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Bee flora of Khumaltar agro-ecosystem, Lalitpur, Nepal

Kishna Singh Thagunna[1], Shreejana Raut[1], Chitra Bahadur Baniya*[1]

[1]Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal
[*]E-mail:cbbaniya@gmail.com

Abstract

This investigation was carried out in Agricultural Research Council (NARC), Khumaltar area, Lalitpur, Nepal to document the seasonal bee flora and diversity patterns. Bees get enough choices to forage in an agro-ecosystem study area. Flowering plants visited by honeybees were observed and documented as per their preferences of foraging, distance away from the bee-hive and seasons. Each plant enlisted as bee-flora if a honeybee visited any flower and rested at least for a while. A total of 168 vascular plant species documented as bee flora in this study. These flora were classified according to season, distance away from the bee-hive, family, genera, species. Simpson and Shannon diversity indices were found higher (0.004 and 3.45) for summer16. Asteraceae family was found to be the most preferred species. Distance of each bee flora was not found significant but season and herbaceous flower were found highly significant contribution. Maximum abundance of *Solanum virginianum* L. appeared towards the positive end of non-metric multidimensional scaling axis (NMDS2) which was closer to summer16. It signified closer affinity to the beehive and high preferences during summer15. Likewise, the maximum abundance of *Vitis vinifera* L. towards summer16 and higher positive end of NMDS1 signified favoring more wet loving early blooming species. Relatively higher abundance of species such as *Parthenium hysterophorus* L., *Solanum tuberosum* L., *Zinnia elegans* Jacq., and *Solanum melongena* L. in the middle of the NMDS axis and spring 16 signified moderate moist loving species. Pattern of bee flora selection, contribution in term of nectar and pollen grain coincided to moisture gradient. This study supports bee farmers for better selection of wild as well as cultivated bee flora for better preference by bees.

Keywords: Abundance, Diversity, Foraging, Moisture, Non-metric multidimensional scaling axis

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Introduction

From time immemorial, beekeeping is an important farming occupation not only elsewhere but also in Nepal. Directories of the world honey sources (Bista *et al.*, 2000/2001), the Hindu-Kush Himalayan region (Verma, 1990, Partap, 1997), and the bee flora of India (Kaur and Sihag, 1994) are some of the existing examples of such efforts. In context of Nepal, Kafle (1984), Thapa, and Dangol (1990) reported more than one hundred bee flora available in Kathmandu valley and Rampur, Chitwan.

Apiculture is a flora-based industry in which honeybees collect nectar and pollen grains from almost 40,000 plant species out of 2,50,000 species expected so far in the world (Crane 1990). It is an important agricultural enterprise that utilizes natural nectar and pollen grains. It contributes income of small local farmers which otherwise would be wasted (Melaku *et al.*, 2008).

The environmental variables greatly affect bee flora and their pollinators (Kearns and Inouye, 1993). Moreover, honeybee acts as a cross-pollinator. Performances of bee colony, honey

production, wax and other hive products depend directly on the quantity, quality, and distance of bee-foraging plants. One-third of the total human diet comes from bee-pollinated crops and pollination value worth's about 143 times higher than honey production (Mishra 1989). The average global value of the pollination system is \$ 117 ha^{-1} yr^{-1} (Costanza *et al.,* 1997).

The flowering time of each plant differs by time and space. Topography, climate, and farming practices differ honey production (Bista *et al.,* 2001). Each local landscape has its own honeybee flora and floral dearth for both short to long duration. Local knowledge on bee flora is greatly helpful in the management of bee colonies.

The flowering period of each plant species is highly crucial to run the life cycle of each plant. Another very important role of beekeeping is to increase the quality and yield of fruits, and seeds of various crops after pollination (Pratap and Pratap, 1997).

Honey-bees are the most important pollinator (Williams, 1994; Sharma *et al.,* 2004). Devkota (2000) and (Free, 1993) concluded that pollination both by honeybees as well as other insects significantly improve the yield and quality of seed crops. Depending upon the soil climatic factors and the habitat of the vegetation, the time for each flowering plant to bloom may change within the same nectar-yielding plant. However, flowering plants of several families are blossoming at different time intervals of the year. Every area has its own bee flora and dearth periods of short and long duration.

The adaptability of bees in exploiting the bee forage in a locality can be studied on the basis of the foraging activity in different seasons of the year. Researchers studied the honey-bees foraging on various aspects of botanical sciences, with special emphasis on floral biology, taxonomy, and palynology (Bhalchandra *et al.,* 2014). Increasing forage frequency results crop pollination efficiency (Singh *et al.,* 2006).

Flower development and its opening, nectar secretion, anther dehiscence, and seed development are dependent on ambient temperature and moisture which affect the activity of flower visitors. Bees, the most important pollinators, can't go outside their hive during cold, foggy, and rainy weather (Adhikari 2003, 2010). The optimum conditions required for dehiscence of pollen are above 20° C temperature and a humidity of 70% or less (Harugade *et al.,* 2013). Sometimes, these values changed due to evolutionary co-adaptation of flowers and their bee pollinators (Macior, 1990, Macior and Ya, 1997).

Bee pollination studies carried out in Kathmandu valley proved that there was a significant increase in the fruit setting, and seed weight (i.e., seed yield and quality). For better pollination and productivity of crops, proper methods of utilizing pollinators are important, which are specific for honeybees, other bees, and other insects (Sihag, 2000).

Various plants were blossoming in different seasons and honeybees visited these plants for nectar and pollen. The plant species like *Diploknema butyracea* (Roxb.) H. J. Lam, *Melaleuca citrina* (Curtis) Dum. Cours. and *Grevillea robusta* A. Cunn. ex R. Br. were found in fewer numbers but these plants were referred to as good nectar and pollen source for honeybees (Partap, 1997).

Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur premises is one of the semi-natural urban ecosystems where different agricultural, and horticultural trials have been going on for many decades. Honeybees are getting almost natural habitats with varieties of plant species almost similar to agro-ecosystem. This led selection of the NARC area as an ideal place for this study. The main objective of this study was to determine the seasonal (summer

15, spring 16 and summer 16) bee flora species composition pattern. The specific objectives were to determine the life-form pattern,, and contributions of each bee flora in term of nectar and pollen or both as well as role of distance between beehive and the bee flora. Understanding bees and bee flora of National Agricultural Research Council (NARC) area may help to produce honey better throughout seasons. In addition, the relationship between the distance of separation of each bee flora and bee hive will also be known.

Materials and Methods

Study Area

Nepal Agricultural Research Council, Khumaltar is located in Lalitpur district, Nepal, having an area of about 4,93,703 sq. m. Geographically, NARC lies between 85^0 19' 30" latitude and 27^0 39' 8" longitudes (Figure 1). The special feature of this area is the presence of varieties of agricultural farms in addition to the garden and horticultural plant species in a closed boundary.

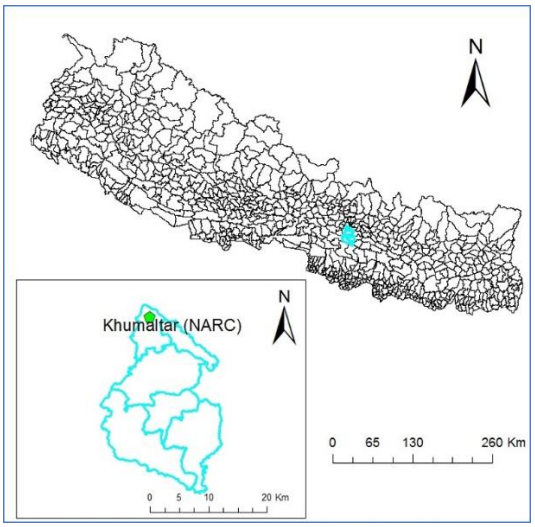


Figure 1. Location map of the study area. The point inside the map is the studied area.

NARC, Khumaltar has its own weather station, and the mean annual rainfall of this study area was recorded as 906.625 mm and the average annual temperature was 18.9^0C (Figure 2). The rainy season starts from early June to mid of September. Rainfall begins in late March and lasts until late September. Rainfall occurred from July to August. The later months are called monsoons. The dry season starts in early November and ends in mid-March and late September to mid-December. The mean annual minimum temperature of the study area was 12.6 ^{0}C and the mean annual maximum temperature was 25.1^0C for the year 2015 (Figure 2).

Data collection

The total land mass covered by the NARC area i.e. is 5 ha. This whole area was considered as the sampling area. This research work was carried out after setting up bee hives and observing bee flora for nine months from 2015 to 2016. June, July, and August of 2015 were considered as summer15 i.e. first summer. March, April, and May of 2016 were considered as spring16 and June, July, and August of 2016 were considered as summer16 i.e. second summer. All bee flora were recorded for one season whole were defined here as the one seasonal bee flora. Thus this study documented three seasonal bee flora i.e. summer15, spring16 and summer16. Each bee flora was considered as a single sampling unit if a bee visited that plant species for a minimum of 5 times. The observation of bees landing on

each flora was done for two days per week starting from early morning (6 A. M.) to evening (6 P. M.). This process was carried out continuously for 9 months (Appendix 1).

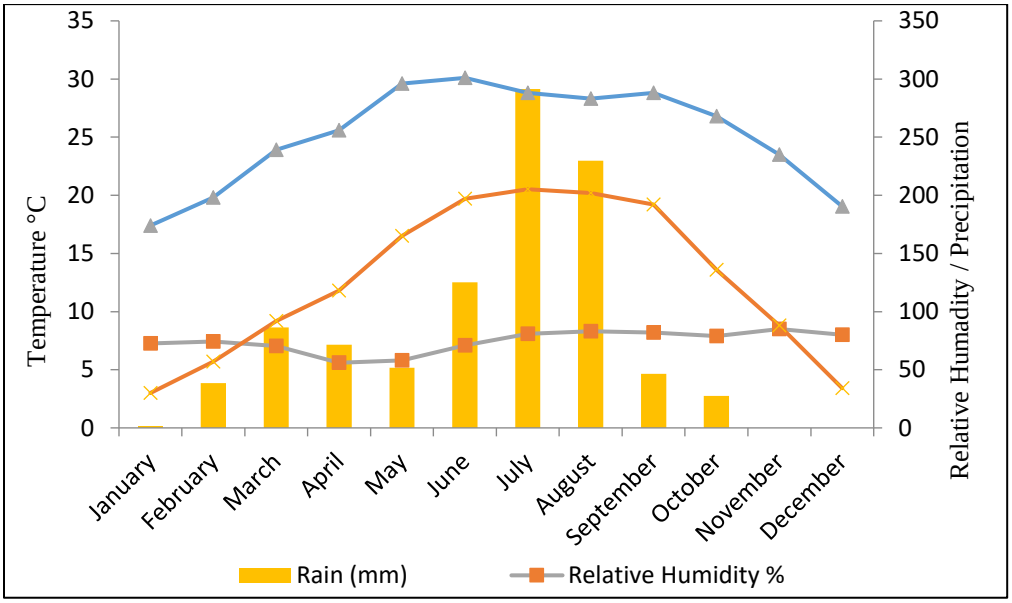


Figure 2. Monthly average maximum, minimum, total rain and relative humidity were shown for the year 2015.

Apiaries were placed almost in the interface between the garden of NARC, Khumaltar area, and its agricultural fields. There were eight hives, among which four were *Apis cerena* Fabricius, 1793, and remaining four were *Apis mellifera* Linnaeus, 1758. All bee hives were placed equidistant distance of 5m apart from each other. This setting made easy to observe bees traveling each bee flora. The distance of each blooming flower from the center of each bee hive was calculated systematically. Each plant visited by a bee was observed carefully at all possible transects or directions by taking one of the bee hives nearest straightly. The date of observation, and season were recorded with their valid scientific name. Photographs of each flowering plant were taken for future confirmation. Each plant was identified carefully by using standard literature (Pratap, 1997) and all valid scientific names were checked after using online resource such as http://www.worldfloraonline.org/.

The average distance (m) between the beehive and the blooming flower inside NARC, Khumaltar area was measured by using a measuring tape. This measurement of bloomed bee flora was made by making a radius all around from the beehive up to the distance of 1 km, inside the NARC area. Concrete buildings and walls were avoided in this measurement. Only visible and unobstructed distance was measured.

Status of bee flora

If a bee thrusts its proboscis into the interior of the flower basin, that bee flora was taken as a source of nectar. The availability of pollen, on the other hand, was determined after observing bees collecting pollen and loading it on their hind legs. The status of the type of bee flora, whether the major or minor source was determined by the intensity of bee visiting that flower (Pratap, 1997). Major bee flora were defined as if, the flora produces surplus nectar and pollen and abundantly available in an area. If bee flora supplied sustained annual flows of nectar and pollen that used for maintenance and development of bee colonies were defined as medium sources. Minor bee flora were plants which did not generate surplus honey but

provided enough nectar and pollen for the bees to survive during the dearth period (Pratap, 1997).

Identification of Bee flora

Identification of the bee flora was done in the field with the help of nameplates to individual species tagged for most plant species. Other unidentified plants were identified after matching to herbaria already deposited at Tribhuvan University Central Herbarium (TUCH), its premises, and National Herbarium, Godawari (KATH). Garden Flowers (Bajracharya *et al.,* 1997), Annotated checklist of Flowering Plants Nepal (Press *et al.,* 2000) were used for final confirmation. All valid scientific names were checked after using the URL: *http://www.worldfloraonline.org/.*

Identified bee flora were categorized further into herb, shrub, and tree based on their habit and morphology. Distance of each flora from the beehive was measured in meter. Similarly, role of each flower was classified as either major, medium or minor bee flora by following Bista *et al.* (2000/2001).

Herbarium preservation

Determination of a particular plant was the bee flora or not, was not possible without contributing much longer attention to that plant. In such cases, the plant was collected, pressed, identified, and compared with authentic and valid published literature and confirmed.

Data analysis

Occurrences of bee flora was tabulated according to seasons. Shannon-Wiener and Simpson indices based on seasons were calculated. They were the most common indices (Oksanen *et al.,* 2022). In most ecological studies values of these diversity indices were generally ranged between 1.5 to 3.5, and rarely greater than 4. The Shannon index is sensitive to species richness. It increases with increase of the richness and the evenness of the community increases.

Shannon-Wiener (H) was calculated by using the formula as used by Oksanen *et al.,* (2022).

$H = -\Sigma pi * \ln(pi)$

where, ln: Natural log

pi: The proportion of the entire community made up of species i

Simpson index (C) was calculated by using the formula given by Magurran, (2004).

$C = \Sigma (pi)^2$

Where pi: The proportion of the entire community made up of species I.

Simpson index (C) measures the dominancy and sensitivity to the species richness when C increases and diversity decreases and its values are ranged between 0- 1.

The relationship between bee flora species composition and seasons was determined through Non-metric Multidimensional Scaling (NMDS, Minchin, 1987). It is a very redundant, multivariate technique with no bias. This NMDS technique was applied through the *vegan* package (Oksanen *et al*., 2022) under R package (R Core Team, 2022). The NMDS projected species with respect to the seasons. The specific position of each species in the NMDS space defined the season favored that particular floral species and other similar or neighboring bee floral species. Significant distribution pattern of the bee flora along NMDS1 indirectly may represent moisture gradient. Likewise, NMDS2 may represent either temperature or other unmeasured environment variables.

Pearson's correlation coefficients among environment variables were calculated. Environmental variables were NMDS1 and NMDS2 scores, status of bee flora (major, medium and minor), distance away from the hive, and seasons. Status of all bee flora and seasons were taken as dummy variable in this study.

All statistical analyses were performed by applying R package version 4.2.2 (R Core Team, 2022) and Microsoft Excel.

Results and Discussion

Bee flora species diversity and families

This study discovered a total of 168 bee flora under 64 families. The Asteraceae was the most abundant family with the highest number of 21 species. This was followed by Leguminosae with nine species, Cucurbitaceae, Rosaceae, Solanaceae with six species each, Amaranthaceae, Brassicaceae, Fabaceae with five species each, Lamiaceae, Papaveraceae, Poaceae, Verbenaceae with three species each, whereas Amaryllidaceae, Apocynaceae, Bignoniaceae, Euphorbiaceae with two species (Figure 3 and Appendix 1). Asteraceae was also the richest family in term of genera (20) followed by Leguminosae with nine genera, Cucurbitaceae, Rosaceae, and Solanaceae with six genera each (Figure 4).

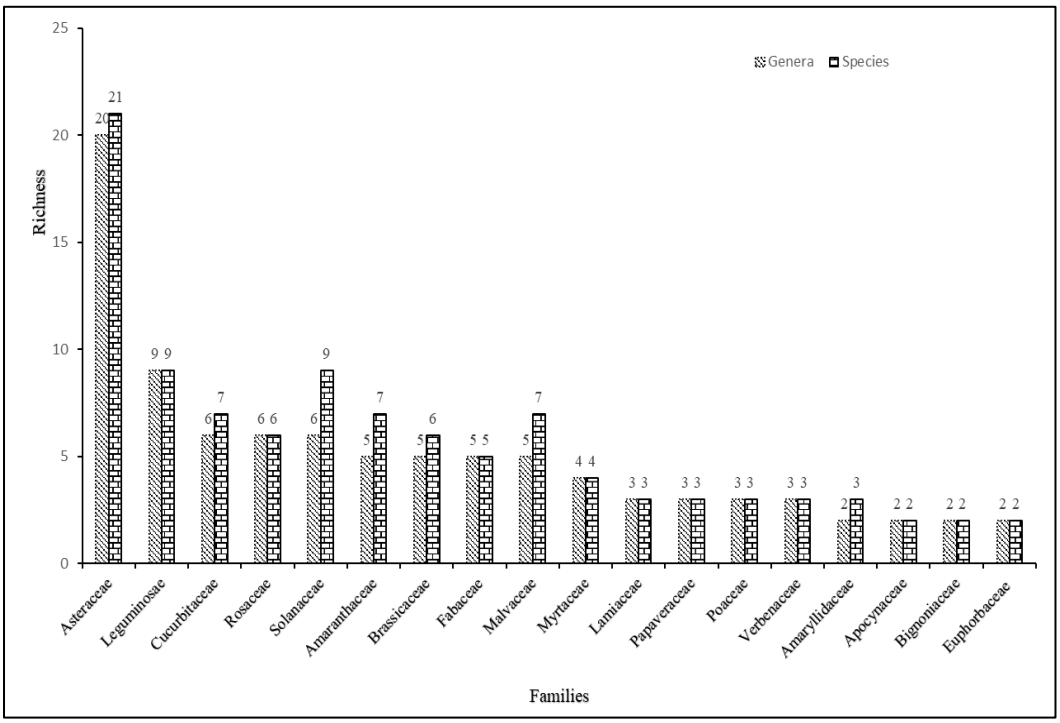


Figure 3. Family-wise representation of Genus and Species of Bee flora.

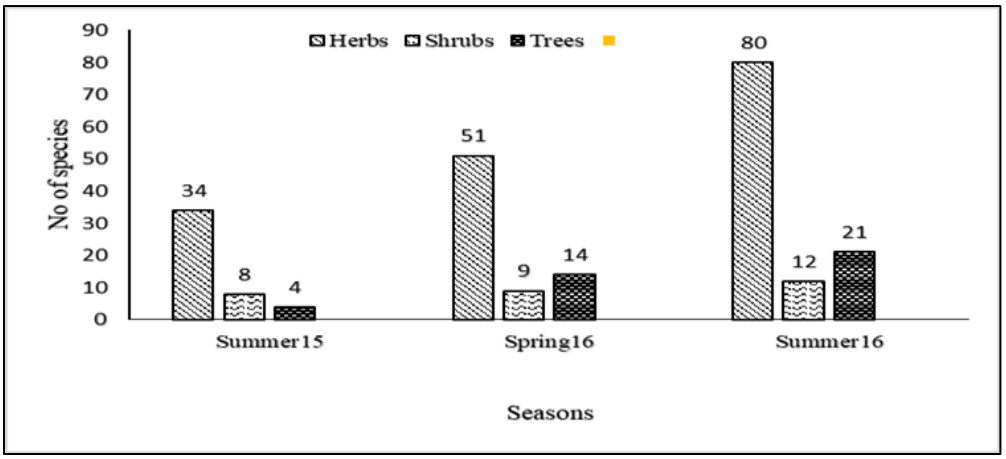


Figure 4. Seasonal Bee flora and life-form diversity

This study found three major life forms for all bee flora (Appendix 1). Among them, herbs were the most dominant with 116 species followed by trees with 29 species and shrubs with 23 species (Figure 4). High preference of the Asteraceae would be due to semi-natural environment inside the NARC area, easily cultivated ornamental plants mostly belonged to the Asteraceae family. That might not true for other ecological settings such as Mbah and Amao (2009) found dominance of Fabaceae in Savannas.

The number of bee flora found varied with seasons from summer15 to summer16. In summer15 bee flora were found comparatively less in number (46) than the other two seasons. There were 34 herbs, eight shrubs, and four tree species found foraging during summer15 (Figure 4). Values for spring16 was 74 which included 51 herbs, nine shrubs, and 14 trees and summer16 consisted of 113 species included of 80 herbs, 12 shrubs, and 21 trees respectively (Figure 4).

The study found three categories of bee flora based on the purpose of visits by bees (Figure 5). These were mainly for nectar and pollen. The highest number of bee flora (60) were accounted as minor bee flora followed by medium and 36 as major (Figure5).

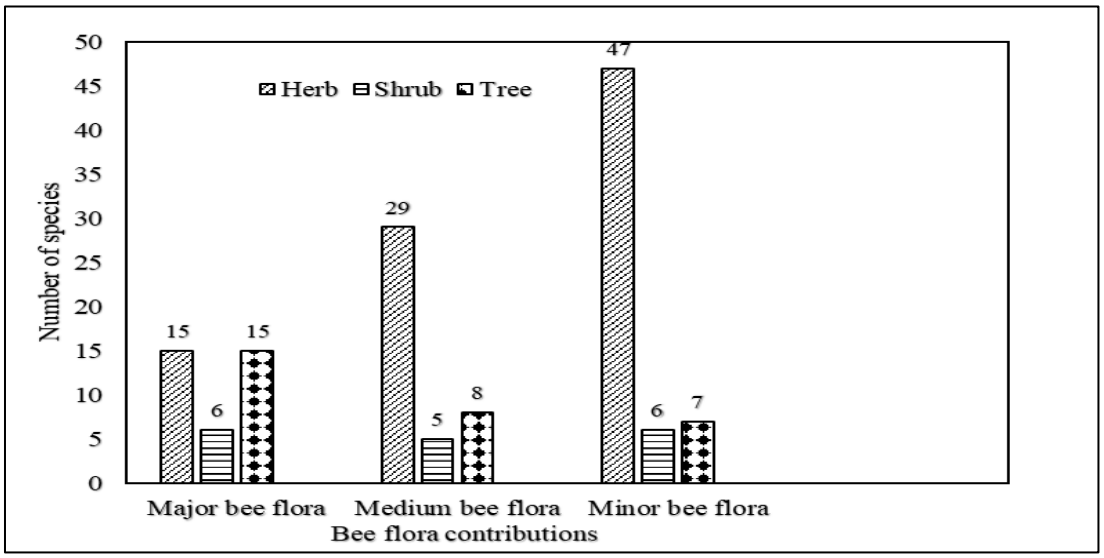


Figure 5. Beeflora contribution in term of total life form diversity

The life form of major bee flora consisted of herb (15), shrub (six) and trees (15) (Figure 5). Medium bee flora consisted of 29 species as herbs, five species as shrubs and eight species as trees**.** Whereas minor bee flora consisted of 47 species as herbs, six species as shrubs, and seven species as tree (Figure 5)

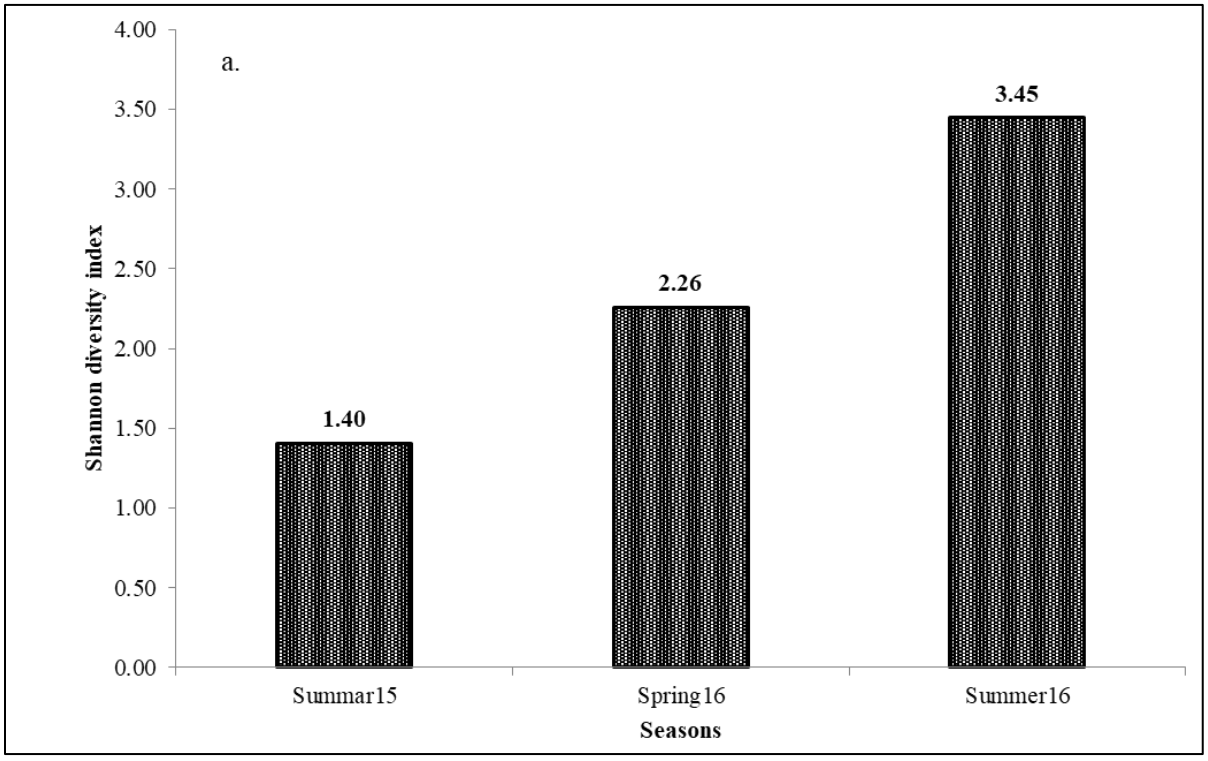
Seasonality and bee flora

Altogether 168 species were recorded as bee flora for three seasons. The total bee flora documented for summer15 was 46, Spring16 got 74, and 113 bee flora for summer16 (Figure 4). A study carried out by Kafle (1984) documented 156 species of bee flora from Kathmandu, while Partap and Verma (1996) documented 113 species of bee flora also from Kathmandu too. Partap (1997) documented 103 bee flora from Jumla, 119 species of bee flora were documented from the Dolkha district by Bista and Siwakoti, (2001), and Devkota (2003) documented 85 species from Eastern Chitwan. Variations among three seasons within this study, a lesser number of species during summer15 than summer16 would be of less amount rainfall received during 2015 which gave a longer dry period. Summer16 got a higher number of bee flora. This would be

enough amount of rainfall gain and most flowering plants bloomed early after rain fully started in the early summer of 2016. Most bee flora existing in spring16 continued to bloom during summer16. That may be the reason to increase in the number of bee flora during summer 16. All of these above findings confirming that the number of bee flora varied as spaces as well as seasons. The early rain and flowering time of most vegetable crops started during summer16. The time of bee landing on flowers and the abundance of full bloom flowers were high during this season. It may have a direct relationship with most insects in general and bees may go for swarming, egg production, and larval growth because of the high availability of pollen, which was the major source of food for larvae of bees (Page and Amdam, 2007). This interpretation is also closer to the findings of Pratap and Verma (1996), Bista and Sivakoti, (2001), Devkota (2003). Most trees also went flowering during the summer season. They were visited by pollinators at that time for excessive pollination.

Diversity indices

The value of the Shannon index was found to be 1.40 for summer15, 2.26 for spring16, and 3.45 for summer16 (Figure 6a). The value for Simpson index was found to be 0.002 for summer15, 0.0026 for spring16, and 0.004 for summer16 (Figure 6b). This denoted that the dominance of bee flora during summer16 was greater than summer15 and spring16. High Shannon index indicated high diversity with changes in seasons and the Simpson index was also found to be higher with the change in season. The Shannon and Simpson index were found to be higher in the third season i.e. summer16 (June, July, and August). The value of the Shannon index was 3.45 and the Simpson index was 0.004 for summer16. This clearly indicated that diversity and dominance of bee flora were found high in the summer16. This finding of high diversity during rainy monsoon was similar with high diversity during wet season (Gebru *et al.*, 2016). That may coincide to moisture gradient.



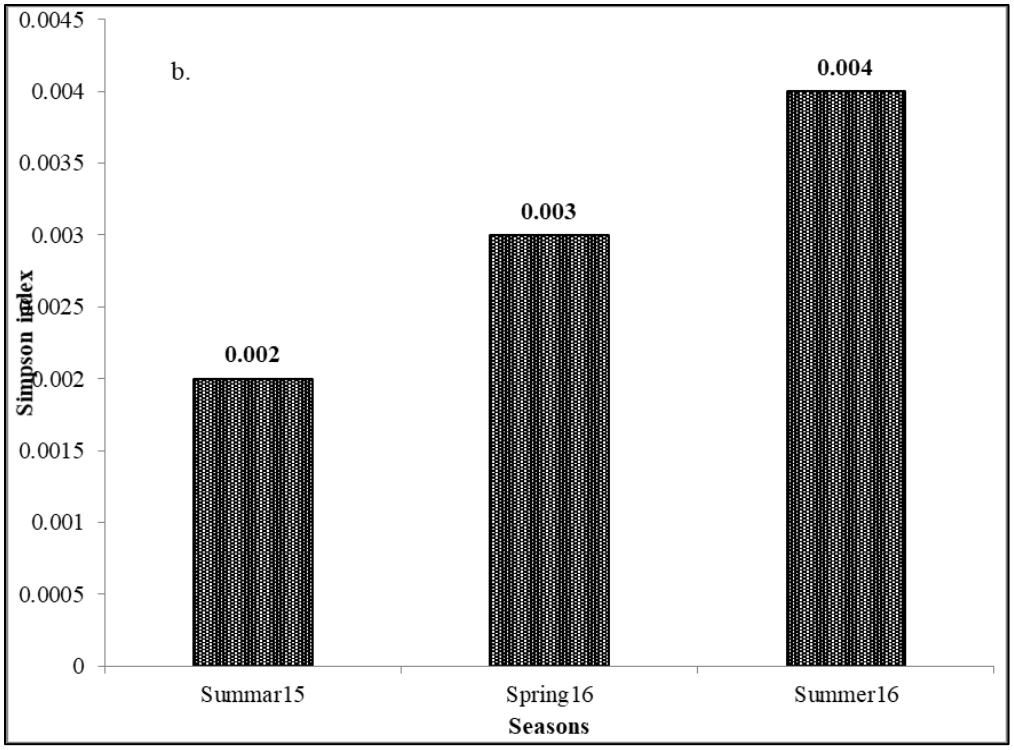


Figure 6. Seasonal diversity Index of bee flora. a. Shannon index b. Simpson index

Life-forms

Herbs were the most dominant life form among all bee flora. Each of them got a short life cycle and went flowering with the start of rainfall and the study was carried out in the spring season and summer seasons. In which most insects and birds go into reproduction, and for pollination and dispersal of seed these plants went into blooming. Another reason was, the area was man-made the gardening was done to grow different types of ornamental plants, these ornamental flowers were mostly herbs.

This study found 36 species as the major bee flora on the basis of pollen and nectar contains. There were 42 species classified as the medium bee flora and 60 species were classified as minor bee flora (Figure 5). This result resembled the previous work done by Adhikari *et. al.*, (2011). The result obtained indicated that if a plant species is a major source of nectar, it is likely that the same plant species would also be a major source of pollen. Thus obtained result was comparable with the previous one (Adhikari *et. al.,* 2011). Horticultural and Ornamental species were more important as sources of nectar and pollens than other categories. The previous study also showed that *Eucalyptus camaldulensis* Dehnh.and *Bidens* species were very important as bee forage species for honeybees and the main source of pollen and nectar (Gebre, 2009).

Correlation coefficient

The Pearson's correlation coefficient matrix among variables showed somewhat mixed results (Figure 7). Species score of summer15, spring16 and summer16 showed statistical significant relation with NMDS1 and NMDS2 sample scores. NMDS1 was directly ascribed here as the moisture gradient. Likewise, NMDS2 ascribed as variables such as flora types, their life-forms etc. Thus NMDS1 in the NMDS space represented the abundance score of bee flora respective to seasons. There was significant negative correlation coefficient between NMDS1 and summer15 which was -0.84. It explained that with the increase in NMDS1 score there will be decrease of the abundance of summer15 loving bee flora which

were favoring late summer rain favoring species (Figure 7). This trend was found significantly opposite for the summer16 bee flora (0.65). Distance of each bee flora away from the beehive as well as contribution of each flora for pollen, nectar or both did not show significant relations

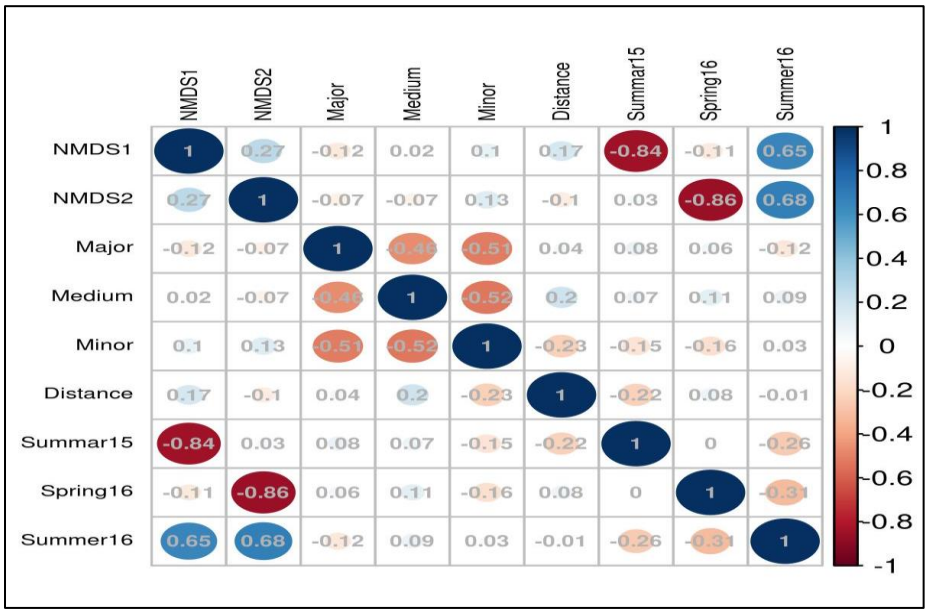


Figure 7. Correlation coefficient matrix among variable. Each value within circle represented correlation coefficient value. Gradient of colors represented significant level

Bee flora species composition pattern

Bee flora composition pattern available at different seasons as analyzed through the NMDS showed significant relationship among species (Figure 8). Seasons showed the most significant latent environmental variable for species composition patter

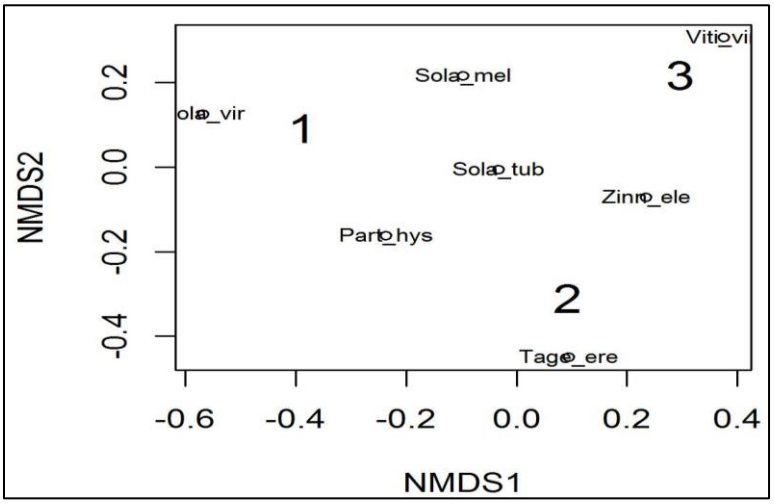


Figure 8. Nonmetric Multidimensional Scaling (NMDS) analysis of seasons by species dataset. The full form of major and dominant species appeared in the figure were Sola_vir: *Solanum virginianum;* Viti_vi: *Vitis vinifera*; Part_hys: *Parthenium hysterophorus*, Sola_tub: *Solanum tuberosum*, Zinn_ele: *Zinnia elegans*, Sola_mel: *Solanum melongena*, Tage_ere: *Tagetes erecta*. Numbers 1, 2 and 3 represented seasons: Summer15, Spring16 and Summer16 respectively.

Maximum abundance of *Solanum virginianum* (Sola_vir) towards higher NMDS2 axis but very less NMDS1 explained summer15 loving bee flora of NARC, Khumaltar area (Figure 8). Likewise, a maximum abundance of *Vitis vinifera* L., towards the maximum positive end of NMDS1 (Figure 8) would have explained significantly by high moisture loving species of summer16. Relatively higher abundance of species such as *Parthenium hysterophorus* (Part_hys), *Solanum tuberosum* (Sola_tub), *Zinnia elegans* (Zinn_ele), *Solanum melongena* (Sola_mel), etc. (Figure 8) nearly at the middle of the NMDS space may support by moderate moisture which was spring16.Therefore, the plantation of horticultural and ornamental species seemed to be more effective than not plantation for beekeeping. Plantation of seasonal herbaceous bee flora showed strong and significant correlation. Distance of each bee flora how far away from the hive did not much matter as contribution of each bee flora in nectar or pollen loads.

Most pollinators were mainly insects and birds. Spring was their reproductive season. So with the start of the rain, these plants went on flowering to complete their life cycle. This result was matched with our study in case of the major plant species. Among major plant species *Pyrus communis* Morog., *Brassica* spp., *Berberis* spp., *Rubus* spp., were identified as extremely important bee flora in previous study (Bista *et al*., 2000/2001). Some of the medium and minor plant species in terms of pollen and nectar blossomed for longer periods (5-6 months or more) were *Chromolaena corymbosa* (Aubl.) R. M. King & H. Rob., and *Oxalis corniculata* L. considered as important floral species. Some ornamental plants *Euphorbia pulcherrima* Willd. ex Klotzsch, *Malvaviscus arboreus* Dill. ex Cav., *Salvia splendens* Sellow ex Nees, and *Tagetes erecta* L., though recorded from some areas, blossomed also for a longer period. Honeybees found utilized these species during colony development and dearth periods. Likewise, plant species *Melaleuca citrina* (Curtis) Dum. Cours. and *Grevillea robusta* A. Cunn. ex R. Br. were found in a few numbers but these plants were referred to as good nectar and pollen source for honeybees. These results matched with the work done before by Bista *et al*., (2000/2001).

Record of horticultural trees species such as *Citrus* spp, *Prunus domestica* Thunb., *Prunus persica* (L.) Batsch, *Pyrus communis* Morog., *Phyllanthus emblica* L., *Choerospondias axillaris (Roxb.) B.L.Burtt & A.W.Hill*, *Musa paradisiaca* L., *Diospyros virginiana* L., *Syzygium* spp. and *Psidium guajava* L. to make sustainable foraging for honey bee (Partap, 1992) was similar to this study too.

Conclusion

In the NARC area, a total of 168 bee flora recorded. They belonged to 64 families out of which 10 were horticultural crops, 30 were vegetable, 86 were ornamental, 32 were wild plants and 10 were naturalized plant species. *Brassica rapa* L., *Melaleuca citrina (Curtis)* Dum. Cours., *Cuphea micrantha* Kunth, *Grevillea robusta* A. Cunn. ex R.Br. Cunningh, *Helianthus agrestis* Pollard, *Helichrysum bracteatum* (Vent.) Haw., *Trifolium repens* L. were the seven top very important bee foraging species for honeybees and main source of pollen and nectar. Though there is a difference in bee flora species diversity and dominancy in different seasons, the main diver of bee flora in this study was found to be moisture of season. Hence mixed farming and cultivation of different ornamental flowers according to the season was a good source of bee foraging, with more diversified species of important bee flora and relatively less in the cultivation of cash crops.

Most of the important bee flora were found bloomed from April to August and this peak period of honeybee foraging activity with strong colony strength as well as the peak time of honey harvest. Shortage of bee forage during the dry season, from January to March due to

which the colony strength was very weak (Shivakoti *et al.*, 2011).

Based on the study and available flora, the NARC area can be considered as suitable to initiate beekeeping. However, attention must be given in maintaining the existing bee flora and the multiplication of multipurpose plant species in order to make it sustainable. In addition, attention must be paid by providing artificial food supply during the rainy and winter months.

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Appendix 1

a. Measuring distance of bee flora from the beehive

b. Monitoring bees contribution to the beehive