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***Research Article***

# FORAGING VARIATION OF *Bombus* SPECIES WITH PLANT FAMILIES AND FLORAL COLORS IN CHITWAN ANNAPURNA LANDSCAPE, NEPAL

**Kishor Chandra Ghimire, Anjeela Pandey, Ganesh Datt Joshi, Daya Ram Bhusal***
*Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal*
**Correspondence: daya.bhusal@cdz.tu.edu.np*
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## Abstract

Little is known about the effect of the type of vegetation and floral color on the foraging behavior of *Bombus* species. In this work, we have investigated the differential foraging association of bumblebees (*Bombus* spp.) with the specific flower color and the plant families in Chitwan-Annapurna Landscape (CHAL). The specimens were collected between April to October 2019 and field visits were carried out by following accessible walking transects between 600 to 3500 m asl covering different habitats of the study area. The bumblebees were collected by opportunistic methods using a sweeping net. We found that the relative frequency of *Bombus* spp. varied significantly with the families of local flowering plants and the particular colors of flowers. Some of the bumblebees visited at the specific plant family for nectar and pollen indicating the specific association with particular flower morphology and color. This study, therefore, gives an insight into the differential foraging preference of *Bombus* spp. to certain plant families with selected specific colors in CHAL.

**Keywords:** *Bombus* spp., CHAL, foraging, floral color, plant families, pollinators

## INTRODUCTION

The impacts of multilevel spatial structure on pollination services have been addressed globally. And the global decline in bumblebee species is often linked with the loss or alteration of vegetation composition (Williams & Osborne, 2009). However, the foraging association of bumblebees with vegetation types, floral color, and structures within the specific plant family has been poorly explored. It is usually suggested that the flower choice behavior of bee communities for floral colors in particular plant families is influenced by their innate preferences and life experiences (Gumbert, 2000). However, there is a long debate on how *Bombus* species select a specific floral color and how they preferentially visit plants with selected floral traits (Lunau & Maier, 1995; Gumbert, 2000; Junker *et al.*, 2013). They possess innate preferences for the recognized patterns of flowers, such as shape (Zeil, 1997) and flower symmetry (Giurfa *et al.*, 1996). Bumblebees have trichromatic color vision with photoreceptors, maximally sensitive at about 350, 440, and 540 nm (Backhaus, 1991; Peitsch *et al.*, 1992), and spontaneously use floral guides of natural flowers (Lunau, 1992; Lunau *et al.*, 2006) of a specific color.

The floral structure and the floral scent are also described as important factors for the foraging attraction of many species of bumblebees (Odell *et al.*, 1999). The bumblebees are also attracted to inflorescences, a plant–level attractant, based on the number of pollen-producing flowers (Thairu & Brunet, 2015). Bumblebees have varying tongue lengths depending on the species, which amongst other factors, determine their preferences for certain specific plants (Fussell & Corbet, 1991). Hence, tongue length is believed to be an important factor in niche separation in bumblebee communities (Hoelzel *et al.*, 1989). The species with a long tongue can easily reach the stigma of the flower with a long corolla, while the short tongue bites the corolla and makes its way to stigma (Goulson & Williams, 2001).

Recently, it has been suggested that the color preferences by the key bee pollinators are one of the vital factors that tend to exhibit weak phylogenetic signals for facilitating the coexistence of related species, especially on a tropical–subtropical island (Tai *et al.*, 2020) in the plant-pollinator interaction (Ibanez *et al.*, 2016). Many authors have claimed the main color preference of bumblebees is a generalization and not absolute (Raine & Chittka, 2008; Brunet *et al.*, 2015), although, bumblebee strongly prefers flowers with blue-purple colors (Raine *et al.*, 2006; Rausher, 2008; Dyer *et al.*, 2012). In other cases, many Bumblebee species prefer pink flowers of *Impatiens sulcate* (Balsaminaceae) over yellow-colored flowers of *Impatiens scabrida* (Balsaminaceae) when both of these plants are growing side by side (Saini *et al.*, 2011). Several studies have also confirmed that some specific plants, for example, the legumes (Fabaceae), are in particular immensely selected by long-tongued bumblebees (Goulson *et al.*, 2015; Hülsmann *et al.*, 2015) whereas the most bumblebees visiting plant families in this other parts of the urban ecosystem of Nepal Himalaya were: Cucurbitaceae, Fabaceae, and Verbenaceae (Bhusal *et al.,* 2019). In general, perennial plants are the major food resources for bumblebees (Fussell & Corbet, 1992; Dramstad & Fry, 1995; Leonhardt & Bluthgen, 2012); and bumblebees forage those plants that have noticed higher protein content (Leonhardt & Bluthgen, 2012; Somme *et al.*, 2014; Vaudo *et al.*, 2016) than the least visited plants species (Goulson *et al*., 2015). In the conservation issue of bumblebees under climate change scenario, it is urgent to identify the priority host plant for the foraging resources of Himalayan bumblebees is highly needed. Further, it is important to identify, how the preferred plant species diversity and composition are influential factors for determining the bumblebee abundance and diversity in different habitats in the Himalayan landscapes. This study aims to establish whether there exists any foraging preference between the flower color and particular plant families visited by the bumblebees in the Chitwan Annapurna landscape.

## MATERIALS AND METHODS

### Study area

This study (Fig. 1) was carried out along an altitudinal gradient (from 500 to 3500 m asl) in three river valleys of the Chitwan-Annapurna Landscape (CHAL), following Kaligandaki (west site), Marsyangdi (mid site), and Budhigandaki (east site) in central Nepal. These sites host diverse habitat types (agriculture, forest, grassland, and human settlements). The study area is rich in biodiversity and includes the Annapurna conservation area which is an important transit route for bird migration, as well as for many endangered species including the snow leopard, red panda, and the Himalayan black bear (Oli *et al*., 1994; Chetri *et al*., 2019). This area is particularly facing many threats under current climate change, and experiencing the rapid invasion of some notorious invasive plants (Bhusal, 2020; Sharma *et al*., 2020; Shrestha & Shrestha, 2021) that might be affecting the pollination process and native floral composition.

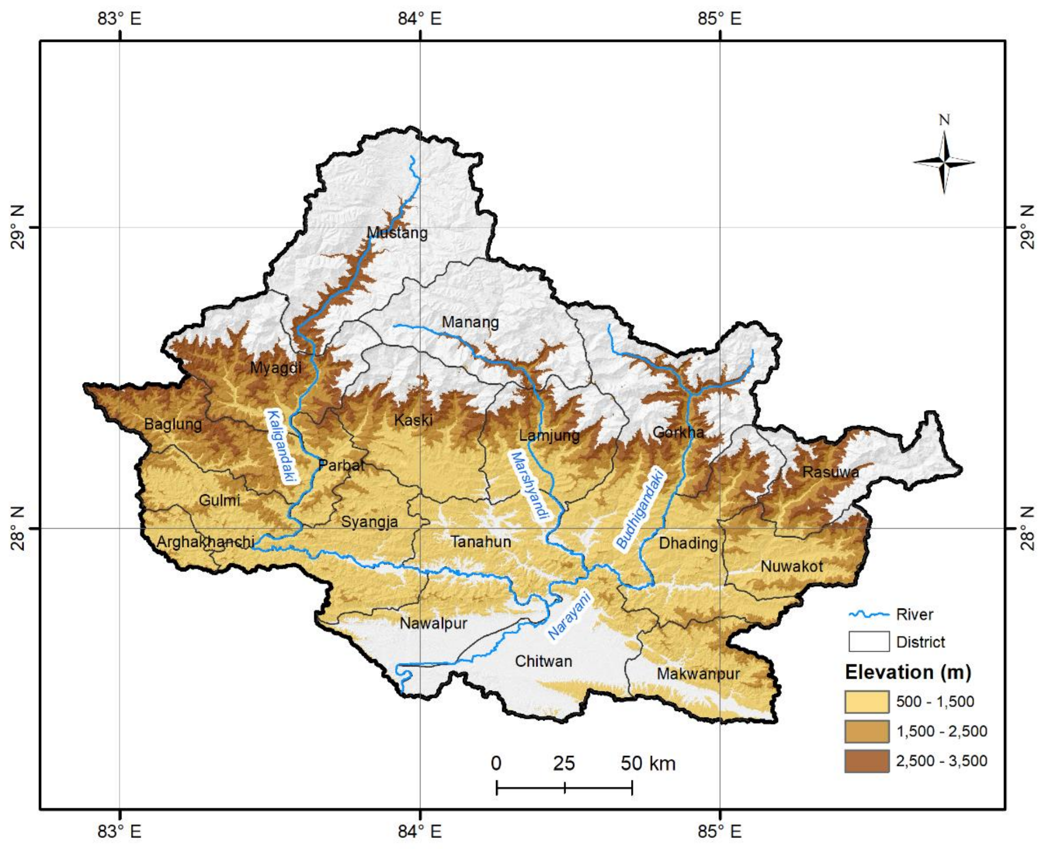


**Figure 1. Map of study area showing walking transects( Kaligandaki, Mashyandi and Budhigandaki region)**

### Bumblebee surveying and identification

Field surveys were conducted throughout the entire flowering season between April and November 2019. We followed three accessible walking routes (transects) along with the river valley sites (Kaligandaki, Marsyangdi, and Budhigandaki) of the study area. Extensive surveys were conducted along the three walking transects from 500 to 3500 m asl. Whenever a foraging bumblebee was detected at a particular point along the walking route, we observed around the flowering plants present there and the bumblebees on the site were collected and recorded their number. The survey was carried out between 9 am and 6 pm (especially morning and afternoon time) when rain was absent and the wind speed was low. *Bombus* spp. were captured using an entomological net, and were immediately killed by using ethyl acetate. During the survey, the habitat type (Agriculture, human settlement, grassland, and forest), altitude, and GPS locations of the collection points were recorded. Specimens were stored in airtight containers with a few layers of tissue paper and the addition of a few drops of ethyl alcohol to prevent the growth of mold during transportation. Specimens were subsequently dry–mounted using standard insect pins and deposited in the Entomological Museum of the Central Department of Zoology, Tribhuvan University, Kathmandu. We collected 600 individual workers, and the collected specimens were observed under a stereoscopic microscope and identified using published identification keys for adjacent regions (Hanley *et al*., 2008; Williams *et al.,* 2010; An *et al*., 2014; Saini *et al*., 2015).

**Data Analysis**

We performed the cross-tabulation (two–way contingency) to find out the relative frequency of bumblebees with foraging plant families and corresponding floral colors. The Chi-square ($\chi^2$) level of significance (<0.05) was observed for each contingency table. Similarly, we analyzed the effect of bumblebee number with families of foraging plants by performing a linear mix effective model (lmm) in **lme4** package in R. The cluster analysis (CA) and corresponding analysis (CA) were also performed to explore how closely the *Bombus* species were associated the particular plant families and the color of their flowers.

## RESULTS

### Foraging association of bumblebees and plant families

The relative frequency of bumblebees and their foraging plant families was cross-tabulated from the samples we got ($\chi^2$ = 579.68, df = 448, p-value < 0.001). Some *Bombus* species were recorded only from the single plant families (Table 1). The bumblebee species, *Bombus branickii* was recorded from the Rosaceae family's plants. The *Bombus miniatus* and *B. haemorrhoidalis* were recorded only from the single plant family Polygonaceae. Likewise, *B. novus* was recorded only in the family Ranunculaceae whereas, *B. pressus* were found to be associated mainly with plants Rosaceae. In our study sites. Moreover, *B. flavescens* was recorded from only two plant families, viz. Asteraceae and Lamiaceae. In the same way, *B. cornutus* was recorded from three plant families such as Ranunculaceae, Oleaceae, and Gesneriaceae. Likewise, *B. parthenius* was recorded from Balsaminaceae, Lamiaceae, and Oleaceae; *B. lepidus* were noted from four plant families (Oleaceae, Ranunculaceae, Fabaceae, and Rosaceae); and *B. turneri* from four plant families (Ranunculaceae, Solanaceae, Fabaceae, and Rosaceae). *Bombus grahami* was recorded wider plant species representing from five plant families as Gesneriaceae, Ericaceae, Papaveraceae, Lamiaceae, and Ranunculaceae. Similarly, the *B. tunicatus* was recorded from six plant families: Asteraceae, Oleaceae, Ranunculaceae, Solanaceae, Lamiaceae, and Verbenaceae. *Bombus asiaticus* and *B. rotundiceps* were recorded from a large number of plant families such as Ophiopogon, Cactaceae, Solanaceae, Oleaceae, Fabaceae, Balsaminaceae, Rosaceae, and Asteraceae. On the other hand, the *B. asiaticus* has commonly exhibited foraging association with Ranunculaceae, Solanaceae, Fabaceae, Rosaceae, Oleaceae, Asteraceae, Cucurbitaceae, and Balsaminaceae. *Bombus breviceps* was recorded from nine plant families: Convolvulaceae, Lythraceae, Oleaceae, Fabaceae, Balsaminaceae, Rosaceae, Asteraceae, Lamiaceae, and Cucurbitaceae. In the same way, *B. festivus* was found most commonly representing plant species from eleven families such as Cannabaceae, Ericaceae, Malvaceae, Liliaceae, Polygonaceae, Ranunculaceae, Solanaceae, Oleaceae, Fabaceae, Rosaceae, and Asteraceae. *Bombus eximus* was recorded from 14 plant families: Acanthaceae, Gesneriaceae, Laureceae, Veronicaceae, Viburnaceae, Lamiaceae, Ranunculaceae, Oleaceae, Fabaceae, Balsaminaceae, Cucurbitaceae, Rosaceae, and Asteraceae. However, *B. haemorrhoidalis* was recorded from nineteen plants families of Acanthaceae, Apocynaceae, Cannabaceae, Compositae, Genenculeceae, Iridaceae, Malvaceae, Polygonaceae, Verbenaceae, Convolvulaceae, Lythraceae, Lamiaceae, Solanaceae, Oleaceae, Fabaceae, Balsaminaceae, Cucurbitaceae, Rosaceae, and Asteraceae. In our study, most foraging families by *Bombus* species were Rosaceae, Oleaceae, Ranunculaceae, Fabaceae, and Asteraceae; and the least foraging plant families were Apocynaceae, Cactaceae, Cannabaceae, Iridaceae, Lauraceae, Liliaceae, Ophiopogon, Papaveraceae, Verbenaceae, and Viburnaceae.

The plant families were classified in cluster analysis (Fig. 2) based on the relative abundance of *Bombus* species ($\chi^2$= 579.68, df=448, p < 0.001). A total of 29 families of foraging plants were clustered.

### Relative foraging association of bumblebees with plant families and colors

In our cluster analysis, some plant families and bumblebees exhibited relatively lower foraging associations. These plant families were Polygonaceae, Cannaceae, Liliaceae, Gesneriaceae, Ericaceae, Papaveraceae, Iridaceae, Apocynaceae, Compositae, Cactaceae Ophiopogon, Viburnaceae, Veronicaceae, Acanthaceae, Cannabaceae, Lauraceae. Similarly, twelve plant families in the sampling sites were recorded with a higher number of foraging associations with the identified bumblebee species. These were Asteraceae, Cucurbitaceae, Solanaceae, Balsaminaceae, Rosaceae, Fabaceae, Oleaceae, Ranunculaceae, Malvaceae, Verbeceae, Lythraceae, and Convulvulaceae.

**Table 1. Presence - absence status of *Bombu*s species with their foraging plant family. *Bombus* species: *Bombus asiaticus(asi), Bombus branickii (bra), Bombus breviceps(bre), Bombus cornutus(cor), Bombus eximius(exi),, Bombus festivus(fes), Bombus graham(gra), Bombus haemorrhoidalis(hae), Bombus Lepidus(lep), Bombus miniatus(min), Bombus novus(nov), Bombus parthenius(par), Bombus pressus(pre), Bombus rotundiceps(rot), Bombus tunicatus(tun), Bombus turneri(tur)***

| Families | asi | bra | bre | cor | exi | fes | fla | gra | hae | lep | min | nov | par | pre | rot | tun | tur |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fabaceae | + | – | + | – | + | + | – | – | + | + | – | – | – | – | + | – | + |
| Acanthaceae | – | – | – | – | + | – | – | – | + | – | – | – | – | – | – | – | – |
| Apocynaceae | – | – | – | – | – | – | – | – | + | – | – | – | – | – | – | – | – |
| Asteraceae | + | – | + | – | + | + | + | – | + | – | – | – | – | – | + | + | – |
| Balsaminaceae | + | – | + | – | + | – | – | – | + | – | – | – | + | – | + | – | – |
| Cactaceae | – | – | – | – | – | – | – | – | – | – | – | – | – | – | + | – | – |
| Cannabaceae | – | – | – | – | – | + | – | – | + | – | – | – | – | – | – | – | – |
| Cannaceae | – | – | – | – | + | – | – | – | – | – | – | – | – | – | – | – | – |
| Compositae | – | – | – | – | – | – | – | – | + | – | – | – | – | – | – | – | – |
| Convolvulaceae | – | – | + | – | – | – | – | – | + | – | – | – | – | – | – | – | – |
| Cucurbitaceae | + | – | + | – | + | – | – | – | + | – | – | – | – | – | – | – | – |
| Ericaceae | – | – | – | – | – | + | – | + | – | – | – | – | – | – | – | – | – |
| Gesneriaceae | – | – | – | + | + | – | – | + | + | – | – | – | – | – | – | – | – |
| Iridaceae | – | – | – | – | – | – | – | – | + | – | – | – | – | – | – | – | – |
| Lamiaceae | – | – | + | – | + | – | + | + | + | – | – | – | + | – | – | + | – |
| Lauraceae | – | – | – | – | + | – | – | – | – | – | – | – | – | – | – | – | – |
| Liliaceae | – | – | – | – | – | + | – | – | – | – | – | – | – | – | – | – | – |
| Lythraceae | – | – | + | – | – | – | – | – | + | – | – | – | – | – | – | – | – |
| Malvaceae | – | – | – | – | – | + | – | – | + | – | – | – | – | – | – | – | – |
| Oleaceae | + | – | + | + | + | + | – | – | + | + | – | – | + | – | + | + | – |
| Ophiopogon | – | – | – | – | – | – | – | – | – | – | – | – | – | – | + | – | – |
| Papaveraceae | – | – | – | – | – | – | – | + | – | – | – | – | – | – | – | – | – |
| Polygonaceae | – | – | – | – | – | + | – | – | + | – | + | – | – | – | – | – | – |
| Ranunculaceae | + | – | – | + | + | + | – | + | – | + | – | + | – | – | – | + | + |
| Rosaceae | + | + | + | – | + | + | – | – | + | + | – | – | – | + | + | – | + |
| Solanaceae | + | – | – | – | – | + | – | – | + | – | – | – | – | – | + | + | + |
| Verbenaceae | – | – | – | – | – | – | – | – | + | – | – | – | – | – | – | – | – |
| Veronicaceae | – | – | – | – | + | – | – | – | – | – | – | – | – | – | – | + | – |
| Viburnaceae | – | – | – | – | + | – | – | – | – | – | – | – | – | – | – | – | – |

### Relative foraging preference of bumblebees with floral colors

We recorded the particular color where bumblebees mostly prefer to visit. In the cluster diagram, we found that most of the bumblebee species preferred white, yellow, and purple color flowers (Fig. 3). Whereas, orange, red, blue, and pink colors were relatively less visited by the *Bombus* species in our field records. Furthermore, we performed a corresponding analysis (Fig. 4) to find out the relationship between the *Bombus* species and the floral color preference. The relative frequency of *Bombus* species was cross-tabulated ($\chi^2 = 97.24112$, $p<0.05$), between the floral colors and the relative visiting frequency of *Bombus* species. There indicated, 12 species of bumblebees mostly prefer to visit white-colored flowers. However, *Bombus cornutus*, *B. eximus*, and *B. haemorrhoidalis* were preferring the yellow flowers. While, *B. grahami* preferred mostly the red–colored flowers, *B. breviceps* foraged highly on the purple flowers. Similarly, blue and orange were seen as less-visited flowers by many species of identified bumblebees.

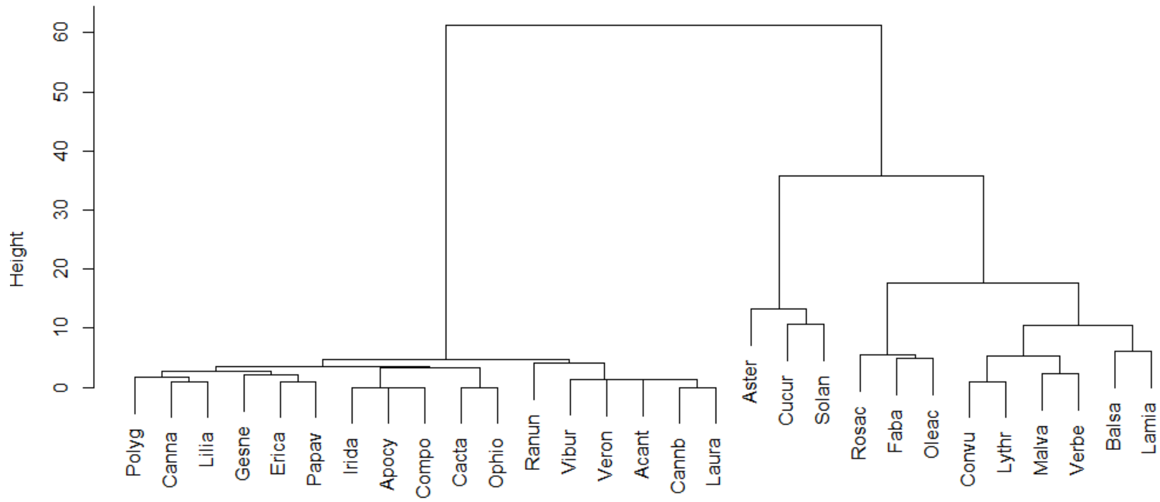


**Figure 2. Cluster analysis (method= ward, distance = Euclidean) of plant families based on the relative abundance of *Bombus* species. Plant families are: *Fabaceae (Faba), Acanthaceae (Acant), Apocynaceae (Apocy), Asteraceae (Aster), Balsaminaceae, Cactaceae (Cacta), Cannabaceae (Cannb),, Cannaceae (Canna), Compositae (Compo), Convulvulaceae (Convu), Cucurbitaceae (Cucur), Ericaceae (Erica), Gesneriaceae (Gesne), Iridaceae (irida),, Lamiaceae (Lamia), Lauraceae (Laura), Liliaceae (Lilla), Lythraceae (Lythr), Malvaceae (Malva), Oleaceae (Oleac), Ophiopogon (Ophio), Papaveraceae (Papav), Polygonaceae (polyg), Ranunculaceae (Ranun), Rosaceae (Rosac), Solanaceae (Solan), Verbenceae (Verbe), Veronicaceae (Veron), Viburnaceae (Vibur).***

**Table 2. Foraging relation (linear mixed model) of *Bombus* species and with colours and plant families**

| Fixed factors (Colour and Plant families) | Estimate | Std.Error | t value |
|---|---|---|---|
| (Intercept) | 10.1192 | 1.72251 | 5.875 |
| Orange colour | –2.97649 | 4.09755 | –0.726 |
| Pink colour | –4.21245 | 2.39768 | –1.757 |
| Purple colour | 0.01049 | 1.7703 | 0.006 |
| Red colour | –2.22082 | 2.22836 | –0.997 |
| White colour | –1.43949 | 1.66404 | –0.865 |
| Yellow yolour | –1.03265 | 1.76356 | –0.586 |
| Acanthaceae | –8.48302 | 3.34983 | –2.532 |
| Apocynaceae | –5.6876 | 4.41702 | –1.288 |
| Asteraceae | –4.39638 | 1.28474 | –3.422 |
| Balsaminaceae | –4.44065 | 1.68987 | –2.628 |
| Cactaceae | –3.6876 | 4.41702 | –0.835 |
| cannabaceae | –4.0067 | 3.58663 | –1.117 |
| Cannaceae | –7.78532 | 4.32607 | –1.8 |
| Compositae | –7.28077 | 4.32833 | –1.682 |
| Convulvulaceae | –4.43046 | 1.95781 | –2.263 |
| Cucurbitaceae | –3.11777 | 1.68974 | –1.845 |
| Ericaceae | –3.03304 | 3.14858 | –0.963 |
| Gesneriaceae | –7.36038 | 2.54733 | –2.889 |
| Iridaceae | –6.69487 | 4.43195 | –1.511 |
| Lamiaceae | –4.93624 | 1.83437 | –2.691 |
| Lauraceae | –7.77157 | 4.42314 | –1.757 |
| Liliaceae | –6.81471 | 4.48232 | –1.52 |
| Lythraceae | 0.32098 | 2.43447 | 0.132 |

| | | | |
|---|---|---|---|
| Malvaceae | –4.75103 | 2.55619 | –1.859 |
| Oleaceae | –2.04918 | 1.67733 | –1.222 |
| Ophiopogon | –7.28077 | 4.32833 | –1.682 |
| Papaveraceae | –0.19215 | 4.42324 | –0.043 |
| Polygonaceae | –0.81138 | 2.36456 | –0.343 |
| Ranunculaceae | –3.79444 | 1.77825 | –2.134 |
| Rosaceae | –2.58771 | 1.50101 | –1.724 |
| Solanaceae | –2.3222 | 1.36507 | –1.701 |
| Verbenceae | 1.20654 | 2.21716 | 0.544 |
| Veronicaceae | –7.78803 | 3.18993 | –2.441 |
| Viburnaceae | –7.53304 | 3.14858 | –2.393 |

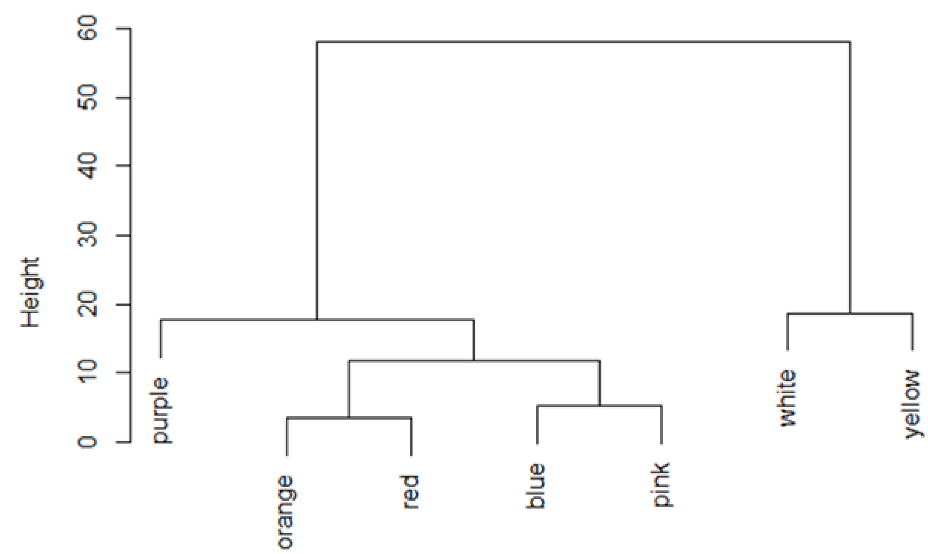


**Figure 3. Clustering of flower colors based on the relative frequency of bumblebees**

## DISCUSSION

Our results indicated that the flower morphology and color of a particular plant family is an important factor to determine the foraging association of Bombus species. Some previous studies have also suggested that family-level variation was distinct in many *Bombus* species especially, family Fabaceae and Verbenaceae which were important plants family visited by a wider number of Bombus species (Westphal *et al*., 2003; Hanley *et al*., 2008). In our study, the most foraging plant families were Rosaceae, Oleaceae, Ranunculaceae, Fabaceae, and Asteraceae whereas, the least foraging plant families were Apocynaceae, Cactaceae, Cannabaceae, Iridaceae, Lauraceae, Liliaceae, Ophiopogon, Papaveraceae, Verbenaceae, and Viburnaceae. Among these, the family Rosacea was highly visited by bumblebee species in many parts of the world (Somme *et al*., 2014). The differential visiting preference by bumblebees is generally conceded with the flower scent, which is an important long-distance signal for native bees (Heinrich *et al*., 1977; Dötter *et al*., 2005). Probably, the floral traits and resources are the determining factors that alter the species foraging selection and community dynamics of bumblebees (Potts *et al*., 2010). Many authors have suggested the effect of morphological characters of flowers and bees, such as corolla length and proboscis on the rate of flower visitation by bumblebees, where short-tongued bees foraged faster on short–corolla flowers than the long-tongued bees. Many studies have suggested the availability of floral resources for frequent visitation of the bumblebee to some plant families such as Oleaceae that alters the foraging preference of bee communities (Bäckman & Tiainea, 2002; Pywell *et al*., 2005). As suggested, it is probably related to the flower structures and the resources rewarded. The floral structures, such as symmetrical and asymmetrical flowers are also important for the nectar production that affect the foraging selection by many insect pollinators (Møller, 1995; Goulson *et al.*, 2015; Reininghaus, 2017). A recent study has suggested that the temperature differences across the floral surface, which may be due to floral architecture constraints within the plant families, might be the important factor for the foraging preference of bumblebee species (Rands & Harrap, 2021). On the other hand, the phonological period of many plant species and colonial peaks are majorly important (Reininghaus, 2017) for the foraging association of bumblebees and plants types. Seasonal and spatial variation in the composition of floral resources may pose challenges for bumblebees' foraging selection in this mosaic landscape. Plant species within habitats at different times lead to temporal turnover in the floral assemblage, which itself may vary spatially that might affect foraging discrimination in plant and bumblebees (Simanonok & Burkle, 2014). However, there is a long debate regarding the native and non-native plant and bumblebees foraging association in different parts of the world (Giurfa *et al.*, 1996; Raine & Chittka, 2007; Schiestl & Johnson, 2013). Probably the bee individuals can exhibit the higher and more general visiting behavior in native plant families rather than the non-native plant species.

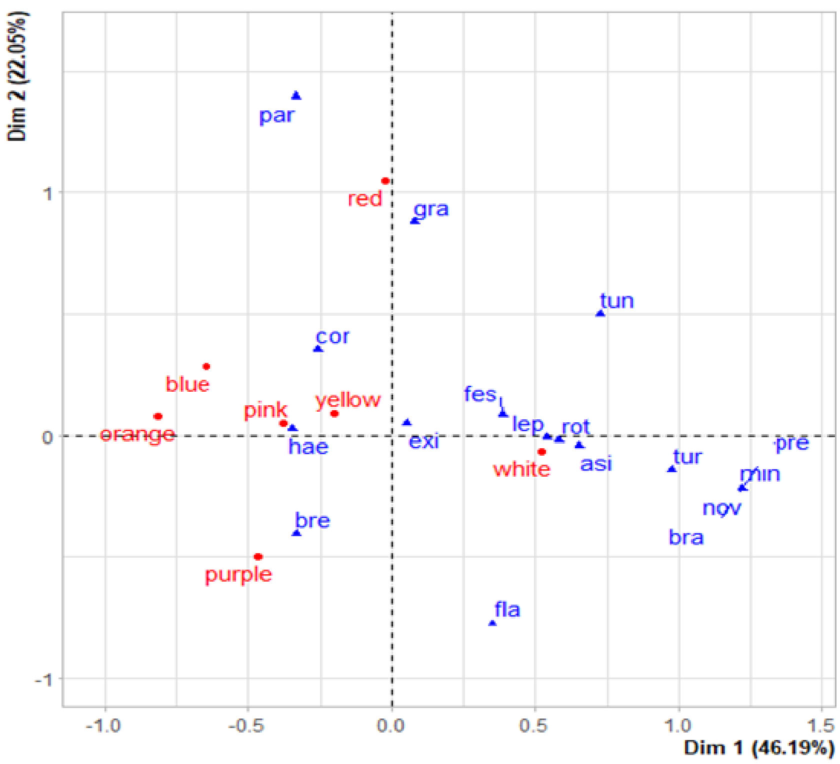


**Figure 4. Corresponding Analysis based on the relative frequency of *Bombus* species and flower color. The Bombus species are: *Bombus asiaticus(asi), Bombus branickii(bra), Bombus breviceps(bre), Bombus cornutus(cor), Bombus eximius(exi),, Bombus festivus(fes), Bombus graham(gra), Bombus haemorrhoidalis(hae), Bombus Lepidus(lep), Bombus miniatus(min), Bombus novus(nov), Bombus parthenius(par), Bombus pressus(pre), Bombus rotundiceps(rot), Bombus tunicatus(tun), Bombus turneri(tur)***

On the other hand, flower color is often one of the main traits that majorly determine the foraging association of bee communities including the bumblebees (Raine & Chittka, 2007; Schiestl & Johnson, 2013). Colors appear to be particularly important to bumblebees for flower recognition (Menzel & Shmida, 1993; Spaethe *et al.*, 2001; Dyer & Chittka, 2004). In this study, the higher foraging intensity was towards the white and yellow-colored flowers by the bumblebees, indicating that they prefer more saturated colors over the less saturated ones (Rohde *et al.*, 2013), and those of high purity (Lunau *et al.*, 1996). Additionally, the bees' communities have a trichromatic color vision in the UV light (Spaethe *et al.*, 2001; Dyer & Chittka, 2004; Hempel *et al.*, 2014) that might be responsive to white and yellow flowers because these flowers are melittophilous and regularly absorb UV light (Kevan *et al.*, 1996).

## CONCLUSIONS

The effects of plant families and the color of flowers are important explanatory factors for the foraging association of bumblebees with particular plant families in the study area. The structures of flowers and resources rewarded by different plant families and associated specific colors of the flowers are vital in determining the foraging preference by *Bombus* species. This study indicated the differential foraging association by *Bombus* species to the plant families across the landscape scale. This is important to identify the priority-based plant families in local and across landscape scales for the foraging preference by bumblebee species and can be implemented in conservation programs. In the future, the experimental approach is needed along the altitudinal gradients to extract a more conclusive idea regarding the foraging choice of *Bombus* species to the particular plant families species.

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**AUTHOR CONTRIBUTIONS**
KCG contributed for data collection, taxonomic work, data analysis and manuscript writing. AP contributed to the fieldwork and taxonomic work for bumblebees. GDJ contributed for the plant identification and data analysis. DRB performed data analysis and manuscript writing and visualization.

**CONFLICT OF INTEREST**
There is no conflict of interest between the authors in this publication.

**DATA AVAILABILITY STATEMENT**
The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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