfolia* J.R.and G.forsst.     |     |     |       |       |     |      |      |     |      |     |     |     |
| 14      | *Celosia argentea* L.                          |     |     |       |       |     |      |      |     |      |     |     |     |
| 15      | *Chrysanthemum indicum* L.                     |     |     |       |       |     |      |      |     |      |     |     |     |
| 16      | *Citrus aurantium* L.                          |     |     |       |       |     |      |      |     |      |     |     |     |
| 17      | *Citrus medica* L.                             |     |     |       |       |     |      |      |     |      |     |     |     |
| 18      | *Clerodendrum inerme*                         |     |     |       |       |     |      |      |     |      |     |     |     |
| 19      | *Cocos nucifera* L.                            |     |     |       |       |     |      |      |     |      |     |     |     |
| 20      | *Commelina benghalensis* L.                    |     |     |       |       |     |      |      |     |      |     |     |     |
| 21      | *Coriandrum sativum* L.                        |     |     |       |       |     |      |      |     |      |     |     |     |
| 22      | *Croton bonplandianum* Baill.                  |     |     |       |       |     |      |      |     |      |     |     |     |
| 23      | *Cyperus* Sp.                                  |     |     |       |       |     |      |      |     |      |     |     |     |
| 24      | *Datura metel* L.                              |     |     |       |       |     |      |      |     |      |     |     |     |
| 25      | *Delonix regia* (Boj.ex.) Raf.                 |     |     |       |       |     |      |      |     |      |     |     |     |
| 26      | *Eucalyptus* Sp.                               |     |     |       |       |     |      |      |     |      |     |     |     |
| 27      | *Evolvulus alsinoides* L.                      |     |     |       |       |     |      |      |     |      |     |     |     |
| 28      | *Feronia elephantum* Corea                     |     |     |       |       |     |      |      |     |      |     |     |     |
| 29      | *Gänickea sepium* (Jacq) Kunth ex.Steud.      |     |     |       |       |     |      |      |     |      |     |     |     |
| 30      | *Grevillea robust* A. Cunn                     |     |     |       |       |     |      |      |     |      |     |     |     |
| 31      | *Guizotia abyssinica* Cass.                    |     |     |       |       |     |      |      |     |      |     |     |     |
| 32      | *Helianthus annus* L.                          |     |     |       |       |     |      |      |     |      |     |     |     |
| 33      | *Hygrophila auriculata* (Schum) Heine.         |     |     |       |       |     |      |      |     |      |     |     |     |
| 34      | *Ipomoea* sp. L                                |     |     |       |       |     |      |      |     |      |     |     |     |
| 35      | *Justicia simplex* Don.                        |     |     |       |       |     |      |      |     |      |     |     |     |
| 36      | *Mangifera indica* L.                         |     |     |       |       |     |      |      |     |      |     |     |     |
| 37      | *Mimosa pudica* L.                             |     |     |       |       |     |      |      |     |      |     |     |     |
| 38      | *Morus alba* L.                                |     |     |       |       |     |      |      |     |      |     |     |     |
Ocimum sanctum L. (8), Coriandrum sativum L. (6), Peltophorum pterocarpum (DC) Baker. (18), Phoenix sylvestris (L.) Roxb. (9), Pongamia pinnata Vent. (4), Ricinus communis L. (6), Rosea indica L. (4), Sapium sebiferum L. (4), Syzygium cumini (L.) Skeels. (9), Tabebuia argentea (R. & S) Britt. (4), Tribulus terrestris L. (18), Vitex negundo Mill. (5), Ziziphus oenoplia (L.) Mill. (8).

Table 4. Contd......

Fig. 3. Number of plant species with economic importance.
| Sl. No. | Taxon          | Aperture | Ornamentation       | Size, Shape & Exine pattern                          | Photomicrograph |
|--------|----------------|----------|---------------------|-----------------------------------------------------|-----------------|
| 1      | *Acacia sp.*   | Tricolpoid| Striato Reticulate | 38-45, 50-58 µm, exine 1.5-3µm                       | ![Micrograph](image1) |
| 2      | *Asteraceae*   | Tricolporate| Echinulate         | 35-38µm, exine 5µm                                  | ![Micrograph](image2) |
| 3      | *A. indica*    | Tetracolporate| Reticulate         | Prolate spheroidal, exine 1-0.5µm                   | ![Micrograph](image3) |
| 4      | *B. purpurea*  | Tricolporate| Striate            | 25x30µm, exine 1.5 µm                               | ![Micrograph](image4) |
| 5      | *B. nigra*     | Tricolpate | Reticulate         | 28-31µm subspherical, exine 1.5µm                   | ![Micrograph](image5) |
| 6      | *Citrus sp.*   | Tetracolporate| Reticulate        | 30-34, 24-31 µm amb tetragonal                      | ![Micrograph](image6) |
| 7      | *C. nucifera*  | Monosulcate| Granulate          | Oblate                                              | ![Micrograph](image7) |
| 8      | *C. sativum*   | Tricolporate ora elliptic| Granulate | 25-28, 40-50µm, exine 2µm                           | ![Micrograph](image8) |

Table 5. pollen morphology of some dominant pollen types of the study area.
|   | Species                  | Aperture   | Surface Pattern         | Measurements               | Exine Thickness |
|---|-------------------------|------------|-------------------------|----------------------------|-----------------|
| 9 | *C. bonplandianum*      | Omni aperturate | Reticulate with crotonoid pattern | 46-48µm, exine 3µm   |                 |
| 10| *Cyperus sp.*           | 3-4 colpoid  | Granulate               | 36-41, 26-34µm, exine 1µm |                 |
| 11| *D. metal*              | Tricolporate | Strito reticulate       | 50x50µm spheroidal, exine 4µm |                 |
| 12| *Eucalyptus ssp.*       | 3-4 syncolporate | Psilate                | 19-22x26-31µm, exine 1µm amb semi-angular exine 0.5µm |                 |
| 13| *G. sepium*             | Tricolporate | Psilate                | 25-28, 29-31µm, exine 1.5µm |                 |
| 14| *G. abyssinica*         | Tricolporate | Echinulate             | 25-30µm spheroidal      |                 |
| 15| *M. indica*             | Tricolporate | Striato reticulate     | 28-24µm, exine 2µm      |                 |
| 16| *M. pudica*             | Tetrad      | Psilate                | Spheroidal, exine 1µm   |                 |
| 17| *O. sanctum*            | Hexacolpate | Reticulate             | 55-75µm suboblate, exine 4µm |                 |
with 14 species contributing to the honey production in the study area. In addition, Rutaceae and Asteraceae comprised of 4 species each, followed by Arecaceae, Lamiaceae and Myrtaceae recorded with 3 species each. Convolvulaceae, Amaranthaceae, Rubiaceae and Acanthaceae were found with 2 species each and Anacardiaceae, Apiaceae, Bignoniaceae, Brassicaceae, Casurinaceae, Commelinaceae, Cyperaceae, Euphorbiaceae, Moraceae, Proteaceae comprised of single species each.

All the 56 pollen types recorded comprised several plant types such as trees, shrubs and herbs. Among the reported habit, there was a dominance of the tree with 51.78%, followed by herbs and shrubs with 32.14% and 16.07%, respectively, represent floral diversity (Fig. 2). The economic importance of the identi-

|   | Pollen Type | Polarity | Shape | Size | Exine Thickness |
|---|-------------|----------|-------|------|----------------|
| 18 | *P. pterocarpum* | Tricolporate | Reticulate | 35-40, 55µm, | exine 3-5µm |
| 19 | *P. pinnata* | Tricolporate | Psilate | 21-41, 43µm, | exine 2µm |
| 20 | *P. guajava* | Tricolporate | Psilate | 14-20µm triangular, | exine 1.4µm |
| 21 | *R. communis* | Tricolporate | Reticulate | 26x26µm spheroidal, | exine 2µm |
| 22 | *R. indica* | Tricolporate | Striate reticulate | 25x45µm, | exine 2.5µm |
| 23 | *S. cumini* | Trisyn colporate | Psilate | 12x28µm oblate, | exine 1.5µm |
| 24 | *T. argentea* | Tricolporate | Reticulate | 44-31µm subprolate | to prolate |
| 25 | *T. indicus* | Tricolporate | Striate | 35-35µm, | amb circular, exine 2µm |
fied plants of apiculture importance was categorized as medicinal, ornamental, vegetable, timber, oil yielding, weeds, fruits and nuts (Fig. 3). According to the present result, predominant and secondary dominant pollen types with medicinal importance were A. catechu, A. chundra, A. indica, Gliciridia sepium, C. inerme, B. hispida, B. stricta, C. benghalensis, Croton bonplandianum, Cyperus sp., Evolvulus alsinooides, H. auriculata, O. sanctum, Prosopis julifera, Sapindus laurifolius, Todalia asiatica, Typha angustata and Vitex negundo. Pollen types of Bauhinia pupleurea, Caesalpinia pulcherima, Delonix regia, C. mimosoides, Chrysanthemum indicum, Rosa indica, Tabebuia argentaia and P. pterocarpum were grouped as ornamental plants. Amaranthus spinosu, Celosia argentea and C. sativum were vegetables and Albizia lebbbeck, Casuarina equisetifolia, Eucalyptus sp. and Grevillea robust were timber plants. B. nigra, Guizotia abyssinica, H. annus, C. nucifera, P. pinnata and R. communis are important oil yielding plants. The fruit and nuts yielding plants were Feronia elephanum, P. sylvestris, P. guajava, S. cumini, C. aurantium, C. medica, Tamarindus indicus, Ziziphus oenoplia and A. catechu. Weeds of forage importance to A. dorsata in the study area were D. metal, M. pudica, P. hyserophorus, Ipomoea sp., J. simplex and Tribulus terrestris, whereas M. alba was cultivated for production of silk.

From the study it is observed that, most of the plant species such as B. hispida, B. stricta, C. pulcherrima, C. nucifera, C. indicum, C. bonplandianum, Eucalyptus sps. F. elephanum, G. robust, Ipomoea sp, M. pudica, O. sanctum, P. hyserophorus, R. communis and R. indica have prolonged blooming period throughout the year. These species provide greater forage potential for honeybees in the study area. Pollen grains are the most important component of honey helps to identify the distribution of floral source of honey. The blooming period of each species was recorded as shown in Table 4. According to the present observation, B. hispida, B. stricta, C. pulcherrima, C. indicum, C. nucifera, C. bonplandianum, F. elephanum, G. robust, Ipomoea sp, M. pudica, O. sanctum, P. hyserophorus and R. indica bloom throughout the year. The peak flowering period of most important honey plants were observed during February to June and less blooming period was observed during October to January. Microscopic analysis of honey helps to identify the pollen types with their size, shape and ornamentation. The morphology of pollen grains differ in shapes, exine structure, symmetry and sculpture among plant species. Table 5 demonstrated the morphology of various types of pollen obtained from the present study. The pollen of Acacia sp. are sub globes, whereas P. pinnata pollen are spherical. It has been established in this study that the species belongs to the family Asteraceae pollen type were spinelous, Myrtaceae pollen types are colporate and prolate. But there is variability in the pollen type of the species belongs to family Fabaceae. Therefore, it is essential to examine a large number of pollen grains from one family in order to obtain a complete knowledge of different types within that family.

Conclusion

The present study contributes to the floral resources of A. dorsata honey produced in Kolar district of Karnataka state. A. dorsata mainly depends on the wild tree and cultivated plant blooms throughout the year as pollen and nectar source. From the results, it is evident that there is a lot of potential in establishing beekeeping industries in the study area. Among 28 honey samples analysed, 18 were unifloral, with the predominant pollen types were C. sativum, E. globulus, G. abyssinica, S. cumini, P. pinnata and P. guajava. The most represented families were Fabaceae, Rutaceae and Asteraceae. These plants may be introduced in social forestry and afforestation programs to enhance the honey yield. Further, the yield of economic crops may also be able to increase by pollination. Assessment of honey bee pollen as a bioindicator of the environment may throw more light on floral diversity.

Conflict of interest

The author declares that he has no conflict of interest.

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