1. INTRODUCTION

1.1 Background

Honey bees are generally regarded as a smart and a wise insect. It has been believed that honey bee evolved over millions of years and earliest record was found in Myanmar. In the Cretaceous period, i.e., 100 million years ago, flowering plants became the prior and huge numbers of pollinators occurred. It gives an idea about evolution of insects that cater the flowering periods came out same period (Crane, 2013). According to Vedas, the Hindu scripture, honey was collected while smoking cane ladders and brought in the skin containers. Before human start beekeeping, "honey hunting" was the best way for acquiring wild honey (Gupta et al., 2014). Apiculture or beekeeping is driven from Latin words "apis" means bees and "culture" means maintenance of honey bee colonies, mostly in natural hives or modern hives (Verma, 1992). After Second World War (1945) in Turkey, beekeeping occupation has developed faster and almost all regions of Turkey (Sirali, 2002).

Beekeeping is mostly dependent on floral diversity with abundant nectar and pollen sources as well as the better strengths of bee colonies (Free, 1970; Akratankal, 1990). Bees are considered as the most important pollinators and also called as social animals. About 2-3rd of the world’s plants requires insects or other animals to pollinate. Among 250,000 plant species in the world about 40,000 species are important for honeybees as a source of food (Crane, 1990). More than 80 % of the total flowering plants needed insects for pollination among which honeybees served 80 % (Robinson and Morse, 1989). Pollination in terms of monetary covers an average global value of worth \$117 hr^{-1} yr^{-1} (Costanza et. al, 1997).

Pollination is one of the most important phases in every plant life cycle for them to survive. Researchers carried out research on pollination have concluded that pollination is not just a charismatic natural history but also an indispensable ecological function. Reproduction among plants is the result after successful pollination and next generation life depends on seeds. There are many pollinators in the world, among which wind, water, bats, butterflies, moths, flies, birds, beetles, ants, bees etc are some of it. There is a mutual relationship between pollinators and plants and cannot be studied in an isolated system (*http://www.pollinator.org)*. The mutual inter-relationship between an anthophilous insect and entomophilous angiosperms reveals their co-evolution (Suryanarayan, 1986).

Incomplete pollination brought deformed fruits and vegetables that are not marketable. Crops which are almighty dependent on pollinators to attain economical yields include almond, apple, cherry, pear, cranberry, blueberry, blackberry, greenhouse tomatoes, asparagus, tomatoes, and squash. Thus, conservation of native bees is highly essential and economically important for quality fruits and vegetables production. In United States every grower’s lease millions of beehives to pollinate their crops each spring. Huge number of honeybees is brought to pollinate crops to ensure their yields that will reach growers expectation (Isaccs and Tuell, 2007). Thus, beekeeping has a great history in case of pollinating crops and horticultural plants.

Beekeeping is one of important agricultural entrepreneurs that utilizes nectar and pollen and contribute farmers otherwise that would be wasted (Melaku et. al, 2008). Beekeeping in Nepal is a simple farming system and marginal farmers can also run it smoothly at a low cost. Beekeeping products can be sold in market which enhances income status of bee farmers. Bee products are honey, bee wax, royal jelly, and pollen (Verma, 1992). In Nepal, beekeeping is highly significant for under-privileged groups. Women can run this occupation due to various reasons: low investment, cash income, part-time job, easy to learn and practice and easy to market (Maskey, 1992). The success of beekeeping depends on many factors but most important among them is knowledge on type, density and quality of bee flora. Honeybee obtained pollen and nectar from flowers for their survival (Bista and Shivakoti, 2001).

Due to presence of diverse floral biodiversity, Nepal is considered as a major centre for beekeeping. Various types of bees have been noticed in Nepal (Joshi, 1999). Since long times, most of the farmers engaged in beekeeping with enriched indigenous knowledge on bee loving plants species and better quality of honey (Ranabhat, 2010). Bees get resources from plants and utilize it to multiply and grow likewise plants gets benefit in turn from bee as pollinated that helps sexual reproduction and genetic recombination (Gutierrez et al., 2015). There is a connecting link between honeybees and floral kingdom. Imagination of floral kingdom without honeybees is impossible. So, often bees are called "Pearls of nature" (Bista, 1997).

In Nepal out of nine honeybees four native honeybees are found and they are *Apis laboriosa* (Smith 1871), *Apis dorsata* (Fabricius 1793), *Apis florea* (Fabricius 1787) and *Apis cerena* (Fabricius 1793) (Thapa, 2003). The Himalayan world's largest honeybee: *Apis laboriosa* ranges between 850 m to 3500 m above sea level elevation in the northern parts of fragile ecological Himalayan region. It is black in color with white stripes on each abdominal segment. *Apis laboriosa* generally build up hives along the cliffs mostly single comb about 0.8 m wide and 1 m long (Thapa, 2001). *Apis dorsata* is generally known as tropical giant honeybee found in the tropical regions of Asia (Ruttner, 1988). During winter season when temperature dropped below 10^0C in hilly areas, they migrate to the Tarai region between 60 m to 350 m asl (Thapa, 2003).

Apis florea also called as dwarf honeybee. It is found between 10 m to 1000 m asl in Nepal. They build a small comb (15.24 cm) in the dense bushes or small tress or along the branches. Especially *Apis florea* is a good pollinator of several fruit plants such as *Mangifera indica* and *Litchi chinensis* (Thapa, 2003). *Apis cerena* is also known as eastern honeybees. This species ranges from 60 m to 3500 m elevation in Nepal. There are three subspecies of *Apis cerena*: *Apis cerena cerena*, *Apis cerena himalaya* and *Apis cerena indica* are recorded from Nepal (Verma, 1990). *Apis mellifera* is not a native but it was introduced in early 1990 through the commercial beekeepers in the Hindu Kush Himalayan regions (Thapa et al., 2000a).

Plants which are visited by bees to collect their food (nectar and pollen) are called as bee plants or bee flora (Pratap, 1997). Plants of one area and another area may vary according to ecological habitats hence condition of pollen and nectar production. Flowers are main step of bee's life. Man can harvest floral sources which may remain useless and micromanipulators (Kevan, 1984). There are many fruits which are self-sterile and needs pollinators for cross pollination to produce fruits and seeds. According to Crane (1991), pollination service provided by honeybees increases ratio in production of apple, lemon, litchi, peach, pear, persimmon and plum by 24, 15, 2, 2, 14, 1.2 and 6 times respectively. Plant types and duration of flower time differ from one place to another due to variation in topography, climate and other cultural and farming practices. Every geographical region has its own kind of honeybee flora and floral dearth period of shorter or longer duration. This information of bee flora helps in management of bee colonies (Bhatta, 2005).

It is said that for proper beekeeping, colony strength is one of the key factors. Larger and stronger colonies provide four to five times better pollinators than smaller and weaker ones, hence larger colonies have a large number of older bees as foragers (Verma, 1998). General survey of bee flora in Kathmandu valley found 156 species (Kafle, 1984). Quality of honey production depends on the seasons and the timing of bees visiting on diverse plant species (Adhikari, 2011). The quantity of nectar or pollen produced by crops on one hectare of land is defined as nectar or pollen potentials (Crane et al., 1984). Bee flora has been differentiated into major, medium and minor sources for bees on the basis of containing pollen and nectar used for maintenance and development of bee colonies (Pratap, 1997). Nectar is a sugary fluid secreted within flowers to encourage pollination by insects and other animals, collected by bees to make honey.

Pollen is a fine, powdery substance consisting microscopic grains of proteins, lipids, minerals, and vitamins to feed young ones (Adhikari, 2010). Pollen itself is not male gamete (Adam, 2001). Each pollen grain contains vegetative (non-reproductive) cells (only a single cell in most flowering plants but multi cells in many other seed plants) and a generative (reproductive) cell. Pollen is produced inside the microsporangia in the male cone of a conifer or other gymnosperms or in the anthers of an angiospermic flower. Except in case of some submerged aquatic plants, the mature pollen grain has a double wall. Pollen apertures are part of the pollen wall that may involve exine thinning or a significant reduction in exine thickness. Pollen may be referred as inaperturate or aperturate. Pollen grains of various species have various size (about 10 to 100 micrometres) and others as round, oval, disc or bean-shaped and sometimes filamentous. The natural colour of pollen is mostly white, creamy, yellow or orange (www.vcbio.science).

Environmental variables greatly affect the bee flora and their pollinators (Kearns and Inouye, 1993). Temperature is the main driving environmental variable for flower development and blooming to nectar secretion, seed development and anther dehiscence all that affect the activity of flower visitors (Adhikari, 2010). Bees have floral preferences, as they visit some plants frequently some do not. Different plants contain different amount of pollen and nectar (Pratap, 1997). Pesticide Action Network North America has stated that, "the weight of evidence demonstrated that pesticides are indeed key in explaining honeybee declines, both directly and in tandem with the other two leading factors, pathogens and poor nutrition. “Global food security is in crisis which is due to threatening of bees. One third of global agricultural production depends upon pollination, especially by honeybees. Nowadays, Europe and America, due to pollution, pesticides, sophisticated developmental works and negligence, honey bees are disappearing. Importance of honey bees is declining with alarming rate. Einstein's theory seems now true than ever that once bees disappear than humankinds have only four years to extinct. Thus, conservation of bees should get urgency otherwise bee crisis can demolish the world food security, already affected by the economic crisis. One of the studies done by Riscu and Bura (2013) showed that number of factors causing declining of honeybees is: disease, parasites, climatic factors (high temperature, drought) or decrease in the diversity of honey flora.

The Coronation Garden area located at Tribhuvan University, Kirtipur seems highly disregarded and bee flora of this region is relatively less explored. This area is typically a Garden, which covers more plantation trees, adjoining with agricultural field and horticulture landscape. Documentation of bee flora and their seasonal variation are important to foresight the land use-based bee farming. Documentation of bee flora also supports to improve income condition of small holder farmers through development of beekeeping. Thus, result of this study will support to know the floral calendar of bee flora that enhances beekeeping productivity. Also provides information about plant species, which are liked by bees. However, very few studies have been carried out in Nepal regarding bee flora. Pratap (1997) has carried out inventory and management of bee flora of the Hindu Kush Himalayas., Adhikari et al. (2011) have accomplished that "Bee Flora in mid hills of Central Nepal" and Bista et al. (2000/2001) have discovered "Honeybee flora at Kabre, Dolakha District". These all research works provide a lot of information about bee flora in relation to their specific regions. Hence, present study has been initiated to document the different honey bee flora of the Coronation Garden where the apiary would be set up and monitored regularly and floral calendar and pollen library will be prepared.

1.2 Research Objectives

1.2.1 General Objectives of the Study

The general objective of the study was to examine the seasonal availability of bee flora of Coronation Garden, Kirtipur.

1.2.2 Specific Objectives

The specific objectives were:

- to prepare list of bee flora based on major, medium and minor.
- to know the relationship of seasonality with bee flora.
- to know the relationship between apiary and the flower type distance.
- to know the relationship between honeybee and flower colour.
- to prepare the pollen library with the help of pollen picture.

1.3 Justification of the Study

Nepal is an agricultural country. About 73% of the total population directly depend upon agriculture. Lack of proper knowledge, agriculture contributes only 31.8% in Gross domestic product (GDP). Thus, this piece of work would be a good choice for beekeeping and colony management.

The selected area, Coronation garden, Kirtipur is one of semi-natural landscapes and which is being deteriorated. People here may unknown about the fact that this kind of area can provide greater habitat to wild and natural experiments such as bee farming. Agricultural land and orchard farm are located nearby it. Residential area is covered by vegetables crops are also found here. This area is rich in ornamental plants, horticultural plants, vegetables crop as well as forest and avenue trees. So, the honeybee can get surplus amount of bee flora for their pollen and nectar. In different seasons we can find different kinds of plants. This area mostly has plant species such as *Citrus* spp, *Callistemon citrunus*, *Grevillea robusta*, *Trifolium repens*, *Oxalis corniculate* , *Oxalis latifolia* , *Cuphea micrantha* , *Lagerstroemia indica* , etc. having nectar and pollen. Many researchers have worked out in the field of bee flora especially in the wild plant species and forest area or at a larger area. This research work was carried out in semi-natural landscape which will provide information on which ornamental plants as well as horticultural plants and vegetable crops will also be a part of bee flora and bee becomes a connecting bridge between animals and plants.

1.4 Limitation of the Study

Due to limited laboratory facilities detail pollen analysis was not feasible. Thus, nectar concentration and its volume from each bee flora during different harvesting periods were not performed. Hence, plants, which were categorized into polleniferous and nectariferous plants were mostly from the secondary sources. Thus, this study mostly limited with garden plant and horticultural plant species. Therefore, the identification becomes much easier and less confusion.

2. LITERATURE REVIEW

The practice of beekeeping not only depends on the honeybee's strain but also on the volume and occurrence of pollen and nectar within the surrounding area of an apiary (Free, 1970; Akrathanakal, 1987). Apiculture is deeply seated in the Ethiopian rural life and has a long tradition of beekeeping with about 3-5 million honeybee colonies producing about 21 thousand tons of honey annually (Fitchal and Admasu, 1994). In Nepalese society honey hunting has been practicing for more than thousand years (Joshi, 2008). Thus, this occupation can be defined as cultural heritage. Beekeeping is an occupation of economically marginal families in Nepal (Adhikari and Ranabhat, 2011).

Beekeeping is a rearing of honeybees for honey and other bee products and also for pollination. It is essential for increasing productivity of both horticultural and agricultural crops (Pratap, 1997, Bhalchandra et al., 2014). Beekeeping is becoming one of the important sectors for sustainable mountain agriculture and integrated rural development (Verma, 1993). Modern beekeeping is not very common in Nepal (Gautam, 1984, Bista and Shivakoti, 2001).

Kafle (1992), studied bee disease in Nepal. He said that Nepal was clueless country for bee diseases until 1980, but started to attack by sacbrood by the Thai sacbrood virus. It occurred first time in the eastern border of Nepal. Later, this bee disease was found spread rapidly and covered the entire country. The incidence of outbreak appeared from the western border of Nepal in 1983 where almost 90% of bee colonies were lost. *Varroa jacobsonii* is an Asian mite causes a serious problem for *Apis cerena indica* but *Apis mellifera* all over the world. While reporting beekeeping, beehives also needed to study for clarification of status of beehives and condition in Nepal. There are traditional and improved beehives found in Nepal. The traditional hives are log hive, wall hive, captivity hive, old trunk hive, and wooden box hive. Similarly, improved bee hive is Netwon 'A' village type, Netwon 'B' type, Indian hive, Godawari hive and African top bar hive. Among them the Netwon 'A' village type hive is the best for honey production (Maskey, 1992).

Honeybees live in the colony and they are called as eusocial animals (Abrol, 2010). Mishra (1997/98) found that one third of human diet comes from bee pollinated crops and pollination value is about 143 times more important than honey production. In China, Chun (1993) estimated the increase in seed yield of four major crops rape, cotton, tea and sunflower through honeybees. Bees contribute about 60-80% pollination service and it is more important than honey and other bee products (Neupane, 2006). Pollination is critical ecosystem services provided by insect and about 16% of world flowering plant species are pollinated by bees and nearly 400 species of agricultural plants (Crane and Walker, 1984). It is estimated to be 153 billion agricultural production used for human food (2005) from worldwide and indicates the importance of insects (Gallai et al., 2009). During middle cretaceous period, the bees and plants are co-evolved (Michener, 1974). The mutual inter-relationship of the anthrophilous insects and entomophilous angiosperms reveals their co-evolution (Suryanarayan, 1986).

Pratap (2001) found a declining relationship between pollinators and plants yield and seed production. Among various pollinators bees are considered as the wisest pollinators and best (Robinson and Morse, 1989). In Nepal honeybees are distributed from high altitude to low altitude i.e., from high hills to lowlands Tarai. Nepal possesses a good rank in biodiversity, also to honeybee diversity (Woyke, 1999).

2.1 Existing Bee types

Four out of nine honeybees found in Nepal are native to Nepal. They were *Apis laboriosa* (Smith 1871), *Apis dorsata* (Fabricius 1793), *Apis florea* (Fabricius 1787) and *Apis cerena* (Fabricius 1793) as described by Thapa (2003).

Apis dorsata is known as giant honeybee or rock bee (Ruttner, 1988; Pratap 1997). The giant honeybee ranges from plains and foothills of Nepal's (Neupane, Dhakal, Thapa and Gautam, 2006). It can migrate several miles in search of food and safe shelter also have strong tendency of absconding, swarming and migration. *Apis dorsata* occupy the same nesting area/site of previous seasons (Paar et al., 2000). Verma (1992) found a single colony has 60,000 to 1, 00,000 worker bees and sometimes on a single tree may aggregate 50 to 100 colonies. Khan (1992) considered a honey chamber; one side of nest is always tapering and the other end consists of the brood. He also concluded that depending upon variable factors like location, flora and blossom duration nest have different sizes.

Apis florea is a dwarf honey bee, lowland species found between 10 m upto1000 m in Nepal (Thapa, 2003). *Apis florea curtai* is a single-combed, open-nesting, highly polyandrous, and predicted to curtail worker reproduction (Halling et al., 2001). Honey produced by this species has a great medicinal value, so farmers are farming it with *Apis dorsata* (Pratap, 1997). Khan (1992) found that this species forms a single comb on a twig or branch of the host plants and also size of comb is in different types. At once time it produces 1 to 2 kg of honey. Verma (1992) reported that honey of *Apis florea* has higher dextrin content and less capacity to crystallize as comparison with other *Apis* species.

Apis laboriosa is black in color with white stripes on each abdominal segment known as cliff (Thapa, 2001). *Apis laboriosa* migrates to several distances for safe shelter. In winter it migrates to warm climate area up to 850 m where they spend about seven months and in summer season temperature above 250C. It migrates to sub alpine zone between 2500 to 3500 m (Underwood, 1990; Thapa, 2001). If colonies are undistributed, they may remain on a given cliff from early spring until conditions are unfavorable.

Apis cerena, the eastern hive bees, ranges from 60 to 3500 m in Nepal. According to Verma, 1990 there are three subspecies of *Apis cerena*, *Apis cerena cerena*, *Apis cerena himalaya* and *Apis cerena indica. Apis cerena* are mostly attractive to rapeseed due to rich both pollen and nectar. *Apis cerena* is migratory in nature and cannot remain in one place all year round (Pratap, 1997). Verma (1992), have carried out survey among farmers and found that Apis *cerena* is not very famous within beekeepers due to its frequent swarming, absconding and robbing habits and production of a large number of laying worker bees and the defenceless against the predators. Khan (1992), found *Apis cerena* possess good characters such as ability to escape from predators and good clustering to avoid cold temperature in winter.

Apis mellifera is native to Europe, Africa, and western Asia and become naturalized throughout the world (Michener, 1974). This bee also builds parallel combs popular among commercial beekeepers because it maintains prolific queens, less absconding and less swarming tendencies and has good honey collection habit (Pratap, 1997). Distinctive behaviors of *Apis mellifera* is foraging which is a link between the ambient environment and the honey bee colony (Shaara, 2014). Khan (1992) founded that *Apis mellifera* is good for migratory beekeeping and produces more honey and hive products as, propolis and royal jelly. Especially, *Apis mellifera* at any foraging trip, it focuses on only one kind of flower. One important feature that makes honeybee so popular for commercial pollination of crops that pollen is transferred between flowers of the same species was studied by Joshi and Joshi (2010).

2.2 Existing Bee Flora

For better apiary management and harvest of bee products depend on floral resources preferred by honeybees. Many researchers have carried out study on bee flora in worldwide but this type of information in Nepal is very light. Only few authors have carried out and published floral survey results.

Gautam (1984) reported important bee plants are clover, mango groove, and orchard of peaches and plums, buckwheat, sunflower, mustard etc. Joshi (1998) illustrated the bee flora of Dadeldhura. He reported 76 bee plants in the district. Out of them, *Aesandra butryraca, Brassica spp., Azadirachta indica, Citrus spp., Berberis asiatica, Pyracantha crenulata* and *Cedrela toona* are important. Likewise, Thapa and Dangol (1993), investigated bee flora at IAAS, Rampur, Chitwan and its vicinity area. They found 100 different species of bee flora. In Dolakha district and its territory there are 119 important bee floras out of which 47 species are found as major sources for bees. Categorization of beekeeping period and floral calendar are the activities based on diversity and abundance of bee floras. Bee flora which are influenced by various climatic parameters are studied by (Bista and Shivakoti, 2000/2001).

In Jumla, Pechhacker et al. (2001), registered Apple (*Malus domestica*), Peach (*Prunus persica*), Plum (*Prunus domestica*), Mustard (*Brassica spp.*), Buckwheaat (*Fagopyrum spp.*) are as major nectar sources as in Dadeldhura major bee floras are Indian butter tree (*Aesandra butyracea*), Soap nut tree (*Sapindus mukorosis*), Toona (*Toona ciliatea*), Berberis (*Berberisis aristata*), Apricot (*Prunus urmemiaca*), Mustard (*Brassica spp.*). Sharma and Kafle (1981) did observation on various places in Nepal regarding development of bee farming. They reported various cultivated as well as wild floral resources which are known to provide mixed type of bee forage. From Mahakali zone, Bista (1997) investigated 65 different bee floras and concluded that there is variation in bee flora at different sites and season. Maskey (1989) recorded bee flora of Kathmandu valley with the help of Kafle (1979) and described different honey flow periods. She also investigated the honey as first (April/May) by *Trifolium repens*, second (Nov, Feb, March) by *Brassica campestris* and the third as described by the mixture of two or more nectar and pollen sources.

Joshi (1999) described floral origin of a honey is important since award prices are paid for honey of specific floral origin. For example, in Austria *Brassica* (rape seed) honey costs 50 shillings (US $ 4) whereas the *Rhododendron* and *Castanea* honey cost more than 150 shillings. In Morocco, thyme (*Thymus* spp.) honey costs US $ 15-20 whereas eucalyptus (*Eucalyptus diversicolor)* honey costs US $ 3-5 only. Bee floras are essential for surplus production of honey and to manage healthy bee colonies for pollination. About 202 bee floras with their ecological habitat, flowering period and nectar/pollen around Hindu-Kush Himalayan region was described by Pratap et al., (1997). Adhikari and Ranabhat (2011) identified about 158 plant species as main bee flora in Kaski district. They also reported that out of 158, 38 species were recognized as major, 35 as medium and 30 as minor sources for both nectar and pollen. Sivaram (2001), revealed more than 340 plant species of both cultivated and wild ones useful to honeybees as food sources in Karnataka state of India. He also found that some genera like *Syzygium*, *Cassia*, *Citrus*, *Pongamia*, *Azadirachta*, *Albezia*, *Brassica*, *Areca*, *Cocos*, *Guizotia*, *Helianthus*, *Lagerstroemia*, *Polinathus*, *Sapindus*, *Tecoma* are some of the important plants as good sources for honeybees.

Phakde (1962); Suryanarayan et al., (1966); Sharma (1989); Sharma and Raj (1985) described different bee flora and identified as nectar and pollen sources at different parts of India. They found that Jamun (*Syzygium cumini* Skeels) is widely planted avenue-cum-fruit tree and naturalized as forests in many parts of India which is a predominant bee flora of Western Ghats. Jamun (*Syzygium cumini*) is reported to be a major bee flora at many parts of India as Bihar (Naim and Phakde, 1976); Maharastra (Deodikar and Thakar, (1953); Chaubal and Deodikar, (1965). They also found Jamun flowers are dirty white and bloom in April-May. Satyanarayan (1975) found that the honey flow extends over a period of 2 to 3 weeks and the nectar-sugar concentration is very high (7.2%). Chemical composition of Jamun honey and reported that sucrose, glucose, fructose, maltose, reffinose and melezitose are present in Jamun honey of which fructose is high (43.3%) given by Narayan (1970).

Deodikar and Thakur (1953), reported Hirad (*Terminialia chebula Retz; fam combretaceae)* as a major flora in beekeeping areas of Maharastra, India. Subramaniam (1975) reported that Moulsari (*Mimusops eleyni* L) has good nectar flow in May-June at Maharastra and also in Uttar Pradesh. It is an evergreen tree with whitish flowers and the honeybees also collect pollen from this flower. Bramble (*Rubus* spp) starts flowering from middle of Janauary and continues till Mid-March around hilly parts of India reported by Gupta and Thakur (1987). He also reported that nectar-sugar concentration in *Rubus ellipticus* is 65-71% and the mean sugar value for the nectar is 2400 µg per flower per 24 hours. Rubber (*Hevea brasiliensis* Muell) is major flora in Kerala and large plantation reported by (Devadason, 1972). Toon (*Toona ciliata*) is as a major nectar source has been reported at various parts of India as, Himanchal Pradesh (Singh, 1948), Kashmir (Saraf, 1972). Litchi (*Litchi chinensis* Sonner) has become very popular in sub-mountainous region as an expensive fruit which blooms in March and is a rich source of nectar to honeybees investigated by (Chaturvedi, 1969; Naim and Phadke, 1976; Chaudhary, 1977; Nair, 1981). Dewan (1980) described 36 bee plants by visual observation in Bangladesh. Islam (1998) reported that Litchi and mustard are important sources of honey in many parts of Pakistan.

Gupta et al., (1984), confirmed that *Apis mellifera* foraging behavior on *Plectranthus rugosus* and taking advantage of surplus honey extraction. In good years an average of 30-40 kg honey per colony can be obtained from this *Plectranthus rugosus*. Rana et al., (1998), surveyed the bee flora of Himanchal Pradesh and reported that surplus honey is collecting during spring summer from mixed flora that include *Brassica* spp., *Eucalyptus* spp., *Citrus* spp., *Litchi* spp., *Syzygium* spp., *Dalbergia* spp., *Trifolium* spp., *Ehretia* spp., *Sapindus* spp., *Acacia* spp., etc. There was diverse bee flora in Yarsha watershed area and confirmed that this area has very rich bee flora such as vegetable crops, temperate fruits, agricultural crops, grasses, shrubs, bushes, forest and avenue trees. Among wild varieties Chutro (Berberis asiatica), Hade bayer (Zizyphus mauritiana), Painyu (*Prunus cerasoides*), Bakaino (*Melia* spp.), Lankuri (*Fraxinus* spp.), Angeri, Jamun, Lapsi, Pati, Rudilo, Bamboo, Aainselu are important. Among cultivated crops *Litchi chinensis*, *Psidium guajava*, *Citrus* spp, *Mangifera indica*, papaya, various cucurbits, *Brassica* spp., *Allium cepa*, *Zea mays*, *Pyrus* spp. are important sources of both pollen and nectar.

Egyptian clover (*Trifolium alexanjdrinum* L.) is a popular fodder crop and the seed crops serves as a major source of surplus honey reported by (Naim and Phadke, 1976). Alfalfa, Lucerne (*Medicago sativa* L) the fodder crops, cultivated in irrigated areas especially in north India is rated as a medium source of nectar which blooms in August-September described by (Chaubal and Deodikar, 1965). They also found that Niger (*Guizotia abyssinica* Cass.) a cultivated oilseed crop which cultivation is extending fast blooms in September-October and is a major source of nectar in Maharastra. Sahid and Quyyam (1977) listed 13 major, 109 minor plants at the northwest frontier province of Pakistan where major nectar flow was recorded from *Trifolium* spp., *Plectoranthus rugosus, Eribotyra japonica, Accacia modesta* and *Dalbergia sisso.* Somerville (1999) found that 97% insects are honeybees that results blossom of fruits visits by them. Mizell (2012) confirmed that, honey bees are most important pollinators to agriculture, gardening and food security. Crape myrtles (*Lagerstroemia indica*) are considered most important pollen sources for honey bees as well as native bees. Nicolson (1993) found that in *Grevillea robusta* nectar concentration remained constant (mean of 16µl per flower) through the whole day but microclimatic condition affects a low nectar concentration on the basis of flower phenology. Harugade (2013) confirmed that the status of flowering plants was determined whether they are major or minor by the frequency and the number of honey bee visits. Riddle and Mizell (2016) found that *Lagerstroemia indica* provides pollen sources during food shortages because they bloom in summer season. It also provides support for a diversity of functional groups of pollinators and may help to increase in pollinator's species richness. Crailsheim (1992) reported that honey bees collected pollen and nectar as the major source of foods; nectar is converted into honey, main energy source while pollen is the source of proteins and lipids and is fed to larvae and workers.

2.3 Floral calendar of honeybee plants

Flowers were categorized into different developmental classes/ conditions while studying flowering phenology viz. tight, unopened bud, developing bud/ opening bud, open flower, mature flower, flower (corolla) wilting, and corolla fallen off, fruit developing, shade off / died out. Further, flowers were categorized in order to observe the construction, arrangement and origin of all parts described by Adhikari and

Adhikari (2010). The phenological map of total flowering plants, defines the changes in the seasonal landscape over the study area. August- September is the major honey flow seaseon while March-May is considered minor honey flow season and considered as biphasic explained by Wubie et al., (2014). There occurs mis-match phenology and climate change alter bee pollinated plant and bee pollinators found by Bartomeus et al., (2011).

Adhikari and Ranabhat (2011) reported that mid- hills of central Nepal are affluent in bee flora and many plants bloomed even in dearth periods which provide great potential for beekeepers. Diver (2002) confirmed that floral calendar is a time-table that helps the beekeeper to know the exact date and duration of the blossoming periods of the honey and pollen plants. Kafle (1984) and Maskey (1989) confirmed that abundance of bee flora in Kathmandu valley leads to the three main stream of pollen and nectar. From their research work it is revealed that first flow of season (Feb to March) followed by *Callistemon lanceolatus*, *Eucalyptus* spp, *Fraxinus floribunda*, *Gravillea robusta*, *Pyracantha crenulata*, *Trifolium repens*, *Bauhinia* spp, *Berberis* spp, *Leucosceptrum canum*, and *Pyrus pashia* helps the bees to increase their brood rearing, resulting in numerous swarms. Second flow (April- May) is unsuitable period for bees due to dry and dearth conditions and another worse condition is rainy season. September- November (third flow) also favored by *Prunus cerasoides*, *Fagopyrum esculentum*, *Aesandra butyraceae*, *Brassica campestris*, *Helianthus annus*, *Innula cappa*, *Solidago longifolia* and *Vernonia talaumifolia*.

Liseki and Boniphace (2008) found that flowering time of single species begins from the full opening of the first few buds till the start of fruit formation end of flowering. Bista and Shivakoti (2001) concluded that every region has different types of honey plants and vary from place to place. Flowering calendars makes easier to beekeepers for proper management of hives and taking decision best time for honey harvesting or colony swarming. Harugade (2013), found in Baramati area that bee plants available throughout the year, categorized into as, Jan-Apr and July-Aug are major and Apr-May is considered as minor flow of pollen while June is dearth period. Mishra (1995) reported that the dearth period of bee flora rises from May to September and highlight the necessity of feeding artificial diets to bee colonies during this time to strengthen their stores. Due to scarcity of bee flora in summer and monsoon seasons (April to

September) and the reserve stores of honey and pollen are rapidly consumed by bees and activities of honey bees including foraging, egg laying, brood rearing is reduced and bee coverage area and bee population are also reduced reported by Kumar et al., (2013). Bhalchandra, Baviskar and Nikam (2014), showed that honey flow season in Western Ghats of Nasik was mid- December to February and mid- July to September while critical dearth periods were mid-April to mid-June during the year. Suryanarayana et al., (1991), reported that there was peak pollen availability from Jan to May and also in November but the dearth period was July- Aug in Bihar state.

2.4 Seasonal colony strength of Honey bee

Akratanakul (1990) concluded that the performance of the colony either weak or strong as well as honey flow period of the colony proportionally depends upon the existing bee flora in each season. In South West of Nigeria, Mbah and Amao (2004) reported that, July to February is the main nectar flow season with peak in January while largest forest trees are in blooming condition, in that time there is enough nectar flow and the colony is strong enough with surplus honey to harvest. Verma (1992), found that larger and stronger colonies provide four to five times better pollinators than smaller and weaker ones, hence larger colonies have a large number of older bees as foragers. Beekeeping mostly depends on floral species with abundant nectar and pollen sources and also depends on the better strength of bee colonies found by Free (1970); Akratankal (1990). Jacobes et al., (2006), confirmed that apiary site should be near by the good forage plants in order to obtain good honeybee products and colony strength. Bista and Shivakoti (2001) found that colony strength as well as honeybee products mostly depend on the availability and types of bee flora next to level of colony management practice.

Liseki and Boniphace (2008), terminate that before starting the dearth periods while few plants are flowering, harvesting period should be first and that is the best when feeding of bees is advised to prevent absconding and to secure the colony strength for the forthcoming season. Heterogeneous application of pesticides in crop fields leads to the demolish the population of *Apis florea* (Thapa and Wongsiri, 1996). *Apis cerena* colonies have been severely affected by European foulbrood (*Mellssococcus pluton*) diseases after introducing *Apis mellifera* (Thapa et al., 2000a). Conte, Ellis and Ritter (2010), have found that in Europe and North America since 2006 disastrous colony losses have been reported and losses were not readily apparent and it may be due to overwintering mortalities and new phenomenon called Colony Collapse Disorder. They also concluded that there is no single reason for extensive colony losses but due to interactions between different stresses. In 1992, Kafle reported that Nepal was clueless about diseases of bee until 1980, recently attacked by sac brood disease caused by the Thai sac brood virus, occurred first time in the eastern border areas. Rapidly diseases spread and covered the entire part of the country.

Gupta et al., (1977), found that predatory wasps act a severe hazard to beekeeping industry in different parts of the world. Absconding is the result due to persistent attack of predatory wasps that causes weakening of bee colonies. Sharma et al., (1985); Abrol and Kakroo (1998), found that wasps attack was peak during July to September (monsoon) season that mostly coincided with the floral dearth period. This results the depletion of colony strength and demoralizing the beekeepers. Ranabhat and Tamarakar, (2008), reported that attack of wasps is different in different time of the day and activity of the wasps is found maximum in morning and noon time than that of late day and evening. Thapa et al., (2000), found that giant hornet (*Vespa magnifica*) and little hornet (*Vespa basalis*) were major predators to honeybees in Nepal. The abundance of different species of wasps varies from different areas of the country. Neupane and Thapa, (2005), confirmed that normal collection of pollen and brood production season were autumn, winter and summer and in rainy season due to acute shortage of pollen, starvation and nutritional deficiencies problems occurs. This was the main reason to decline or collapse the bee population before the honey flow season. Verma, Rana and Verma (1990), found that Thai Sacbrood virus disease severely attacks *Apis cerena* colonies and leads to the reduction in proliferation in parent than in daughter colonies. Mishra et al., (1989), confirmed that many species of vespidae are serious enemies of honeybees and causes significant damage in colony of bees.

2.5 Role of bee flora distance from beehive

Pratap (1997), reported that normally within a radius of 300-800 meters of the apiary, hive bees lean to forage closely to their hives. She also carried out; within this range honey plants are of great value for beekeepers. However, in necessary conditions, bees can forage a long distance from their hives. Crane (1990); Phillips (2001), found that bee can forage up to a radius of 3 km around the apiary. Verma (1990), confirmed that the *Apis cerena*, Himalayan honeybee have maximum foraging range within a radius of up to two kilometers from the apiary. Dancing pattern is also related with foraging behavior. Waggle dance is the dance language of honeybees that generates specific code message to describe the direction and distance from the hive or apiary for a new source of food but may differ in space and time of foragers studied by Riley et al, 2005; von Frisch (1967), personated that *Apis mellifera* provides an ideal opportunity in foraging studies because waggle dance directly communicates where it has collected food. Also, Dornhaus and Chittka (2004) found that dance language of honeybee is used to engage nest mates to food sources as one of the fascinating communication systems in animals. But it may be important to some habitats, not in others habitat. Dhaliwal and Sharma (2015) reported that during April 1970 and 1971 foraging range of *Apis cerena indica* on cauliflower was 900m and on barberry 1100m from the hive. Thom et al., (2007), confirmed that waggle dance is a sophisticated system of communication which is related to the colony's foraging effort towards nectar- and pollen- producing flowers and successful foragers plays good role in dancing pattern within nest to recruit other bees to a profitable food source. Study carried out by Pudasaini and Thapa (2014), showed that, higher numbers of flowers were visited by *Apis cerena* F. as compared to *Apis mellifera* L. and *Apis dorsata* and maximum foraging hours occurred at 2.00 pm and least at 10.00 am.

Foraging is the final task performed by honey bees while flight is the initiation. There were higher flights with combined diet than feeding low dose sugar syrup alone indicating necessity of feeding appropriate found by Thapa and Pokhrel (2005). Pratap, Shukla and Verma (2000); Joshi and Joshi (2010), found that foraging activities of *Apis cerena* started earlier in the morning and ceased later in the evening than that of Apis *mellifera*. They also concluded that foraging activity of *Apis cerena* worker bees is significantly more than those of *Apis mellifera*. Singh et al., (2006), confirmed that important factors to compare pollination efficiency of different species are foraging rate. Also, pollination efficiency is directly proportional to the foraging frequency. Free (1993), explained that bee makes four million trips per year and during each trip about 100 flowers are visited by bees. Eckert (1933); Free (1993), found that in extreme circumstances, the European honeybees, *Apis mellifera* foraged on a crop up to a distance of 11.3 km away from the apiary.

2.6 Role of Flower Color in case of bee foragers

Firstly, it was described by Aristotle that, honey bee (*Apis mellifera*) workers display a great tendency to visits flowers of only one type during one foraging trip. It also reveals that workers bee rapidly pick-up flower color when awarded with artificial nectar i.e., sucrose and solution (Gruter et al., 2011). Lunae et al., (2011), described that for pollen and nectar collection bees have special type of mechanism, based upon photoreceptors types have trichromatic color vision maximally sensitive in the ultraviolet (UV), blue and green waveband. Likewise, Hempel et al., (2014), found that trichromatic color vision of honeybees shares some characters with primate and human color perception, such as color constancy, color opponency, segregation of color and brightness coding. *Apis mellifera* become constant to one of the two flower colors, mixed with alternative color when presented with artificial flower of blue and yellow pedicellate. Some bees visited only while others blue ones. Flower constancy in honey bees is thus spontaneous but it can be isolated by some experimental methods described by Hill et al., (1977).

Menzel and Erber (1978) said that. “A bee is able to learn quickly and to remember for long periods the colour and the odour of flowers that yield nectar or pollen. Now the neural basis of this programmed behaviour is being elucidated*"*. Aristotle to Charles Darwin already said that bees can see the colours and smell the odours of flower but it was proved by experimentally in 1973 by Karl von Frisch at the University of Munich, Federal Republic of Germany. In his experiment, he attracted foraging bees offering a honey solution on a table. Bees regularly visit the dish containing the honey placed on a piece of blue cardboard. Therefore, the bees saw the blue colour as they approached the table and as they sucked the honey. Abrol (1992) found that most bees are attracted to those flowers which provides higher amount of energy and foraging populations of *Apis cerana* and *Apis mellifera* were positively correlated and significantly with energy values. The foraging size of populations on different floral species is determined by the variability in caloric contents of them. Stout and Goulson (2000), described that honeybees and bumble bees both refuse less than 25% of inflorescence that were visited 24h earlier and they both uses a less volatile chemical odour to detect whether flowers have been recently visited by others species.

Dotterl et al., (2014), explained that olfactory sallow cues are more attractive to honey bees than visual cues but both combinations make strong to attract pollinators in bees. Backhaus (1993) concluded that the bee is able to differentiate the colours of different flower species from their respective backgrounds. Also, honeybees can distinguish distance of bee flora and higher the intake of nectar and pollen which is benefit for honey colony. Giurfa et al., (1995), found that bees learning capacity is very high regarding colour preferences which were strongly related with flower colour and it is associated with nectar reward. Barbola et al., (2006), described in his study that a complex character of floral structure like violet- blue colour of flowers, long floral tubes without scents, but nectar not exposed, allowed identification of floral syndromes (melittophily and pscicophily) and function for each visitor. Giovanetti and Aronne (2011), explained that, flowers which retain clear anemophilous characters are more interested by honeybees and exploit plenty pollen resources that help in colony strength even unsuited flower morphology may limit resource collection and also get benefited by increasing reproductive success when adverse climatic conditions to wind pollen dispersal. Kevan (1978), described in his work that to understand the role of floral colors in attracting insects. Full colorimetric analysis must be made in relation to the ambient colour spectrum in which they live. He applied physical and universal definition of white, a colorimetric scheme erected to define floral colour with respect to the day light spectrum and insect colour vision. His work gives the answers of how pollinators recognized flowers and floral structures, competitive interactions, phenology and pollination ecology generally.

2.7 Pollen Morphology

Pollen analysis of honey samples is known as melissopalynology or melittopalynology. Honey contains a large number of pollen grains from different plants which are collected by honeybees during the process of collecting nectar from flowers to be used as food. Bees generally carry pollen grains that are nutritionally rich and reject those which are unsuitable for their consumption. But every area has a floral gap and there is an acute shortage of normal nectar and pollen grains. In such adverse periods, starvation impels them to forage even on unpalatable poisonous plants (Chaubal and Deodikar, 1963). The nutritional value of honey depends upon the quality and quantity of the pollen grains and their assemblages (Pratap, 1997).

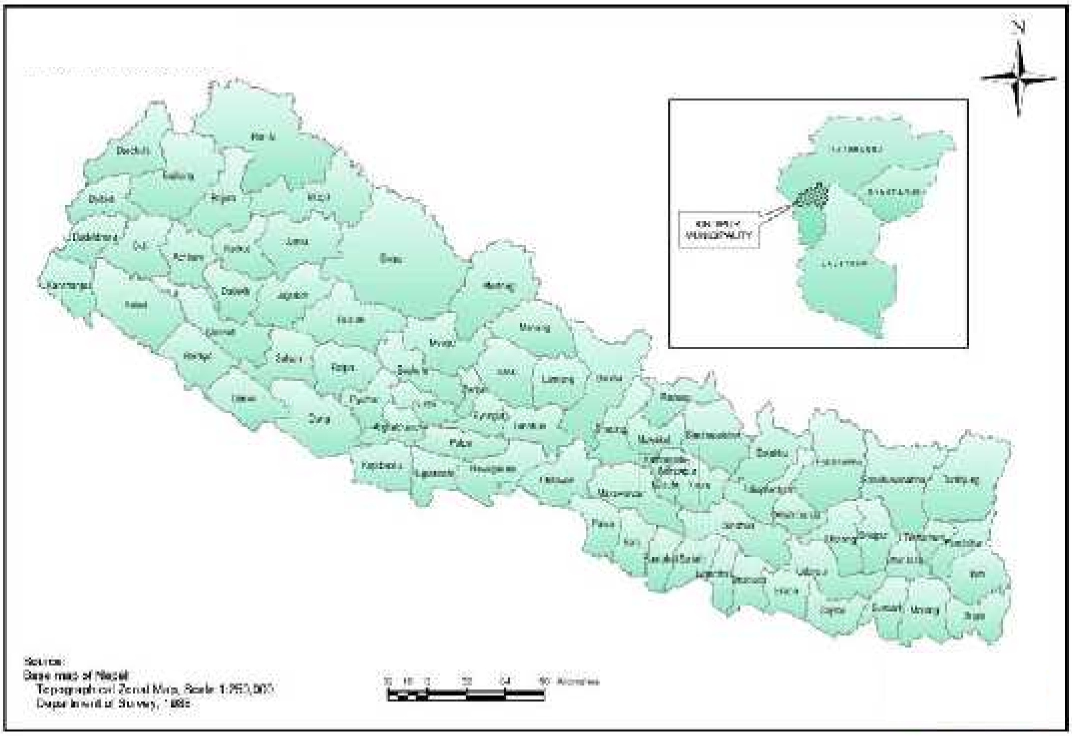
Pollen morphology is of great significance in taxonomy, phylogeny, palaeobotany, aeropalynology, and pollen allergy. Morphological characters of pollen are more or less similar in structure in the same family (Paul, et al., 2014).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location and Physiography

The study included afforested land becomes semi natural landscape lies seven km. south west from the Kathmandu valley. Coronation Garden located inside Tribhuvan University Campus, Kirtipur is the study site located between latitudes of $27^{0}40^{'}$ N- $27^{0}41^{'}$ N and $85^{0}16^{'}$E- $85^{0}18^{'}$E and its altitude ranges from 1300-1400m (Figure 1). Eight apiaries were set up nearby garden of Tribhuvan University Campus (Coronation Garden) which was collaborative research between PhD thesis granted Kansas University, Lawrence and Tribhuvan University. It covers an area of 2.76 Km Sq. The diagnostic character of this area is having diversities of planted trees in addition to garden and horticultural plant species along nearby cultivated land and open areas.



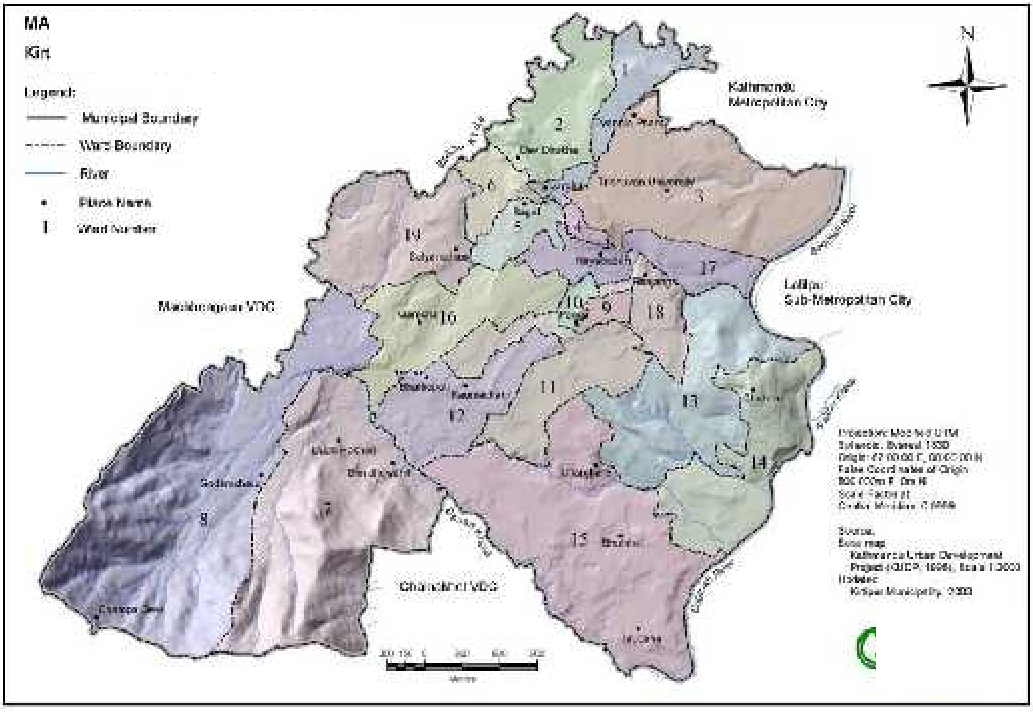


Figure 1: Map of study area, Source: ICIMOD, MENRIS 2003

3.1.2 Climate

According to the altitude, the Kirtipur falls within the subtropical zone. Climatological observations based on meteorological records showed the mean annual temperature was 18.85^{0}C from late March and lasts to the late September. But heavy rainfall occurred during July to August. This is also called monsoon season in Nepal. Dry season starts from late September to mid-December and also from early November and ends to the mid-March (Figure 2). The average annual minimum temperature of the study area was 12.6^{0}C and the average maximum temperature was 25.1^{0}C for the year 2015 (Figure 2).

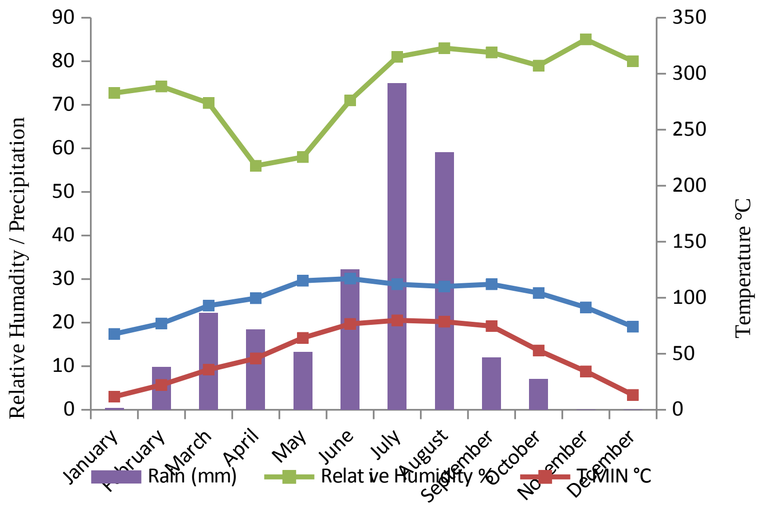


Figure 2: Meteorological data of study area of year 2015

3.1.3 Surrounding Vegetation and Bee flora

The vegetation of Kirtipur area is of subtropical type which is represented by the presence of *Schima wallichii*, *Castanopsis indica*, *Castanopsis tribuloides*, *Alnus nepalensis*, *Rhododendron arboreum* etc. Due to absence of natural forest in study area, there were many planted tree species like *Populas* sp., *Jacarandra mimisaefolia*, *Cinnamomum camphora*, *Callistemon citrinus*, *Grevillea robusta*, *Cinnamomum tamala*, *Eucalyptus camaldulenis* etc. The study area is also rich in ground vegetation and herbaceous flora. The foraging plants were marked and observed on different three seasons. The observation on nectar and pollen sources was based on activities performed by honeybees on different flowers. Honeybees with their activities of extending their proboscis into flower are considered as nectar source and bees carrying pollen on their hind leg were determined as pollen source following Bista and Shivakoti (2000/2001). These plants were later identified by experts and from published reports.

3.1.4 Sampling Unit

The sampling unit was a single bee flora and at least minimum five times should visit by the bee to consider as the bee flora at once foraging trip. It was through the visual observation. The observation of flora visited/landed by honeybees was observed for three days in a week from early morning 6 A.M. to evening 6 P.M. This process was carried out continuously for 9 months consisting of three seasons. Whole Coronation garden and adjoining horticultural garden were surveyed for this study.

3.1.5 Setting of bee hives

There were eight hives among them four were of *Apis cerena* and four were of *Apis mellifera.* These hives were placed at the interface of Coronation garden, Tribhuvan University Kirtipur. These hives were placed keeping 5 m distance apart from each other. Mostly these hives were placed near the Truffle laboratory of Biotechnology. This type of setting helped honeybees from being colony collapse disorder (CCD) problems and due to the interaction of human provides safe shelter for honeybees. Also, better providing source of pollen and nectar due to many blooming species nearby the hives. From the centre of hives distance of each blooming flower was calculated scientifically. All feasible blooming plant species was observed carefully whether *Apis cerena* and *Apis mellifera* were landing on it or not. At least five times honeybee should visit on the blooming species to confirm that the flora is a bee flora. The pollen collection and season of each blooming plant species was recorded with their valid scientific names. Pollen was generally collected to know the different structure of pollen for different plant species. Photograph of each flowering plant species was taken. After collection, pollen from different plant species was taken further laboratory analysis.

3.1.6 Distance of Bee Flora

For measurement of each blooming/flowering species was done by making radius of 1 km around beehives inside the Coronation Garden of Tribhuvan University. Firstly, distance was categorized into three subunits as: near (0-150) m, far (150-300) m and very far (above 300) m which was done by using measuring tape. Near distance was possible to measure by measuring tape but far and very far distance was not possible. GPS was used to categorize far and very far distance. Only bloomed plant species was recorded which was covered by bees at least five times. All the physical buildings and walls were eluded during measurement. Near, far and very far distances were noted as D1, D2 and D3 respectively.

3.1.7 Colour of Bee Flora

Different types of flowering species were blooming during field visits in different time periods. Mostly ornamental plants and horticultural plants were recorded. Different flowers have different colors in the fields. On the basis of field visits, flowers were classified into Red, White, Yellow and Blue. Primary colors are Red, Blue and Green but while field observations green colors flowers were not found. So, green colour was eliminated and Yellow and White colour were added. Red colors have different types as: red, cherry, rose, crimson, apple, candy etc. Blue colors was also varied as: Azure, Indigo, Navy, Persian blue, Zaffre, Tiffany blue etc. Colour of flowering species were identified with the help of the photograph taken and by seeing the additive colour-Wikipedia. Based on the research work done by Grueter et al., (2011), Lunae et al., (2011) and Hempel et al., (2014), colour plays a vital role in foraging of honeybees. They also observed that honeybee easily understood flower colour when rewarded with nectar concentration.

3.1.8 Identification of Bee Flora

Most of the bee flora species were ornamental and horticultural. Identification of bee flora was in some extent simpler because most of the plants were already tagged on them with valid scientific names. Photos of all plants were also taken during the field visits, so most of them identified through photo plates as well. The major bee foraging plants were further confirmed by direct observation. The surrounding flora and the locations were also interrogating regularly. Remaining unidentified plants were identified through matching herbaria deposited at Tribhuvan University Central Herbarium (TUCH), its premises and National Herbarium, Godawari (KATH). Garden Flowers by Bajaracharya et al., (1997), Common English Flower names, Annotated checklist of Flowering Plants of Nepal (Press et al., 2000) were used for the identification of plant species. All scientific names were checked through: *www.theplantlist.org.* On the basis of habit and morphology, all plant species were classified into its life form: herb, shrub and tree. Major bee flora was considered those flora, which produces surplus nectar and pollen and are abundantly accessible (Pratap, 1997, Crane, 1996, Verma, 1990, Phillips, 2001). Medium bee floras were considered those floras, which sustained annual flows of nectar and pollen used in development and maintenance of bee colonies. Likewise, flora that do not generate surplus honey, but the flora provides enough nectar and pollen for the honeybees to survive on during dearth periods are referred as minor or also that plants which are not beneficial to honey bees (Pratap, 1997). Distance of each flower from bee hives was measured on the basis of assumption made by Pratap (1997), Crane (1996), Phillips (2001) and Verma (1990). Bee flora was categorized into major, medium and minor bee flora on the basis of Bista *et al.* (2000/2001), Adhikari and Ranabhat (2011), and Sivaram (2001).

3.1.9 Time and Duration of Field Survey

This study carried out during 2015 to 2016 in areas of Coronation Garden inside the Tribhuvan University covering nine months. The first field data was collected during June, July and August of 2015. Second was collected from September, October and November of 2015. The colder months (November to February) were the dearth i.e., not favourable for the honey bees (Adhikari and Ranabhat, 2001). In this work also these periods were also eliminated due to scarcity of sources and colony collapse disorder (CCD) problems. After this time, resetting of eight hives in previous places was continuing. Third data or tertiary data was collected during March, April and May of 2016. Mostly these months were considered as the most productive period for honeybees (Adhikari and Ranabhat, 2011). From these above information bees' floral calendar was prepared for the Coronation Garden of Kirtipur. All the foraging plants were marked and observed them carefully. Later, Jun/July/Aug months were termed as Summer Season of 2015 and Sept/Oct/Nov were also known as Autumn Season of 2015 and finally Spring Season was given for the Mar/Apr/May of 2016. From each season bee floras were recorded and pollen was also collected for further study.

3.1.10 Analysis of Bee Flora

The bee floras of Coronation Garden were analysed by following methods:

3.1.10.1 Direct Observation

The identification of bee flora in the study area was mainly done by observing the bee visitation. The flower species were identified as bee flora only after visual confirmation and collection of food by honey bees (Sivaram, 2001; Pratap, 1997; Adhikari and Ranabhat, 2011). There was also another method for the identification of bee flora, i.e., Melissopalynogy. Melissopalynogy is the pollen analysis of honey samples collected from the bees. But due to short time period and lack of laboratory it was not possible in this study. Foraging activity of *Apis mellifera* was maximized at mid-day while in case of *Apis cerena* was maximum at early morning and late hour of the day (Pudasaini and Thapa, 2014). Therefore, in this case also observation and documentation of bee flora was carried out early morning (at 6 A. M.) and mid-day (at 2 P.M.). Mostly field observation was carried out for three days in a week throughout the whole three seasons including nine months.

3.1.10.2 Secondary Data

Finding of foraging honeybees and blooming plant species were not possible during all field survey time. In such cases, the plant was collected, pressed, identified and then compared with the published reports, articles or literature and confirmed whether that plant species was bee flora or not. Also, the categorization of bee floras into major, medium and minor sources on the basis of pollen and nectar was done with the help of secondary data because while performing this study it was not calculated the nectar and sugar concentration.

3.1.11 Preparation of Pollen Library

Pollen library was prepared by these following methods:

3.1.11.1 Collection of Pollen from Plant

During field observation of bee foraging, pollen of each blooming species was collected in Eppendorf tube with the help of forceps and painting brush (Weihmann et al., 2014). Pollen was collected carefully from plants in order to prevent mixing with different pollen. Different tag was given for each pollen of plants. Pollen was collected in Eppendorf tube and carried out in laboratory for further analysis.

3.1.11.2 Preparation of Fixative Solution for Pollen Slides

There were various fixative solutions for pollen slides. In this work Calberla's fluid was prepared. By mixing 5 ml of glycerol with 10 ml of 95 % ethanol, 15 ml of distilled water, 3 drops of saturated solution of basic fuschin and glycerine jelly. Glycerine jelly was made by mixing 10 g of Gelatin in 60 ml water. By mixing both two mixtures, it was left for two hours. After two hours, 70 ml of glycerol and 0.25g of phenol crystal was added in a mixture solution. The mixture solution was warmed by stirring for 15 minutes until flakes produced by phenol disappeared. In this way fixative was prepared and kept in dark brown bottle for later use (www.Seniorphysics.com/boil/eei.html).

3.1.11.3 Preparation of Slides of Pollen

After collection of pollen in Eppendorf tube from the field, it was kept in refrigerator so that it can be fresh. In a clean glass slide very little part of collected pollen was kept and Calberla's fluid was added. By covering pollen from cover slip, it was left for 24 hours in a shadow zone. While preparing slides, plant name, common name, date of collection and photo number was written. It helps us to prevent from confusion because all the pollen slides look similar. After 24 hours pollen slide was ready for observation under microscope (Jones, 2012).

3.1.11.4 Observation and Storage

The study of pollen slides was carried out with the help of a light microscope Olympus at different magnifications. To determine the size, polar axis and equatorial axis of pollen grains were measured at 40X magnifications. A photo of each pollen slide was taken and it was saved for preparation of pollen library. After the observation pollen slides were kept in slide box and it can remain fresh until six months.

3.1.11.5 Pollen Description

Pollen was described on the basis of size, aperture and surface pattern (based on secondary sources). The size of the pollen grain is express in micrometre. While describing the size of pollen it is based on the longest length of the pollen axis (Erdtman, 1945, cf Shrestha et al., 1994).

1. Small 0-25µm
2. Medium 25-50µm
3. Large 50-100µm
4. Very large 100-200µm

Pollen grains are provided with apertures or openings on the surface.

1. Pore: Equatorial more or less iso-diametric aperture.

2-porate- with two pores

3-porate- with three pores

Porate- with pores

2. Colpa- Equitorial, longitudianl aperture

3-Colpate- with three colpa

4-Colpate- with four colpa

6-Colpate- with six colpa

Colporate-colpa with pore

3. Surface Pattern:

Smooth or indefinite- Showing no definite pattern or marking

Granular- Pattern with granules

Reticulate- Net like stripes

Striate – Numerous long stripes

Dots- Due to beads or spines

Crotonoides- Small triangular structures regularly arranged in circle.

3.2 Data Analysis

3.2.1 Diversity Index

3.2.1.1 Species Diversity

A diversity index is a mathematical measure of species diversity in a community. Species diversity consists of two components i.e., species richness and species evenness. Species richness is the number of different kinds of organisms present in a particular area. The similarity of the population size of each of the species present is known as species evenness. Species diversity is a common term for both species' richness and species evenness. Species richness can be expressed in most common indices such as Shannon- Weiner's and Simpson indices (Oksanen et al., 2013).

3.2.1.1.1 Shannon-Weiner's index

Shannon-Weiner's index (H) is commonly used to characterize species diversity in a community by applying given formula:

Shannon- Weiner's index (H) = $-\Sigma\ pi \ln pi$

Where,

pi = pi is the proportion of individuals found in species i.e., for a well-sampled community, we can estimate this proportion as pi=

ni/N, where ni is the number of individuals in species i and N is the total number of individuals in the community.

ln = ln is the natural log.

Σ = Σ is the sum of the all calculation.

In most ecological studies, its value ranges from 1.5 to 3.5 and rarely greater than 4. Shannon- Weiner's index increases as the species richness and evenness of the community increases. Shannon-Weiner's index is very sensitive to species richness (Magurran, 2004).

3.2.1.1.2 Simpson index

Simpson index is used in community ecology to quantify the biodiversity of a habitat. It was calculated by using the Andale (2017) formula as:

$D= \Sigma\ (n/N)^2$

Where,

n= the total number of organisms of a particular species.

N= the total number of organisms of all species.

The value of D ranges from 0 to 1 where, high score (close to 1) indicates high diversity and low scores (close to 1) indicate low diversity.

3.2.2 Non- metric Multidimensional Scaling (NMDS)

It is an ordination technique based on a distance or dissimilarity matrix. It can tolerate missing pair wise distances. Relationship between bee flora and season was determined from the presence and absence of data matrix of bee flora represented inside Coronation Garden, Tribhuvan University area by applying Non-metric Multidimensional Scaling (NMDS). It is a very redundant multivariate technique without bias. This NMDS technique was applied through the vegan package (Oksanen et al., 2017) under R (R Core Team, 2017). The NMDS was projected species with respect to season. NMDS clearly defined the position of each species in season and distribution of species with its surrounding species. Pearson's Correlation Coefficients was calculated among environmental variables. All these biostatistical analyses were done after using free open-source package R (R Core Team, 2017).

4. RESULTS

4.0 Listing of bee flora based on major, medium and minor

Table-1 Major bee flora

S.No.	*Scientific name*	Family
1	*Agapanthus africanus* (L.) Hoffmanns	Amaryllidaceae
2	*Amomum aromaticum* Roxb.	Zingiberaceae
3	*Aster ageratoides* Turcz	Asteraceae
4	*Brassica campestris* L.	Brassicaceae
5	*Brassica juncea* (L.) Czern	Brassicaceae
6	*Butea monosperma (Lam.) Taub*	Leguminosae
7	*Calliandra brevipes* Benth.	Leguminosae
8	*Callistemon citrinus* (Curtis) Skeels	Myrtaceae
9	*Carica papaya* L.	Cariaceae
10	*Chaenomeles japonica* (Thunb.) Lindl.ex Spach	Rosaceae
11	*Cirsium wallichii* DC.	Asteraceae
12	*Citrus aurantifolia* (Christm.) Swingle	Rutaceae
13	*Citrus grandis* (L.) Osbeck	Rutaceae
14	*Citrus jambhiri*	Rutaceae
15	*Citrus limon* (L.) Osbeck	Rutaceae
16	*Citrus medica* L.	Rutaceae
17	*Citrus paradisi* Macfad	Rutaceae
18	*Citrus reticulate*	Rutaceae
19	*Cucumis sativus* L.	Cucurbitaceae
20	*Cucurbita maxima* Duchesne	Cucurbitaceae
21	*Eriobotrya japonica* (Thunb.) Lindl.	Rosaceae
22	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae
23	*Grevillea robusta* A. Cunn.ex R.Br.	Proteaceae
24	*Lagerstroemia indica* L.	Lythraceae
25	*Magnolia grandiflora* L.	Magnoliaceae
26	*Malius domestica* Borkh.	Rosaceae
27	*Oenothera rosea* L'Her.ex Aiton	Onagraceae
28	*Prunus americana* Marshall.	Rosaceae
29	*Prunus cerasoides* Buch.-Ham. Ex D.Don	Rosaceae
30	*Prunus persica* (L.) Batsch.	Rosaceae
31	*Prunus pygeoides* Koehne	Rosaceae
32	*Psidium gaujava* L.	Myrtaceae
33	*Raphanus sativus* L.	Brassicacea
34	*Salvia splendens* Sellow exSchult	Lamiaceae
35	*Sesamum indicum* L.	Pedaliaceae
36	*Taraxacum officiniale* (L.) Weber ex F.H. Wigg.	Asteraceae
37	*Trifolium repens* L.	Leguminosae

Table -2 Medium Bee flora

S.No.	Scientific Name	Family
1	*Abelmoschus esculentus* (L.) Moench	Malvaceae
2	*Abelmoschus Manihot* (L.) Medick	Malvaceae
3	*Althea rosea* Cav.	Malvaceae
4	*Alyssum maritum* (L.) Lam.	Brassicaceae
5	*Antirrhium majus* L.	Plantagianaceae
6	*Artemisia indica* Wild.	Compositae
7	*Berberis aristata* DC.	Berberidaceae
8	*Cannabis sativus* L.	Cannabaceae
9	*Chenopodium album* L.	Amarantheceae
10	*Choerospondias axillaris* (Roxb.) B.L. Burtt & A.W.Hill	Anacardiaceae
11	*Cineraria cruenta* Masson ex L'Her.	Asteraceae
12	*Cleome spinosa* Jacq.	Cappariadaceae
13	*Diospyros kaki* L.F.	Ebenaceae
14	*Gazania rigens* (L.) Gaertn	Asteraceae
15	*Hibiscus rosa-sinensis* L.	Malvaceae
16	*Justicia adhatoda* L.	Acantheceae
17	*Lathyrus odoratus* L.	Leguminosae
18	*Luffa cylindrica* (L.) M. Roess	Cucurbitacecae
19	*Malvasiscus arboreus* Cav.	Malvaceae
20	*Magnifera indica* L.	Anacardiaceae
21	*Melia azedarach* L.	Meliaceae
22	*Morus nigra* L.	Moraceae
23	*Ocimum sanctum* L.	Labiateae
24	*Oxalis corniculate* L.	Oxalidaceae
25	*Oxalis latifolia* Kunth	Oxalidaceae
26	*Phaseolus vulgaris* L.	Leguminosae
27	*Phyllanthus emblica* L.	Euphorbiaceae
28	*Pyracantha crenulate* (Roxb. Ex D.Don) M. Roem	Rosaceae
29	*Pyrus pashia* Buch.-Ham ex D.Don	Rosaceae
30	*Sambucus canadensis* L.	Adoxaceae
31	*Sechium edule* (Jacq.) Sw	Cucurbitaceae
32	*Veronica persica* Poir	Plantagianaceae
33	*Zinnia elegans* L.	Asteraceae

Table -3 Minor Bee flora

S.N.	Scientific Name	Family
1	*Albizia jullbrissin* Durazz	Leguminosae
2	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae
3	*Allium sativum* L.	Amaryllidaceae
4	*Asclepias curassavica* L.	Apocynaceae
5	*Azalea japonica* A.Gray	Ericaceae
6	*Bauhinia purpurea* L.	Leguminosae
7	*Bauhinia variegate* L.	Leguminosae
8	*Begonia rubella* Buch. -Ham ex D.Don	Begoniaceae
9	*Cajanus cajan* (L.) Millsp.	Leguminosae
10	*Calendulla officinalis* L.	Asteraceae
11	*Canna indica* L.	Cannaceae
12	*Carya illinoinensis* (Wangenh.) K. Koch	Juglandaceae
13	*Catharanthus roseus* (L.) G.Don	Apocynaceae
14	*Cinnamomum camphora* (L.) J. Presl	Lauraceae
15	*Cinnamomum tamala* (Buch.-Ham.) T.Nees& Eberm	Lauraceae
16	*Clivia miniate* (Lindl.) Bosse	Liliaceae
17	*Cynoglossum zeylanicum* (Vahl) Brand	Boraginaceae
18	*Dianthus caryophyllus* L.	Caryophyllaceae
19	*Dorotheanthus bellidiformis* (Burm.F) N. E.Br.	Aizoaceae
20	*Erythrina blakei* R.Parker	Leguminosae
21	*Euphorbia pulcherrima* Wild. Ex Klotzsch.	Euphorbiaceae
22	*Geranium pyrenaicum* Burm.F	Geraniaceae
23	*Glycine max* (L.) Merr.	Leguminosae
24	*Gomphrena globose* L.	Amaranthaceae
25	*Hippeastrum vittatum* (L'Her.)	Amaryllidaceae
26	*Hydrocotyle nepalensis* Hook	Umbelliferae
27	*Hymenocallis coronaria* (Leconte) Kunth	Liliaceae
28	*Jacaranda mimosifolia* D.Don	Bigoniaceae
29	*Jatropha cureas* L.	Euphorbiaceae
30	*Lagenaria siceraria* (Molina). Standl.	Cucurbitaceae
31	*Lycoris radiata* (L'Her) Herb	Amaryllidaceae
32	*Maesa chisia* Buch.- Ham. Ex D.Don	Myrsinaceae
32	*Mesembryanthemum criniflorum* L.F.	Mesembryanthemuss
33	*Momordica charantia* L.	Cucurbitaceae
34	*Pelargonium x hortorum* L.H. Bailey	Geraniaceae
35	*Persicaria acuminata* (Kunth) M. Gomez	Polygonaceae
36	*Petunia hybrida* Vilm.	Solanaceae
37	*Plumbago zeylancia* L.	Plumbaginaceae
38	*Primula acaulis* (L.) Hill	Primulaceae
39	*Sida cordifolia* L.	Malvaceae
40	*Tagetes erecta* L.	Asteraceae
41	*Tagetes patula* L.	Asteraceae
42	*Viola tricolor* L.	Violaceae
43	*Vitis labrusca* L.	Vitiaceae
44		

4.1 Generic Diversity of Bee Flora and Families

Coronation Garden of Tribhuvan University comprises highly diverse varieties of bee flora. This study found a total of 197 bee flora consisting of 70 families (Annex I). Asteraceae was the largest family in term of genera containing 17 genera and second highest number was Leguminosae family with 16 genera. This was followed by Rosaceae with 9 genera and Cucurbitaceae and Malvaceae with 7 genera in each. Amaryllidaceae has 5 genera followed by Amaranthaceae and Apocyanaceae having 4 genera each. Euphorbiaceae, Acanthaceae, and Brassicaceae have 3 genera each (Figure-3).

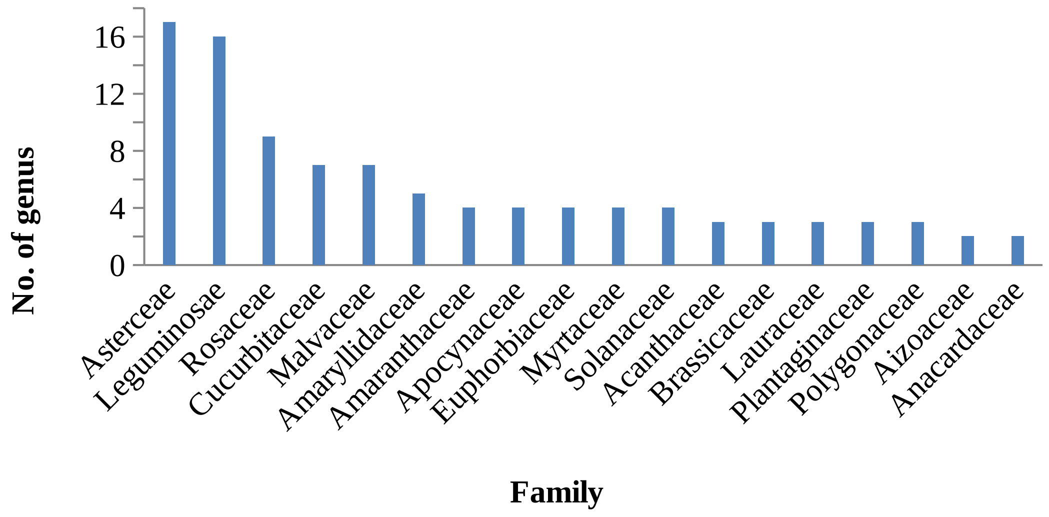


Figure 3: Generic Representation of bee flora along family.

4.2 Species Diversity of Bee Flora along Families

A total of 197 species were found within 70 families (Annex I). Among them Asteraceae and Leguminosae were the largest family with 18 species of each (Figure 4). There were 14 species found in Rosaceae. Malvaceae and Rutaceae comprised of 9 species each (Figure 4).

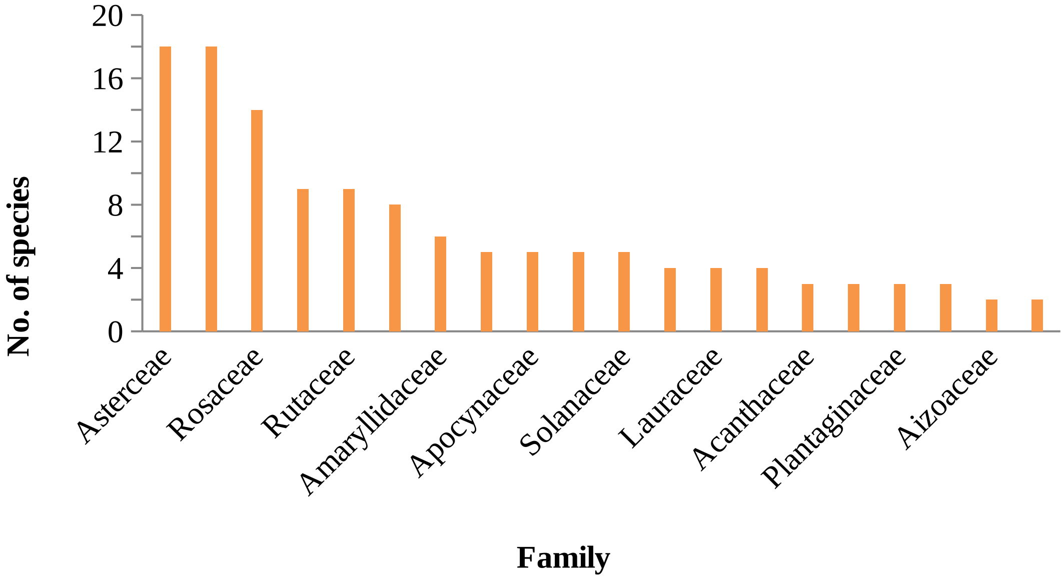


Figure 4: Family wise representation of species

4.3 Life Form Diversity of Bee Flora

From this study, four major life forms: Tree, Shrub, Herb and Climber among the bee floras were found. Among them, the most dominant lifeform was herb with 119 species, followed by trees with 71 species, shrubs with 21 species and climbers with 20 species. But in season wise, there was variation among distribution of species. In Summer Season (2015), it was found those 54 herbs, 15 trees, 10 shrubs and 10 climber species (Figure 5).

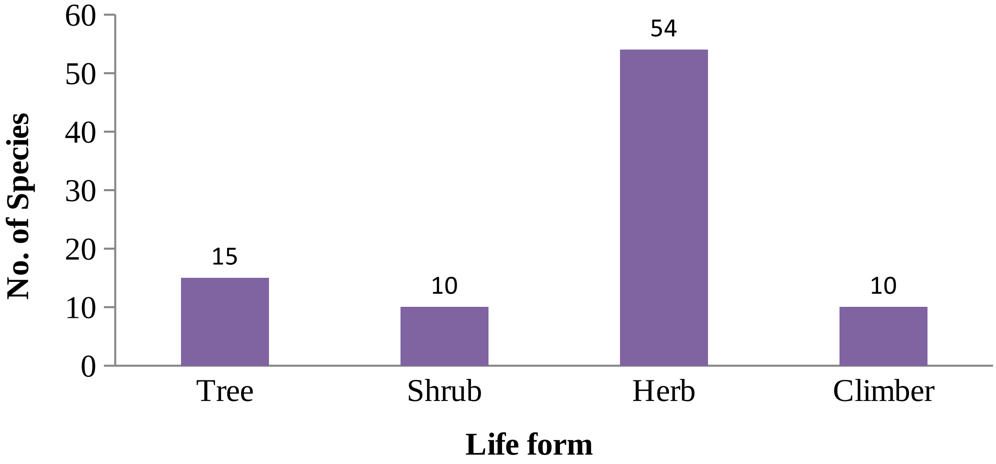


Figure 5: Life Form Diversity of Summer (2015) plants.

During Autumn Season (2015), it was found 2 tree species, 4 shrubs, 24 herbs and 7 climber species (Figure 6).

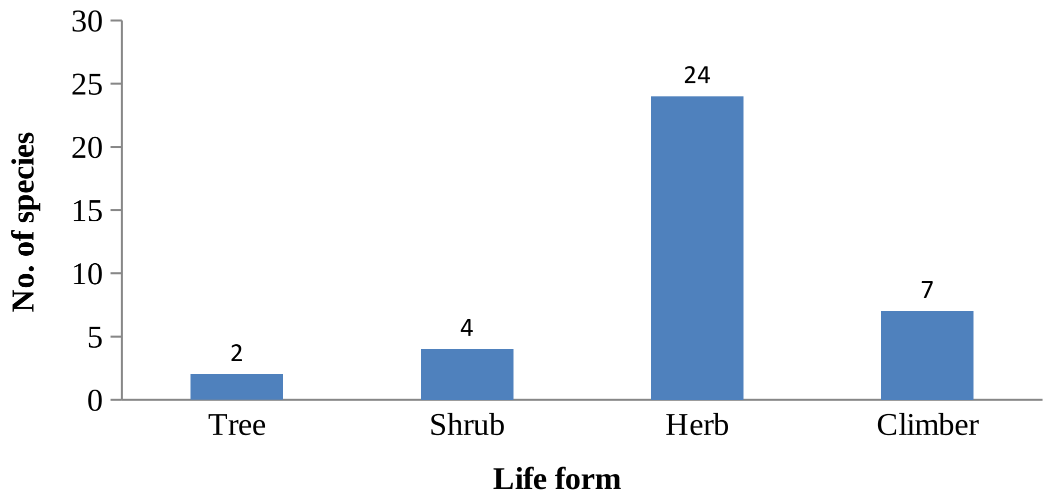


Figure 6: Life Form Diversity of Autumn (2015) plants

Likewise, in Spring Season (2016), it was found 54 tree species, 7 shrubs, 41 herbs and 3 climber species (Figure 7).

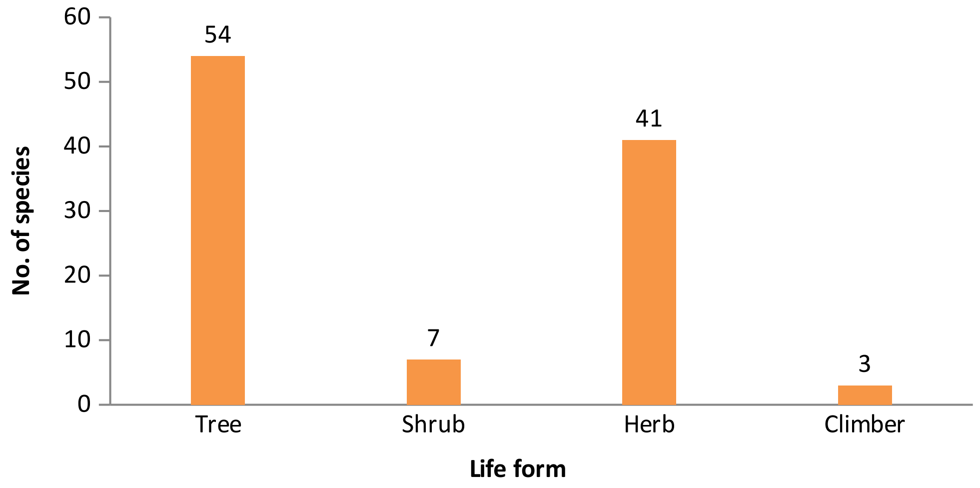


Figure 7: Life Form Diversity of Spring (2016) plants

4.4 Pollen and Nectar Status of Bee Flora

A total of 197 plant species identified as important bee floras in the study area. Plant species were mostly visited by *Apis cerena* with *Apis mellifera.* Among them, ornamental plant species were 77, 27 were crops, 50 plant species were wild plant species, 8 species were naturalized species and 35 species were horticultural plant species (Annex II). Out of 197 bee flora identified, 45 species were recognized as the major (N1P1), 41 as medium (N2P2) and 62 as minor (N3P3) sources for both nectar and pollen (Figure 8). There were 49 bee floras species having unequal status (N1P2, N1P3, N2P1, N2P3, N3P1 and N3P2) of pollen and nectar.

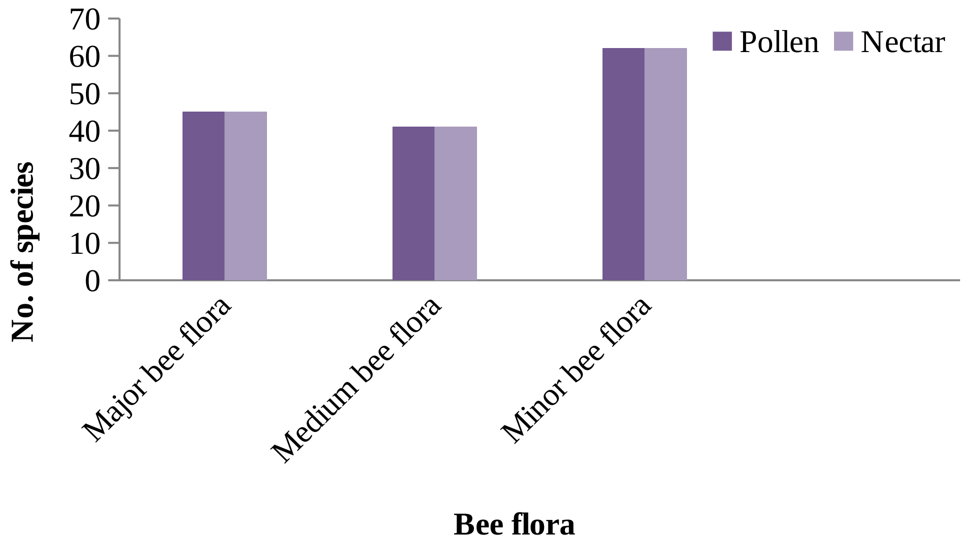


Figure 8: Bee Flora according to source of pollen and nectar

4.5 Bee Flora in relation to distance along with pollen and nectar status

There were 139 species found as near species followed by 28 species as far and 30 species as very far respectively (Figure 9).

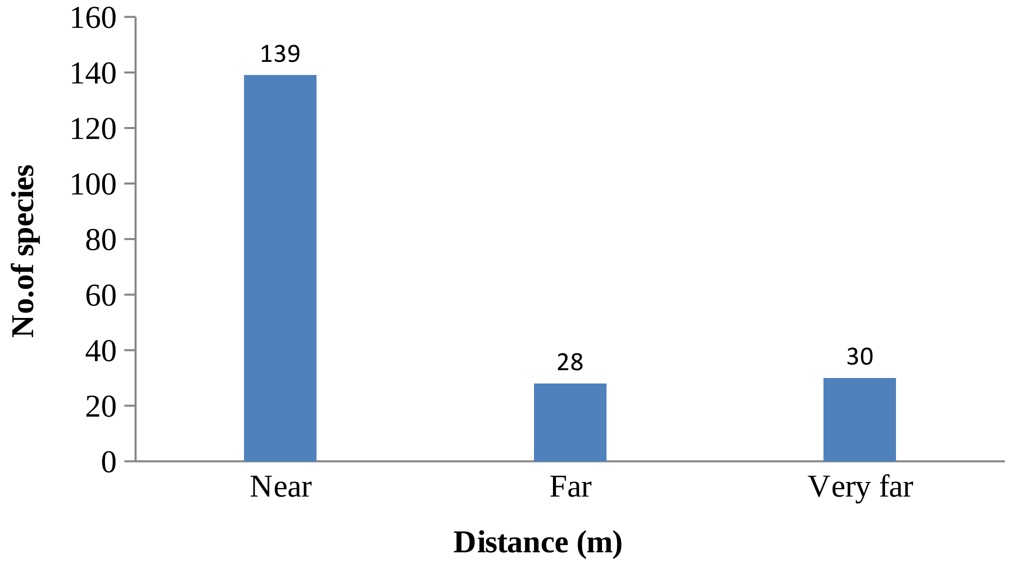


Figure 9: No. of bee flora with reference to distance (m)

Also, among near species 48 species were considered as major bee flora, 47 as medium and 44 species as minor one. Likewise, far species were also categorized into 5 as major, 8 as medium and 15 as minor species. Very far distance species were also classified into 22 as major species, 5 as medium and 3 as minor species (Figure 10).

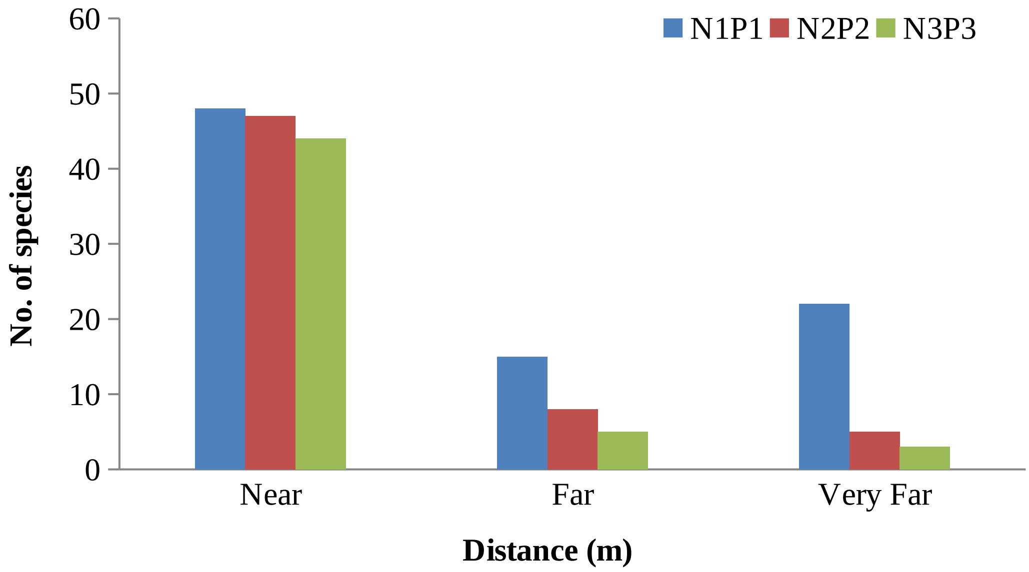


Figure 10: Distance of bee flora in source of pollen and nectar

4.6 Categorization of Bee Flora according to Color

Among a total of 197 bee floras found 56 species were red colour followed by 15 species as blue color, 46 species as yellow and 79 species as white (Figure 11).

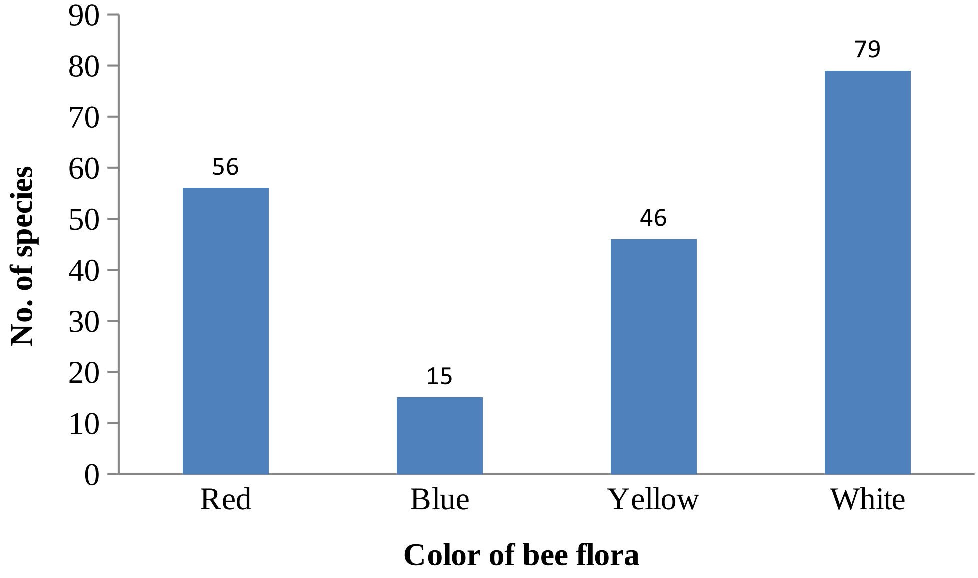


Figure 11: Representation of bee flora along color

Bee flora of each color was categorized into major, medium and minor sources of pollen and nectar. In case of red color, 9 species were considered as major, 10 species as medium and 24 species as minor species. Likewise, among blue color 3 species were major, 2 species as medium and 5 species as minor species. Among yellow color 10 species were considered as major sources, 14 species as medium and 10 species as minor species. Likewise, 25 species of white color were considered as major, 16 as medium and 21 as minor sources (Figure 12).

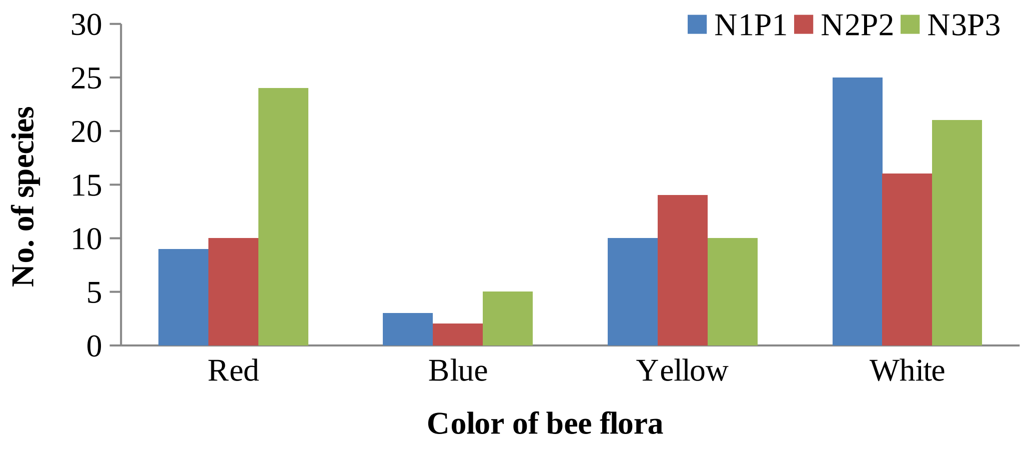


Figure 12: Representation of bee flora along color with pollen and nectar sources

4.8 Diversity Index

4.8.1 Shannon Index

The value of Shannon index was found to be 0.59 for summer (2015), 0.42 for autumn (2015) and 0.60 for spring (2016) (Figure 13).

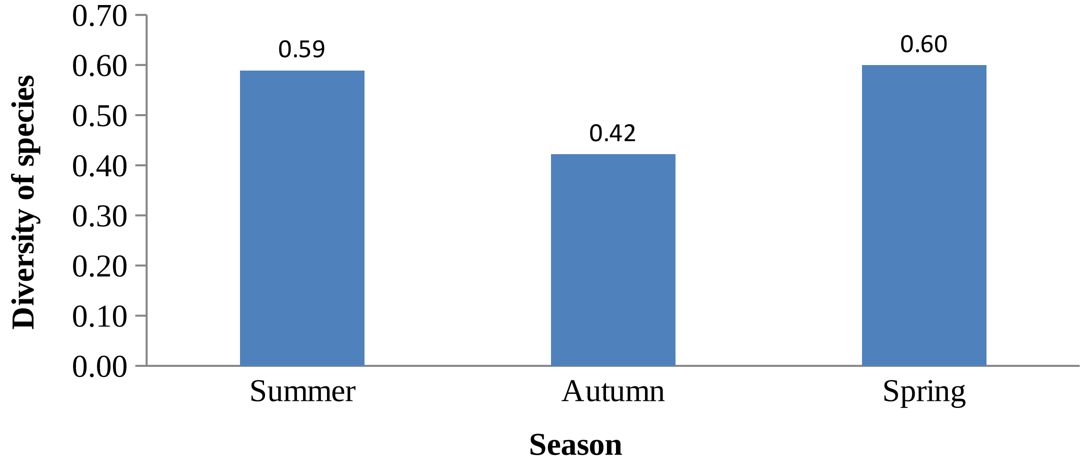


Figure 13: Seasonal Shannon Index of bee flora

4.8.2 Simpson Index

The Simpson index was found to be 0.31 for summer (2015), 0.36 for autumn (2015) and 0.31 for spring (2016) (Figure 14).

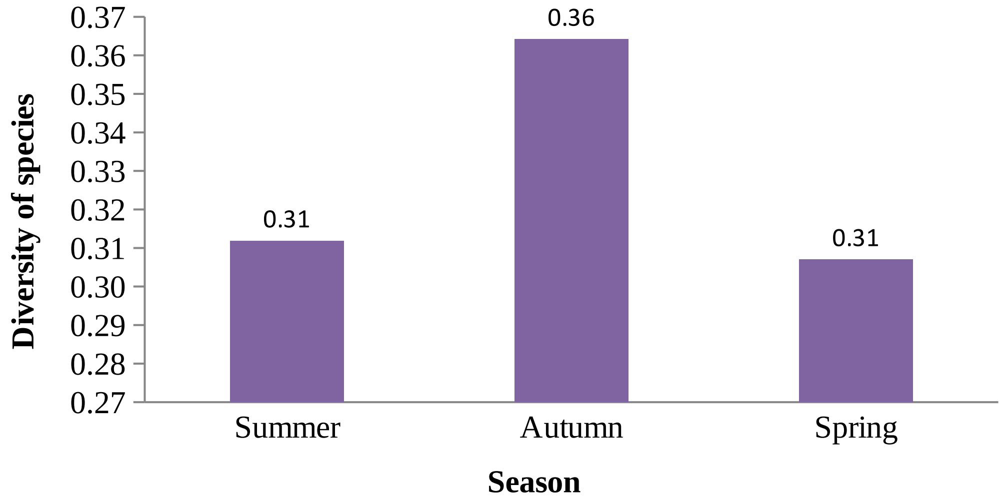


Figure 14: Seasonal Simpson Index of bee flora

4.8.3 Species Richness

Species richness found to be 116 for summer (2015), 83 for autumn (2015) and 118 species for spring season (2016) (Figure 15).

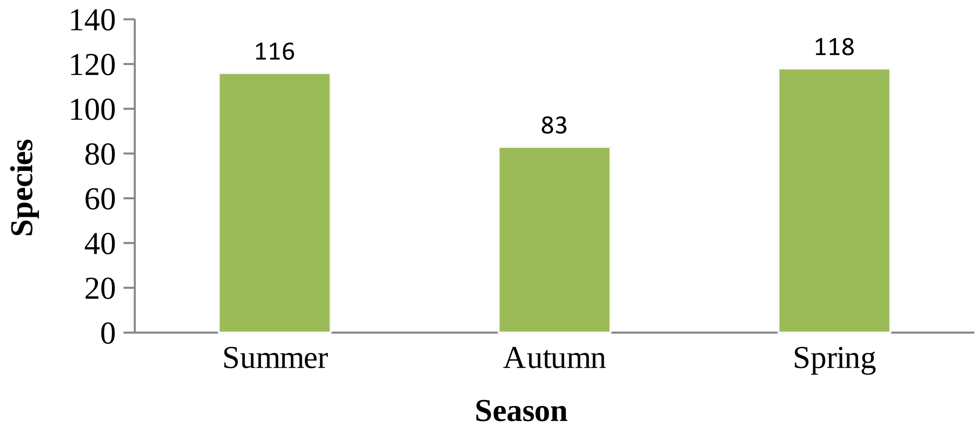


Figure 15: Seasonal Species Richness of bee flora

4.9 NMDS Analysis

The NMDS Analysis graph provides the information about the distribution of bee flora along three different seasons and maximum gradient distance from the bee hive it also represent intra specific distance between trees.

Maximum abundance of *Gossypium hirsutum* (Goss-hir) and *Ziziphus xylopyrus* (Zizi-xyl) towards higher NMSD2 axis but very less towards NMDS1 explained best by autumn (2015) at Coronation Garden of Kirtipur. Maximum abundance of *Vitis labrusca* (Viti-lab) towards maximum value of NMDS1 and NMSD2 axes explained significantly by the occurrence of them during spring (2016) (figure 16). Relatively higher abundance of species such as *Viola tricolor* (Viol-tri), *Tagetes patula* (Tage-pat), *Tithonia rotundifolia* (Tith-rot), *Antirrhinum majus* (Anti-maj) were favored by summer (2015) (figure 16).

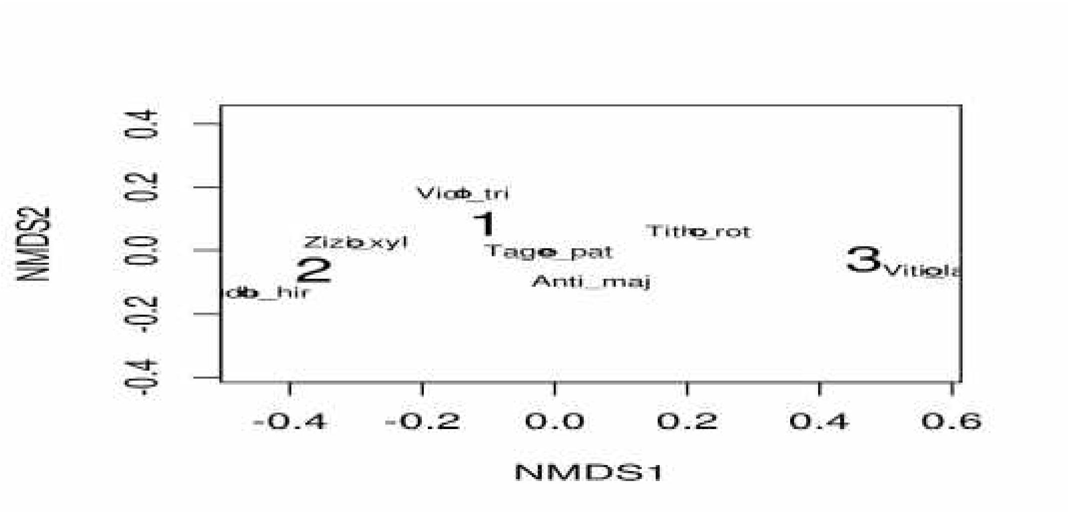


Figure 16: Nonmetric Multidimensional Scaling (NMDS) analysis of season by species dataset. Full form of each species was given in an Annex-I.

4.10 Correlation coefficient of bee flora variable

NMDS analysis clearly justified the seasonality among bee flora (Figure 16). Spring 2016 accounted as the most significant environment gradient for abundance of all species. The correlation coefficient value between NMDS1 score and summer (2015) bee flora species score value was -0.89 (Figure 17). This means that the higher the NMDS1 score value significantly lesser abundance of summer (2015) favouring species. With this relation, abundance of autumn (2015) bee flora was negative with NMDS1 but significantly positive relation with spring (2016). Summer (2015) and autumn (2015) were significantly negative correlated with spring (2016) with correlation coefficient values -0.81 and -0.93 respectively.

The correlation coefficient values between NMDS2 score and bee flora species scores of summer (2015) was 0.7 and autumn (2015) was 0 values. It means bee floras of summer (2015) and autumn (2015) have great roles in bee floras. Summer (2015) seemed highly important and positive to bee floras and autumn (2015) was also important for favouring bee floras. The correlation coefficient values between NMDS2 and bee flora species, scores of spring (2016) was found -0.25. It was also quite significant but negative to bee flora.

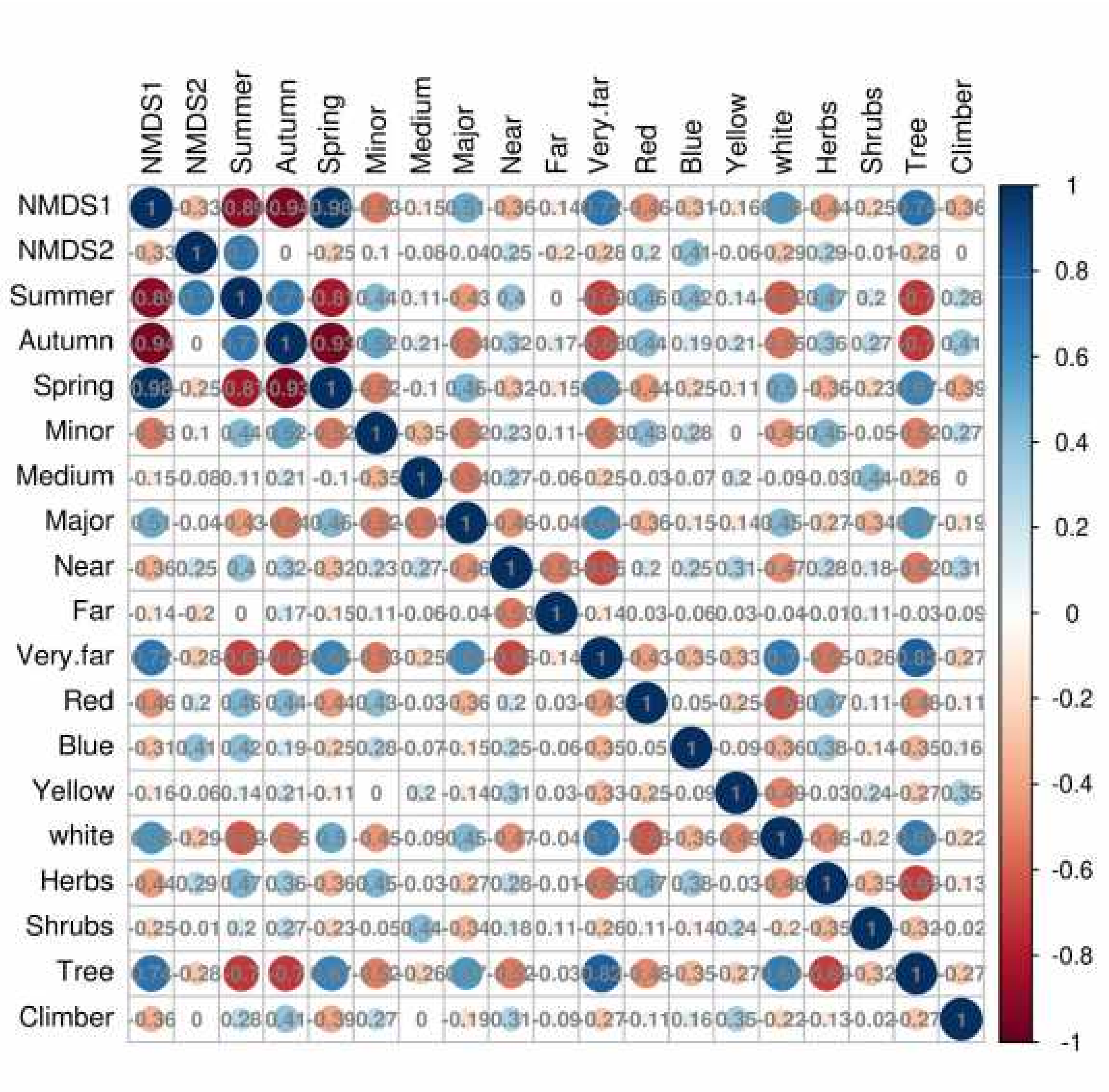


Figure 17: Correlation coefficient matrix among variables

Distance showed a significant correlation with NMDS1 score with near and far distance appeared as -0.36 and -0.14 respectively. Very far distance had positive values as 0.72. Spring (2016) showed significant values as 0.05 with very far distance. Minor bee flora was found positive values in summer (2015) and autumn (2015) as 0.44 and 0.52 respectively and negative values in spring (2016) as -0.52. Medium bee flora also showed significant positive values in summer (2015) and autumn (2015) as 0.11 and 0.21. Likewise, major bee flora was high in spring (2016) scoring 0.46 values while -0.43 and -0.54 were found in summer (2015) and autumn (2015) respectively.

Among flower color of bee flora species, white colors have significant values with spring (2016). While Red colors have positive significant with summer (2015) and autumn (2015) and blue colors with summer (2015) had positive values. Also, yellow colours have positive relation with autumn (2015). It was found positive values as 0.67 with spring 2016 and tree species.

5. DISCUSSIONS

Altogether 197 plant species belonging to 70 families were identified as bee flora in the Coronation Garden of Tribhuvan University area, and they bloomed in different seasons. Out of which 70 families, Leguminosae and Asteraceae were found to be containing the highest number of bee flora. Among them, plants having both nectar and pollen with their same status were more than the plants having unequal status of pollen and nectar. Our result was similar to Sivaram (2001) and Mbah and Amao (2004) found that Fabaceae family having highest number of species as a bee flora. Coronation Garden of Kirtipur is semi-natural landscape which includes a considerable area of tree plantations, besides large extent of land is under the cultivation of agri-horticultural crops. So, in this region Leguminosae and Asteraceae families were found as major families for honeybees.

Categorization of bee flora into major, medium and minor

In search of pollen and nectar, honeybees visited various plants of Coronation Garden of Kirtipur which have different flowering periods. Depending upon the pollen and nectar status, bee flora of Coronation Garden was categorized into major (N1P1), medium (N2P2) and minor (N3P3). Each and every bee flora were considered important for honeybees in spite having high or low nectar or pollen sources. Similarly, 49 no. of plants were found having unequal status (N1P2, N1P3, N2P1, N2P3, N3P1 and N3P2) of pollen and nectar. Even these types of plants also have positive relationship of the presence of two major floral cues, i.e., nectar and pollen in the flowering plants. Within three seasons, 197 species were recorded as bee flora. Among them, 116, 83 and 118 species were found in summer (2015), autumn (2015) and spring (2016) respectively. This gives the conclusion that bee flora in different area has different flowering period. This may be due to variation in climate and topography of that area. This assumption was close to conclusion of Bista and Shivakoti, (2000/2001) described that the flowering period of bee flora may differ from one place to another due to variation in topography, climate and other cultural and farming practices. Documentation of bee flora in different regions has been carried out. Our results also resemble with their findings. Joshi (1998), Devkota (2003), Adhikari et al., (2011), Thapa and Dangol (1993) documented bee flora in different parts of the country.

The plants were found in number as; 77, 27 ,35, 8 and 50 and categorized into ornamentals, vegetables, cereals, pulses, horticultural, naturalized and wild forms respectively. Among these categories, horticultural species as well as ornamental plants were more important as sources of nectar and pollens than other categories. Therefore, for proper beekeeping, plantation of horticultural species seemed to be more effective than the other kinds of plant species. Adhikari and Ranabhat (2011) also documented 19 species of horticultural plants on the basis of pollen and nectar sources and most of them were as major source. Even plant having low status of pollen and nectar were also utilized by honeybees during colony development and dearth periods. Like *ALbizia julibrissin, Azalea japonica, Calendulla officinalis, Cineraria cruenta, Malvaviscus arboreus, Ageratum conyzoides* were bloomed for longer periods. Bista and Shivakoti (2001), found that *Salvia splendis, Malvaviscus arboreus, Tagetes erecta* helping during colony development and dearth periods. Likewise, plant species *Callistemon citrinus, Lagerstroemia indica, Grevillea robusta, Trifolium repens, Oxalis corniculata, Cuphea micrantha* were species referred to as good sources of pollen and nectar for honeybees (Pratap, 1997). Various vegetables such as *Cucumis sativus, Fagopyrum esculentum, Luffa cylindrica, Cucurbita maxima, Raphanus sativus, Sesamum indicum, Sechium edule, Cucurbita pepo* etc. were rich sources of pollen and nectar and honeybees also visits these plants regularly.

Seasonal wise bee flora

Within three seasons, there exists a variation among number of bee flora. Spring (2016) had higher number of bee flora as 118 species. This result was closer to findings of Adhikari 2003, 2010; Kearns and Inouye 1993. Their results showed that March to May and August to October was the most favorable period for honey production, while winter season was considered as critical dearth periods. Autumn (2015), had comparatively fewer number of bee flora. This may be due to micro-climatic conditions, human interference also due to less bee forage plants. Due to limited bee flora, most of the honeybees showed absconding and swarming behaviours resulting CCD problem. But even in summer season many plants bloomed like, *Lagerstroemia indica, Impatiens balsamina, Sesamum indicum, Zea mays, Trifolium repens, Callistemon citrinus, Eucalyptus camaldulensis* etc. Due to enough amount of rainfall and moderate temperature in summer (2015) there was highest number of bee flora. Mostly summer season is favored by crop species so, in this time many crop species were bloomed and honeybees' forage. This was quite similar with the findings of Devkota (2003), Bista and Shivakoti (2001) and Pratap and Verma (1996). Having good value, the flowering plants of an area as bee forage are necessary to maintain bee colonies (Baptist and Punchihewa, 1980). The economically important bee flora provides substantial quantity of pollen and nectar for bees during different months of the year. Because of economic importance the bee flora is not only protected but should also propagate (Sivaram, 2001).

Bee flora calendra

It was found that, most of the tree species were bloomed during spring season. Spring season is the best time for pollinators for resource collection that results excessive pollination process in species. Floral phenology was found in different time for different species. In summer (2015), it was considered those 54 herbs, 43 shrubs, 15 tress and 10 climber species. In autumn (2015), it was found those 24 herbs, 4 shrubs, 2 trees and 7 climber species. While in spring (2016), 41 were herbs, 54 tree species, 7 shrubs and 3 climber species. Altogether herbaceous species were most dominant types of species in the study area. Main reason was lack of natural forest in the study area and most of the species were planted. Among planted species ornamental flowers were found to be dominant. Horticultural species were also found quite high in number in comparison to natural species. Herbaceous species have short life cycle. In summer season, most herbaceous species were found because herbaceous are very sensitive to environmental factors. With the start of rainy season, herbaceous species starts to flowering and end within this season. This research work was carried out autumn, spring and summer season which were considered most favorable periods because most of the plants bloomed in these months and environment was favorable for bee's activities was coincided with results of (Adhikari et al., 2011).

Every species has different phenological patterns. Among phenological patterns, blooming period of flower is essential in case of beekeeping farmers. Altogether 197 plant species were documented with flowering period. Most of the species have very short period of flowering time and only few species have longer time period of flowering. Plants having longer flowering time have great importance for bee foragers. It is necessary to know the floral calendar of each and every species of bee flora for proper management of bee keeping. Also, migratory bee keeping can be run smoothly to those areas where the resources are available but lack of pollinators. Preparation of floral calendar resembles with other research works carried out by different person in different regions. Adhikari et al., (2011); Shivakoti et al., (2000/2001); Sivaram (2001) have also prepared floral calendar of 158, 119, 192 species respectively in different regions.

Relationship between apiary and the flower type distance

On the basis of distance bee flora was categorized into three sub-divisions as: near (0-150) m, far (150-300) m and very far (above 300) m respectively. It was recorded that, near species were 139, 28 species as far and 30 species as very far species. This showed that distance plays major role in bee foraging activities. Near species were considered most favored species because they were near to bee hives and bees can detect easily as sources of food. Pratap (1997) found that bees can forage up to 300-800 meters from the apiary and hive bees lean to forage closely to their hives. Among near species were also further classified into 48 as major bee flora, 47 as medium and 44 as minor bee flora species. Very far species were categorized into 22 as major bee flora, 5 as medium bee flora and 5 as minor bee flora. This showed that in necessary conditions bees can forage a long distance from their hives. This finding was similar to Phillips (2001); Crane (1990) found that bees could forage up to 3km around the apiary. Among very far species, horticultural species were considered as major bee flora. Among far species groups, 5 were considered as major bee flora, 8 as medium bee flora and 15 as minor bee flora. Honeybee visits plant species on the basis of abundance of nectar and pollen concentrations. Honeybee generally visits near flowering species but in case of food scarcity it can forage far distance. This may be also due to a smaller number of species were bloomed in that area or bloomed species may not be liked by honeybees. Near the hives, most of the species should be bloomed in order to colony development and honey production. Near species can be frequently visited by honeybees and can make many trips. Free (1993), reported that bees make 400 million trips per year and during each trip 100 flowers are visited by bees.

Relationship between honeybee and flower colour

Flowers have different colors and also in different amount of pollen and nectar concentration. According to type of color bee flora was divided into four groups as: red, blue, yellow and white color. In each color also there was a variation of its own color. Our results were quite similar to Lunae et al., (2011), who have found that bee can see ultraviolet, blue and green color. There were 56 species found under red type color, 15 species as blue color, 46 species as yellow and 79 species as white color. Most dominant color was white color. Based on pollen and nectar color were also grouped. Among red colors, 9 species were as major bee flora, 10 medium and 24 as minor bee flora. In addition, mixed type of flora was also found in red colors type species. Most of the red colors species were ornamental and they were herbaceous in nature. This was quite similar to Gruter et al., (2011), findings that workers bees pick up flower color rapidly along with pollen and nectar concentration. Blue color were also grouped into 3 groups as major bee flora, 2 species as medium bee flora and 15 species were minor bee flora species. Out of 46 yellow flowers, 10 species as major bee flora, 14 as medium bee flora and 10 species as minor bee flora. Flowers having higher concentration of pollen and nectar plays great role in bee foragers. Due to low amount of pollen and nectar yellow type of flowers were not favored by bees. Likewise, 79 white color flowers were divided into 25 as major bee flora, 16 as medium and 21 as minor species. Bee visits only one type of species during one foraging trip (Hill et al., 1977); this was related with our findings. This proved that white colors are mostly liked by bees because white type of color species had high concentration of pollen and nectar. Also, it was found that, white color flowers were mostly from horticultural plant species. So, horticultural plant species have major function in beekeeping purpose.

Species Diversity : Shannon-Weiner's index and Simpson index

Species richness was found high in spring (2016) season as 118 species followed by summer (2015) season as 116 species. Most of the species were overlapping in both spring and summer season. In autumn (2015) season there was 83 species it may be due to short life cycle of spring and summer species. Only newly blooming species and unfavorable climatic conditions were there so it has lesser number of bee flora. Shannon index shows the diversity of bee species within three seasons. The Shannon index was found highest in (Mar, Apr, May) spring (20160 season as 0.59. It represents that both the abundance and evenness of bee flora was high in spring (2016). Simpson index was to be 0.36 which was high in (Sep. Oct, Nov) autumn (2015) season. It shows that there was diverse habitat of each bee flora in autumn (2015) season.). The value of Simpson index 0.36 was nearer to 1, so having higher value resulting higher biodiversity.

Non-metric Multidimensional Scaling (NMDS)

NMDS data analysis, NMDS1 with spring season (2016) shows significant relations. It means spring (2016) was the best time period for blooming flowers. This provides best sources for honey bees. The correlation coefficient value was found strong as 0.58 for white color. It was also found that plants having white colors were considered as major bee flora on the basis of pollen and nectar concentrations. Color was correlated with presence of pollen and nectar concentrations. NMDS1 with very far distance signified the positive values as 0.72 which was strong relation. Bees forage in near distance species as well as long distance also. It shows that, if the bee found better source of food in far distance than it can forage up to long distance also. Spring (2016) was found positive with NMDS1 axes whereas autumn (2015) was found quite negative with NMDS2 axes. It means that spring season loving species have positive relation towards NMDS1 axes and autumn season had 0 values that means neither positive nor negative relations.

Preparation of pollen library

On the basis of pollen structure, total 71 species of bee flora pollen was described. Mostly morphological parts were described with most of the recent photographs. It was found that every plant species has quite different pollen structures. On the basis of pollen size, aperture and surface pattern pollen can be identified. Shrestha et al., (1994) and Pratap (1997) have described pollen structure in detail forms. After collection of pollen and observed on microscope, floral origin of honey can be determined. We can identify the plant species from pollen and remark them as important species for honeybees. A large number of indigenous bee plants are still to be explored because it is difficult to filter which plants give a major contribution to the honey. It also helps in identification of toxic honey. It also enlightens that which is the sources of pollen and nectar species.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

A total of 197 commonly grown bee flora species belonging to 70 families were identified. Bee flora was categorized into ornamental, horticultural, vegetable and crop species, naturalized and wild forms. Among them ornamental species were found dominant throughout the study area. Also, horticultural species were found in huge number as a major source. Accordingly, in the study area *Trifolium repens*, *Oxalis corniculata*, *Grevillea robusta*, *Cuphea micrantha*, *Lagerstroemia india*, *Citrus spp*., *Callistemon citrinus* were considered as important bee flora for honeybees and main source of pollen and nectar. All the grouped plant species are useful to honeybees as food sources. The most important and common bee plant species with family, life forms, nectar and pollen status are shown in Annex I and flowering period of each species in Annex II.

There has innumerable number of plants yielding both pollen and nectar in same status than the mixed ones. The region has a greater number of herbaceous and their distribution, blooming period is very essential in predicting the pollen and nectar flow for successful beekeeping. The knowledge of blooming season is important reason for sustainable management of bee colonies and for good honey harvest. The flowering duration of any given region helps in migratory beekeeping practice. Plant species nearer to hives were considered more important than in comparison to far ones. It shows that bee can forage long distance to gain sufficient amount of food sources. Near as well as far distance species were equally important for bee forage. This ultimately helps in colony management. Flower color also plays an important factor in search of food resources. Many researchers have found that bee can see color in different aspects. Bee can see ultraviolet rays also. Bee rapidly picks up color of bee flora having high content of pollen and nectar sources that enhances the activity of bee foragers.

The Coronation Garden of Kirtipur is a semi-natural landscape containing cultivation area besides it with horticultural plant species. The presence of large number of bee flora species in the area suggests that this Garden is undoubtedly suitable for commercial beekeeping.

6.2 Recommendations

- Plantation programme should be launched for the conservation of honey flora in the area.
- In this area many horticultural species can be plant to increase the fruit and honey production.
- By using advanced technologies methods, we can calculate concentration of pollen and nectar.
- This semi-natural landscape gives the best platform for pollination ecology.
- Local, Public and government should run programs to retrieve life in this area.

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ANNEXES

Annex I

List of bee flora from the coronation Garden, Kirtipur

S.N.		Family	Abbreviation	Distance from bee hive (m)	Flower color	Life form
1	*Abelmoschus esculentus* (L.) Moench	Malvaceae	Abe_esc	87	Whitish yellow	Shrub
2	*Abelmoschus manihot* (L.) Medik.	Malvaceae	Abe_man	7	Whitish yellow	Shrub
3	*Actinidia deliciosa* (A.Chev.) C.F.Liang & A.R.Ferguson	Actinidiaceae	Act_del	455	White	Tree
4	*Agapanthus africanus* (L.) Hoffmanns.	Amaryllidaceae	Aga_afr	91	Royal blue	Herb
5	*Ageratum conyzoides* (L.) L.	Asteraceae	Age_con	22	Steel blue	Shrub
6	*Albizia julibrissin* Durazz.	Leguminosae	Abl_jul	15	Pink	Tree
7	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Alt_phi	7	White	Herb
8	*Alcea rosea* Cav.	Malvaceae	Alc_ros	9	Purple	Shrub
9	*Alyssum maritimum* (L.) Lam.	Brassicaceae	Aly_mar	5	White	Herb
10	*Allium cepa* L.	Amaryllidaceae	All_cep	81	White	Herb
11	*Allium sativum* L.	Amaryllidaceae	All_sat	78	White	Herb
12	*Amaranthus caudatus* L.	Amaranthaceae	Ama_cau	18	Crimson red	Herb
13	*Amaranthus spinulosa* L.	Amaranthaceae	Ama_spi	13	Powdery white	Herb
14	*Amomum aromaticum* Roxb.	Zingiberaceae	Amo_aro	9	Whitish yellow	Shrub
15	*Antirrhinum majus* L.	Plantaginaceae	Ant_maj	6	Pink	Herb
16	*Argemone mexicana* L.	Papavaraceae	Arg_mex	49	Yellow	Herb
17	*Artemisia indica* Willd.	Asteraceae	Art_ind	56	Moroon red	Shrub
18	*Asclepias curassavica* L.	Apocynaceae	Asc_cur	52	Yellow	Herb
19	*Asparagus racemosus* Willd.	Asparagaceae	Asp_rac	141	White	Shrub
20	*Aster ageratoides*	Asteraceae	Ast_age	14	White	Herb

	Turcz.					
21	*Azadirachta indica* A.Juss.	Meliaceae	Aza_ind	12	White	Tree
22	*Azalea japonica* A.Gray	Ericaceae	Aza_jap	94	Magenta red	Shrub
23	*Bauhinia purpurea* L.	Leguminosae	Bau_pur	198	Pinkish white	Tree
24	*Bauhinia variegata* L.	Leguminosae	Bau_var	58	Light Pink	Tree
25	*Begonia rubella* Buch.-Ham. ex D.Don	Begoniaceae	Beg_rub	62	Deep red	Herb
26	*Berberis aristata* DC.	Berberidaceae	Ber_ari	28	Yellow	Shrub
27	*Bidens pilosa* L.	Asteraceae	Bid_pil	123	Yellow	Herb
28	*Bougainvillea glabra* Choisy	Nyctaginaceae	Bou_gla	257	Pink	Shrub
29	*Brassica campestris* L.	Brassicaceae	Bra_cam	29	Yellow	Herb
30	*Brassica juncea* (L.) Czern.	Brassicaceae	Bra_jun	47	Yellow	Herb
31	*Butea monosperma* (Lam.) Taub.	Leguminosae	But_mon	18	Red	Shrub
32	*Cajanus cajan* (L.) Millsp.	Leguminosae	Caj_caj	83	Yellow	Shrub
33	*Calendulla officinalis* L.	Asteracaeae	Cal_off	229	Yellow	Herb
34	*Calliandra brevipes* Benth.	Leguminosae	Cal_bre	84	Pink	Shrub
35	*Callistemon citrinus* (Curtis) Skeels	Myrtaceae	Cal_cit	52	Red	Tree
36	*Campsis grandiflora* (Thunb.) K.Schum.	Bignoniaceae	Cam_gra	23	Orange	Climber
37	*Canna indica* L.	Cannaceae	Can_ind	53	Red	Herb
38	*Cannabis sativa* L.	Cannabaceae	Can_sat	85	Powdery white	Herb
39	*Coriandrum sativum* L.	Apiaceae	Cor_sat	452	White	Herb
40	*Capsicum annuum* L.	Solanaceae	Cap_ann	81	White	Herb
41	*Carica papaya* L.	Caricaceae	Car_pap	493	White	Tree
42	*Carya illinoinensis* (Wangenh.) K.Koch	Juglandaceae	Car_ill	19	White	Tree
43	*Cassia siamea* Lam.	Leguminosae	Cas_sia	44	Yellow	Tree
44	*Cassia tora* L.	Leguminosae	Cas_tor	502	Yellow	Shrub
45	*Castanea* sp.	Fagaceae	Cas_sp	316	Whitish green	Tree
46	*Catharanthus roseus* (L.) G.Don	Apocynaceae	Cat_ros	68	Violet	Herb

47	*Chaenomeles japonica* (Thunb.) Lindl. ex Spach	Rosaceae	Cha_jap	172	Red	Shrub
48	*Chenopodium album* L.	Amaranthaceae	Che_alb	544	Whitish green	Herb
49	*Choerospondias axillaris* (Roxb.) B.L.Burtt & A.W.Hill	Anacardiaceae	Cho_axi	156	White	Tree
50	*Chrysanthemum morifolium* Ramat.	Apocynaceae	Chr_mor	34	Red purple	Herb
51	*Cineraria cruenta* Masson ex L'Hér.	Asteraceae	Cin_cru	232	Red purple	Herb
52	*Cinnamomum camphora* (L.) J.Presl	Lauraceae	Cin_cam	262	White	Tree
53	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae	Cin_tam	57	White	Tree
54	*Cirsium wallichii* DC.	Asteraceae	Cir_wal	552	Light purple	Shrub
55	*Citrus aurantiifolia* (Christm.) Swingle	Rutaceae	Cit_aur	568	White	Shrub
56	*Citrus grandis* (L.) Osbeck	Rutaceae	Cit_gra	557	White	Tree
57	*Citrus jambhiri* Lush.	Rutaceae	Cit_jam	561	White	Shrub
58	*Citrus limon* (L.) Osbeck	Rutaceae	Cit_lim	567	White	Tree
59	*Citrus medica* L.	Rutaceae	Cit_med	551	White	Shrub
60	*Citrus paradisi* Macfad.	Rutaceae	Cit_par	569	White	Tree
61	*Citrus reticulata* Blanco	Rutaceae	Cit_ret	572	White	Tree
62	*Citrus sinensis* (L.) Osbeck	Rutaceae	Cit_sin	565	White	Tree
63	*Citrus unshiu* (Yu.Tanaka ex Swingle) Marcow.	Rutaceae	Cit_uns	582	White	Tree
64	*Cleome spinosa* Jacq.	Cappariadaceae	Cle_spi	172	Red purple	Herb
65	*Clivia miniata* (Lindl.) Bosse	Liliaceae	Cli_min	186	Yellowish orange	Shrub
66	*Coreopsis grandiflora* Hogg ex Sweet	Asteraceae	Cor_gra	137	Yellow	Herb
67	*Cuphea micrantha* Kunth	Lythraceae	Cup_mic	93	Red purple	Shrub

68	*Cucumis sativus* L.	Cucurbitaceae	Cuc_sat	94	Yellow	Climber
69	*Cucurbita maxima* Duchesne	Cucurbitaceae	Cuc_max	89	Yellow	Climber
70	*Cucurbita pepo* L.	Cucurbitaceae	Cuc_pep	87	Yellow	Herb
71	*Cynodon dactylon* (L.) Pers.	Gramineae	Cyn_dac	22	Dusty white	Herb
72	*Cynoglossum zeylanicum* (Vahl) Brand	Boraginaceae	Cyn_zey	128	Blue	Herb
73	*Dahlia pinnata* Cav.	Asteraceae	Dah_pin	43	Red	Shrub
74	*Dalbergia sissoo* DC.	Leguminosae	Dal_sis	119	yellow	Tree
75	*Datura stramonium* L.	Solanaceae	Dat_str	54	Yellowish white	Herb
76	*Dianthus barbatus* L.	Caryophyllaceae	Dia_bar	518	Pink	Herb
77	*Dianthus caryophyllus* L.	Caryophyllaceae	Dia_car	95	Crimson red	Herb
78	*Diospyros kaki* L.f.	Ebenaceae	Dio_kak	81	Yellow	Tree
79	*Dorotheanthus bellidiformis* (Burm.f.) N.E.Br.	Aizoaceae	Dor_bel	39	Pink	Herb
80	*Eriobotrya japonica* (Thunb.) Lindl.	Rosaceae	Eri_jap	154	White	Tree
81	*Erythrina blakei* R.Parker	Leguminosae	Ery_bla	92	Red	Tree
82	*Eschscholzia californica* Cham.	Papaveraceae	Esc_cal	34	Yellow	Herb
83	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae	Euc_cam	167	White	Tree
84	*Eupatorium adenophorum* Spreng.	Asteraceae	Eup_ade	22	White	Shrub
85	*Euphorbia milii* Des Moul.	Euphorbiaceae	Eup_mil	178	Red	Herb
86	*Euphorbia pulcherrima* Willd. ex Klotzsch	Euphorbiaceae	Eup_pul	68	Red	Shrub
87	*Fagopyrum esculentum* Moench	Polygonaceae	Fag_esc	93	White	Herb
88	*Fragaria indica* Jacks.	Rosaceae	Fra_ind	119	Yellow	Herb
89	*Fuchsia hybrida* hort. ex Siebert & Voss	Onagraceae	Fuc_hyb	38	Reddish white	Herb
90	*Gazania rigens* (L.) Gaertn.	Asteraceae	Gaz_rig	31	Yellow	Herb
91	*Gentiana*	Gentianaceae	Gen_ped	51	Blue	Herb

	pedicellata (D.Don) Wall.					
92	*Geranium pyrenaicum* Burm.f.	Geraniaceae	Ger_pyr	24	Pink	Herb
93	*Gladiolus hybrid*	Iridaceae	Gla_hyb	27	Yellowish orange	Herb
94	*Glycine max* (L.) Merr.	Leguminosae	Gly_max	91	Purple blue	Herb
95	*Gomphrena globosa* L.	Amaranthaceae	Gom_glo	43	Red	Herb
96	*Gossypium arboreum* L.	Malvaceae	Gos_arb	115	Yellow	Shrub
97	*Gossypium hirsutum* L.	Malvaceae	Gos_hir	183	White	Shrub
98	*Grevillea robusta* A.Cunn. ex R.Br.	Proteaceae	Gre_rob	127	Orange yellow	Tree
99	*Hellianthus annus* L.	Asteraceae	Hel_ann	161	Yellow	Shrub
100	*Hibiscus rosa-sinensis* L.	Malvaceae	Hib_rosa_sin	93	Pink	Shrub
101	*Hippeastrum vittatum* (L'Hér.) Herb.	Amaryllidaceae	Hip_vit	156	Red	Shrub
102	*Hydrocotyle nepalensis* Hook.	Umbelliferae	Hyd_nep	158	White	Herb
103	*Hymenocallis coronaria* (Leconte) Kunth	Liliaceae	Hym_cor	143	White	Herb
104	*Hypoestes phyllostachya* Baker	Acanthaceae	Hyp_phy	98	Blue	Shrub
105	*Impatiens balsamina* L.	Balsaminaceae	Imp_bal	37	Red	Herb
106	*Ipomoea nil* (L.) Roth	Convolvulaceae	Ipo_nil	32	Blue	Climber
107	*Ipomoea quamoclit* L.	Convolvulaceae	Ipo_qua	28	Dark red	Climber
108	*Jacaranda mimosifolia* D.Don	Bignoniaceae	Jac_mim	154	Blue	Tree
109	*Jacobinia carnea* (Lindl.) G.Nicholson	Acanthaceae	Jac_car	83	Crimson red	Shrub
110	*Jasminum grandiflorum* L.	Oleaceae	Jas_gra	81	Yellow	Climber
111	*Jasminum humile* L.	Oleaceae	Jas_hum	162	Yellow	Shrub
112	*Jatropha curcas* L.	Euphorbiaceae	Jat_cur	484	Whitish yellow	Shrub
113	*Juniperus indica* Bertol.	Cupressaceae	Jun_ind	164	Whitish yellow	Tree
114	*Justicia adhatoda* L.	Acantheceae	Jus_adh	78	Pink strip	Shrub

					on white	
115	*Lagerstroemia indica* L.	Lythraceae	Lag_ind	45	Red	Tree
116	*Lagenaria siceraria* (Molina) Standl.	Cucurbitaceae	Lag_sic	91	White	Climber
117	*Lantana camara* L.	Verbenaceae	Lan_cam	38	Yellow and red	Shrub
118	*Lathyrus odoratus* L.	Leguminosae	Lat_odo	76	Purple	Herb
119	*Lens culinaris* Medik.	Leguminosae	Len_cul	153	White	Herb
120	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Leu_leu	85	White	Tree
121	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	Lit_mon	99	White	Tree
122	*Luffa cylindrica* (L.) M.Roem.	Cucurbitaceae	Luf_cyl	123	Yellow	Climber
123	*Lycoris radiata* (L'Hér.) Herb.	Amaryllidaceae	Lyc_rad	148	Red	Herb
124	*Maesa chisia* Buch.-Ham. ex D. Don	Myrsinaceae	Mae_chi	484	White	Shrub
125	*Magnolia grandiflora* L.	Magnoliaceae	Mag_gra	41	White	Tree
126	*Malus domestica* Borkh.	Rosaceae	Mal_dom	453	White	Tree
127	*Malvaviscus arboreus* Cav.	Malvaceae	Mal_arb	146	Red	Shrub
128	*Mangifera indica* L.	Anacardiaceae	Man_ind	23	Whitish yellow	Tree
129	*Melia azedarach* L.	Meliaceae	Mel_aze	34	White with violet	Shrub
130	*Mesembryanthemum criniflorum* L. f.	Aizoaceae	Mes_cri	261	Purple	Herb
131	*Metasequoia disticha* (Heer) Miki	Cupressaceae	Met_dis	47	White	Tree
132	*Michelia champaca* L.	Magnoliaceae	Mic_cha	41	Golden yellow	Tree
133	*Mimosa pudica* L.	Leguminosae	Mim_pud	127	Pink	Herb
134	*Mirabilis jalapa* L.	Nyctaginaceae	Mir_jal	27	Dark red	Herb
135	*Momordica charantia* L.	Cucurbitaceae	Mom_cha	36	Yellow	Climber
136	*Morus nigra* L.	Moraceae	Mor_nig	24	White	Tree
137	*Muehlenbeckia platyclada* (F.J. Müll.) Meisn.	Polygonaceae	Mue_pla	27	Whitish red	Shrub
138	*Nerium indicum* Miller	Apocynaceae	Ner_ole	43	White	Tree

139	*Nerium oleander* L.	Apocynaceae	Ner_bas	45	Pink	Tree
140	*Ocimum basilicum* L.	Labiateae	Oci_bas	27	White	Shrub
141	*Ocimum sanctum* L.	Labiateae	Oci_san	24	White with violet	Shrub
142	*Oenothera rosea* L'Hér. ex Aiton	Onagraceae	Oen_ros	31	Pink	Herb
143	*Opuntia monacantha* (Willd.) Haw.	Cactaceae	Opu_mon	121	Yellow	Shrub
144	*Oxalis corniculata* L.	Oxalidaceae	Oxa_cor	22	Yellow	Herb
145	*Oxalis latifolia* Kunth	Oxalidaceae	Oxa_lat	34	Purple	Herb
146	*Passiflora caerulea* L.	Passifloraceae	Pas_cae	193	Blue	Climber
147	*Pelargonium* × *hortorum* L.H. Bailey	Geraniaceae	Pel_hor	38	Red	Herb
148	*Persea americana* Mill.	Lauraceae	Per_ame	581	Yellow	Tree
149	*Persicaria acuminata* (Kunth) M.Gómez	Polygonaceae	Per_acu	23	Red	Herb
150	*Petunia hybrida* Vilm.	Solanaceae	Pet_hyb	34	Fuscia	Herb
151	*Phaseolus vulgaris* L.	Leguminosae	Pha_vul	118	White	Climber
152	*Phyllanthus emblica* L.	Phyllanthaceae	Phy_emb	148	White	Tree
153	*Pinus roxburghii* Sarg.	Pinaceae	Pin_rox	254	Yellow dusty powder	Tree
154	*Plantago major* L.	Plantaginaceae	Pla_maj	42	White	Herb
155	*Plumbago zeylanica* L.	Plumbaginaceae	Plu_zey	48	White	Shrub
156	*Primula acaulis* (L.) Hill	Primulaceae	Pri_aca	24	Red	Herb
157	*Prunus americana* Marshall	Rosaceae	Pru_ame	561	White	Tree
158	*Prunus cerasoides* Buch.-Ham. ex D.Don	Rosaceae	Pru_cer	568	Fuscia	Tree
159	*Prunus domestica* L.	Rosaceae	Pru_dom	574	White	Tree
160	*Prunus persica* (L.) Batsch	Rosaceae	Pru_per	558	White	Tree
161	*Prunus pygeoides* Koehne	Rosaceae	Pru_pyg	563	White	Tree

162	*Psidium guajava* L.	Myrtaceae	Psi_gua	586	White	Tree
163	*Punica granatum* L.	Punicaceae	Pun_gra	543	Candy red	Tree
164	*Pyracantha crenulata* (Roxb. ex D.Don) M.Roem.	Rosaceae	Pyr_cre	45	White	Tree
165	*Pyrus communis* L.	Rosaceae	Pyr_com	26	White	Tree
166	*Pyrus pashia* Buch.-Ham. ex D.Don	Rosaceae	Pyr_pas	138	White	Tree
167	*Raphanus sativus* L.	Brassicaceae	Rap_sat	98	White	Herb
168	*Regia juglans*	Juglandaceae	Reg_jug	589	Green	Tree
169	*Reinwardtia indica* Dumort.	Linaceae	Rei_ind	216	Yellow	Shrub
170	*Ricinus communis* L.	Euphorbiaceae	Ric_com	128	Yellow	Shrub
171	*Rosa indica* L.	Rosaceae	Ros_ind	39	Pink	Shrub
172	*Rubus ellipticus* Sm.	Rosaceae	Rub_ell	68	White	Shrub
173	*Rudbeckia hirta* L.	Asteraceae	Rud_hir	32	Yellow	Herb
174	*Salvia splendens* Sellow ex Schult.	Labiateae	Sal_spl	49	Red or Violet	Herb
175	*Sambucus canadensis* L.	Adoxaceae	Sam_can	89	White	Shrub
176	*Sechium edule* (Jacq.) Sw.	Cucurbitaceae	Sec_edu	93	Light yellow	Climber
177	*Sesamum indicum* L.	Pedaliaceae	Ses_ind	88	Light violet	Shrub
178	*Sida cordifolia* L.	Malvaceae	Sid_cor	44	Yellow	Herb
179	*Solanum nigrum* L.	Solanaceae	Sol_nig	53	White	Herb
180	*Solanum tuberosum* L.	Solanaceae	Sol_tub	94	White	Herb
181	*Syzygium cumini* (L.) Skeels	Myrtaceae	Syz_cum	247	White	Tree
182	*Tagetes erecta* L.	Asteraceae	Tag_ere	28	Yellow	Herb
183	*Tagetes patula* L.	Asteraceae	Tag_pat	23	yellow	Herb
184	*Taraxacum officinale* (L.) Weber ex F.H.Wigg.	Asteraceae	Tar_off	25	Yellow	Herb
185	*Tithonia rotundifolia* (Mill.) S.F.Blake	Asteraceae	Tit_rot	108	Red orange	Herb
186	*Trifolium repens* L.	Legiminosae	Tri_rep	23	White	Herb
187	*Trichosanthes anguina* L.	Cucurbitaceae	Tri_ang	97	White	Climber
188	*Urena lobata* L.	Malvaceae	Ure_lob	91	Pink	Shrub
189	*Verbena hybrida* Groenl. & Rumpler	Verbenaceae	Ver_hyb	45	Red	Herb
190	*Veronica persica* Poir.	Plantaginaceae	Ver_per	37	Blue	Herb

191	*Vicia faba* L.	Leguminosae	Vic_fab	89	White	Herb
192	*Viola tricolor* L.	Violaceae	Vio_tri	73	Violet	Herb
193	*Vitis labrusca* L.	Vitaceae	Vit_lab	445	White	Climber
194	*Zea mays* L.	Gramineae	Zea_may	157	Yellow dusty powder	Shrub
195	*Zephyranthes carinata* Herb.	Amaryllidaceae	Zep_car	31	Pink	Herb
196	*Zinnia elegans* L.	Asteraceae	Zin_ele	34	Pink	Herb
197	*Ziziphus xylopyrus* (Retz.) Wild.	Rhamnaceae	Ziz_xyl	160	White	Tree

ANNEX 2 Bee flora calendar

Horticultural plants (35 species)

S.N.	Scientific name	Sources and status	Flowering M						
			Jan	Feb	Mar	Apr	May	Jun	Jul
1	*Actinidia deliciosa* (A.Chev.) C.F.Liang & A.R.Ferguson	N1P1				■	■		
2	*Citrus reticulata* Blanco	N1P1			■	■			
3	*Citrus unshiu* (Yu.Tanaka ex Swingle) Marcow.	N1P1			■	■			
4	*Citrus sinensis* (L.) Osbeck	N1P1			■	■			
5	*Citrus grandis* (L.) Osbeck	N1P1			■	■			
6	*Citrus paradisi* Macfad.	N1P1			■	■			
7	*Citrus limon* (L.) Osbeck	N1P1			■	■			
8	*Citrus aurantiifolia* (Christm.) Swingle	N1P1			■	■			
9	*Citrus jambhiri*	N1P1			■	■			
10	*Citrus medica* L.	N1P1						■	■
11	*Castanea* sp.	N3P1					■	■	
12	*Carya illinoinensis* (Wangenh.) K.Koch	N3P3					■	■	
13	*Eriobotrya japonica* (Thunb.) Lindl.	N1P1					■	■	
14	*Gossypium hirsutum* L.	N1P3					■	■	
15	*Psidium guajava* L.	P1N1					■	■	
16	*Phyllanthus emblica L.*	N2P2H2					■	■	
17	*Prunus domestica* L.	N2P1					■	■	
18	*Prunus americana* Marshall	N1P1					■	■	
19	*Prunus pygeoides* Koehne	N1P1					■	■	
20	*Prunus persica* (L.) Batsch	P1N1					■	■	
21	*Prunus cerasoides* Buch.-Ham. ex D.Don	N1P1						■	■
22	*Malus domestica* Borkh.	N1P1				■	■		
23	*Vitis labrusca* L.	N3P3		■	■	■			
24	*Persea americana* Mill.	N1P2							■
25	*Diospyros kaki* L.f.	N2P2					■	■	■
26	*Regia juglans*	P2					■	■	■
27	*Punica granatum* L.	N3P1				■	■		
28	*Carica papaya* L.	N1P1					■	■	■
29	*Fragaria indica* Jacks.	N1P1				■	■		
30	*Helianthus annuus* L.	N1P1					■	■	■
31	*Mangifera indica* L.	N2P2					■	■	
32	*Rubus ellipticus* Sm.	N1P2H2					■	■	■
33	*Syzygium cumini* (L.) Skeels	N1P1H3							■
34	*Pyrus communis* L.	N1P1					■	■	
35	*Ziziphus xylopyrus* (Retz.) Wild.	N1P3						■	■

Crops (vegetables, cereals, pulses and others: 27 species)

S.N.	Scientific name	Sources and status	Flowering Mon						
			Jan	Feb	Mar	Apr	May	Jun	Jul
1	*Abelmoschus esculentus* (L.) Moench	N2P2						■	■
2	*Allium cepa* L.	N2P3				■	■		
3	*Allium sativum* L.	N3P3				■	■		
4	*Brassica campestris* L.	N1P1	■	■	■	■	■		
5	*Brassica juncea* (L.) Czern.	N1P1		■	■				
6	*Cajanus cajan* (L.) Millsp.	N3P3							
7	*Capsicum annuum* L.	N3P3							■
8	*Coriandrum sativum* L.	N3P2		■	■	■			
9	*Cucumis sativus* L.	N1P1						■	■
10	*Fagopyrum esculentum* Moench	N1P2	■	■	■				
11	*Glycine max* (L.) Merr.	N3P3							■
12	*Lagenaria siceraria* (Molina) Standl.	N3P3							■
13	*Luffa cylindrica* (L.) M.Roem.	N2P2							■
14	*Momordica charantia* L.	N3P3						■	■
15	*Lens culinaris* Medik.	N1P3							
16	*Solanum tuberosum* L.	N3P3							
17	*Phaseolus mungo* L.	N3P3							■
18	*Phaseolus vulgaris* L.	N2P2							■
19	*Cucurbita maxima* Duchesne	N1P1		■	■	■			
20	*Vicia faba* L.	N3P1		■	■				
21	*Raphanus sativus* L.	N1P1		■	■				
22	*Trichosanthes anguina* L.	N3P3						■	■
23	*Sesamum indicum* L.	N1P1						■	■
24	*Sechium edule* (Jacq.) Sw.	N2P2							■
25	*Asparagus racemosus* Willd.	N3P1					■	■	■
26	*Cucurbita pepo* L.	N1P3				■	■		
27	*Zea mays* L.	P3						■	■

Naturalized plants (8 species)

S.N.	Scientific name	Sources and status	Flowering Mont						
			Jan	Feb	Mar	Apr	May	Jun	Jul
1	*Bauhinia variegata* L.	N3P3				■	■	■	■
2	*Bauhinia purpurea* L.	N3P3			■	■	■	■	
3	*Choerospondia axillaris*(Roxb.) B.L.Burtt & A.W. Hill	N2P2			■	■	■		
4	*Cinnamomum camphora* (L.) J.Presl.	N3P3				■	■	■	■

5	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	N3P3			■	■	■	■	
6	*Eucalyptus camaldulensis* Dehnh.	N1P1							■
7	*Grevillea robusta* A.Cunn. Ex R.Br.	N1P1				■	■	■	
8	*Leucaena leucocephala* (Lam.) de	N3P1			■	■	■	■	■

Wild species (50 species)

S.N.	Scientific name	Sources and status	Flowering Mon						
			Jan	Feb	Mar	Apr	May	Jun	Jul
1	*Ageratum conyzoides* (L.) L.	N3P2		■	■	■	■	■	■
2	*Artemisia indica* Willd.	N2P2					■	■	■
3	*Azadirachta indica* A.Juss.	N1P3				■	■		
4	*Berberis aristata* DC.	N2P2H2				■	■	■	
5	*Bidens pilosa* L.	N3P2							
6	*Cannabis sativa* L.	N2P2						■	■
7	*Cynodon dactylon* (L.) Pers.	P3				■	■	■	■
8	*Cynoglossum zeylanicum* (Vahl) Brand	N3P3				■	■	■	■
9	*Eupatorium adenophorum* Spreng.	N2P1		■	■	■	■	■	
10	*Fragaria indica* Jacks.	N2P2	■	■	■	■	■		
11	*Gentiana pedicellata* (D.Don) Wall.	N2P3			■	■	■	■	■
12	*Hydrocotyle nepalensis* Hook.	N3P3						■	■
13	*Justicia adhatoda* L.	N2P2		■	■	■			
14	*Jatropha curcas* L.	N3P3				■	■		
15	*Cassia tora* L.	N3P2						■	■
16	*Litsea monopetala* (Roxb.) Pers.	N3P3	■	■	■				
17	*Melia azedarach* L.	N2P2		■	■				
18	*Maesa chisia* Buch.-Ham. ex D. Don	N3P3			■	■			
19	*Mimosa pudica* L.	N3P2						■	■
20	*Urena lobata* L.	N3P3							■
21	*Oxalis corniculata* L.	N2P2		■	■	■	■	■	■
22	*Plantago major* L.	N2P1		■	■	■	■	■	■
23	*Pyrus pashia* Buch.-Ham. ex D.Don	N2P2			■	■	■		
24	*Pyracantha crenulata* (Roxb. ex D.Don) M.Roem.	N2P2				■			
25	*Rubus ellipticus* Sm.	N2P2H1			■	■			
26	*Trifolium repens* L.	N1P1		■	■	■	■	■	■
27	*Brassica campestris* L.	N1P1					■	■	■
28	*Oxalis latifolia* Kunth	N2P2		■	■	■	■	■	■
29	*Cirsium wallichii* DC.	N1P1				■	■	■	
30	*Opuntia monacantha* (Willd.) Haw.	N2P2		■	■	■	■	■	
31	*Ricinus communis* L.	P2					■	■	■
32	*Butea monosperma* (Lam.) Taub.	N1P1	■	■					
33	*Argemone mexicana* L.	P3					■	■	
34	*Lantana camara* L.	N1P3					■	■	■
35	*Abelmoschus manihot* (L.) Medik.	N2P2						■	■
36	*Datura stramonium* L.	P3						■	■

37	*Sida cordifolia* L.	N3P3			■	■	■	■	
38	*Sambucus canadensis* L.	N2P2	■	■	■	■	■	■	■
39	*Solanum nigrum* L.	N1P1						■	■
40	*Oenothera rosea* L'Hér. ex Aiton	N1P1						■	■
41	*Chenopodium album* L.	N2P2						■	■
42	*Ipomoea nil* (L.) Roth	N3P1						■	■
43	*Alternanthera philoxeroides* (Mart.) Griseb.	N3P3						■	■
44	*Persicaria* sp	N3P3						■	■
45	*Veronica persica* Poir.	N2P2						■	■
46	*Lycoris radiata* (L'Hér.) Herb.	N3P3						■	
47	*Taraxacum officinale* (L.) Weber ex F.H.Wigg.	N1P1		■	■	■	■		
48	*Amaranthus spinulosa* L.	N3P1						■	■
49	*Geranium pyrenaicum* Burm.f.	N3P3					■	■	■
50	*Alternanthera philoxeroides (Mart.)* Griseb	N3P3						■	■

Ornamental plants (77 plants)

S.N.	Scientific name	Sources and status	Flowering Mon Jan	Feb	Mar	Apr	May	Jun	Jul
1	*Agapanthus africanus* (L.) Hoffmanns.	N1P1						■	■
2	*Albizia julibrissin* Durazz.	N3P3				■	■		
3	*Althea rosea* Cav.	N2P2				■	■	■	
4	*Alyssum maritimum* (L.) Lam.	N2P2		■	■	■	■	■	
5	*Amaranthus caudatus* L.	N3P3							■
6	*Antirrhinum majus* L.	N2P2				■	■	■	■
7	*Azalea* sp.	N3P3			■	■	■		
8	*Aster ageratoides* Turcz.	N1P1	■	■	■	■	■	■	■
9	*Asclepias curassavica* L.	N3P3						■	■
10	*Begonia rubella* Buch.-Ham. ex D.Don	N3P3			■	■	■		
11	*Bougainvillea glabra* Choisy	N2P3						■	■
12	*Cuphea micrantha* Kunth	N2P3		■	■	■	■	■	■
13	*Callistemon citrinus* (Curtis) Skeels	N1P1		■	■	■	■	■	■
14	*Campsis grandiflora* (Thunb.) K.Schum.	N2P3					■	■	■
15	*Chrysanthemum morifolium* Ramat.	N3P3							
16	*Cineraria cruenta* Masson ex L'Hér.	N2P2							■
17	*Cleome spinosa* Jacq.	N2P2					■	■	■
18	*Canna indica* L.	N3P3					■	■	■
19	*Calendulla officinalis* L.	N3P3		■	■	■			
20	*Catharanthus roseus* (L.) G.Don	N3P3			■	■	■		
21	*Clivia miniata* (Lindl.) Bosse	N3P3			■	■			
22	*Dahlia pinnata* Cav.	N2P1						■	■
23	*Dianthus barbatus* L.	N3P1				■	■	■	
24	*Dorotheanthus bellidiformis* (Burm.f.) N.E.Br.	N3P3						■	■
25	*Dianthus caryophyllus* L.	N3P3				■	■	■	

26	*Eschscholzia californica* Cham.	N3P1								
27	*Euphorbia milii* Des Moul.	N3P3								
28	*Euphorbia pulcherrima* Willd. ex Klotzsch	N3P3								
29	*Erythrina blakei* R.Parker	N3P3								
30	*Gazania rigens* (L.) Gaertn.	N2P2								
31	*Hibiscus rosa-sinensis* L.	N2P2								
32	*Hippeastrum vittatum* (L'Hér.) Herb.	N3P3								
33	*Impatiens balsamina* L.	N1P2								
34	*Jacaranda mimosifolia* D.Don	N3P3								
35	*Jacobinia carnea* (Lindl.) G.Nicholson	N2P2								
36	*Juniperus indica* Bertol.	H3								
37	*Pinus roxburghii* Sarg.	P1H3								
38	*Lathyrus odoratus* L.	N2P2								
39	*Lagerstroemia indica* L.	N1P2								
40	*Petunia hybrida* Vilm.	N3P3								
41	*Hymenocallis coronaria* (Leconte) Kunth	N3P3								
42	*Rudbeckia hirta* L.	N2P2								
43	*Salvia splendens* Sellow ex Schult.	N1P1								
44	*Reinwardtia indica* Dumort.	N2P2								
45	*Gossypium arboreum* L.	N1P2								
46	*Michelia champaca* L.	N2P2								
47	*Malvaviscus arboreus* Cav.	N2P2								
48	*Jasminum grandiflorum* L.	N2P3								
49	*Jasminum humile* L.	N2P3								
50	*Rosa indica* L.	N3P1								
51	*Ocimum sanctum* L.	N2P2								
52	*Muehlenbeckia platyclada* (F.J. Müll.) Meisn.	N2P3								
53	*Plumbago zeylanica* L.	N3P3								
54	*Ocimum basilicum* L.	N2P3								
55	*Tagetes erecta* L.	N3P3								
56	*Tagetes patula* L.	N3P3								
57	*Viola tricolor* L.	N3P3								
58	*Zephyranthes carinata* Herb.	N3P1								
59	*Zinnia elegans* L.	N2P2								
60	*Gomphrena globosa* L.	N3P3								
61	*Tithonia rotundifolia* (Mill.) S.F.Blake	N2P1								
62	*Passiflora caerulea* L.	N1P3								
63	*Hypoestes phyllostachya* Baker	N2P3								
64	*Mesembryanthemum criniflorum* L. f.	N3P3								
65	*Pelargonium × hortorum* L.H. Bailey	N3P3								
66	*Primula acaulis* (L.) Hill	N3P3								
67	*Verbena hybrida* Groenl. & Rumpler	N3P3								
68	*Fuchsia hybrida* hort. ex Siebert & Voss	N1P3								
69	*Gladiolus* sp.	N3P1								
70	*Mirabilis jalapa* L.	N1P3								
71	*Calliandra brevipes* Benth.	N1P1								

72	*Nerium indicum* Miller	N3							
73	*Nerium oleander* L.	N3							
74	*Lagerstroemia indica* L.	N1P1							
75	*Coreopsis grandiflora* Hogg ex Sweet	N1P1							
76	*Ipomoea quamoclit* L.	N3P1							
77	*Chaenomeles japonica* (Thunb.) Lindl. ex Spach	N1P1							

Note: N1= major nectar source, N2= medium nectar source, N3= minor nectar source, P1= major pollen source, P2= medium pollen source, P3= minor pollen source, H1= major honey dew source, H2= medium and H3= minor honey dew source. (Source: compiled from secondary data)