Review of literature
The application of the scientific methods to the entities and events of the universe is a progressive and accumulative activity. New information modifies, clarifies and supplements the old. Old information serves as an ever increasing foundation of the new. One wonders how much subtle information that has developed as a result of professional experience is stored in the memory of bank of the science, i.e. literature.

A thorough and scrupulous browsing of literature concerning the genus *Bombus* manifests that studies on this group started right in the beginning of 18th century. At national level the work on bumblebees was initiated by Linnaeus, 1758. In the fauna of British India (1897) only 23 species of this genus were put on record. These species were mainly contributed by Lepeletier, 1832 (1 sp.), Smith, 1852a, 1861, 1873, 1879 (16), Gribodo, 1882 (3) and Bingham, 1897 (3).

Prior to Bingham, all earlier works were systematically compiled by Dalla Torre (1896) in the catalogue of Hymenoptera. However, after the compilation of fauna of British India, volume of work continued on this aspect and at present 48 species are on record from the Indian faunistic limits. These species are contributed by Linnaeus, 1758, 1761 (2); Fabricius, 1781 (1); Lepeletier, 1836 (1); Smith, 1852a, 1861, 1879 (11), Morawitz, 1875, 1883, 1886, 1887, 1890 (6), Radoszkowski, 1893 (2), Bingham, 1897(1), Friese, 1909, 1916, 1918 (4), Cockerell, 1910 (1), Skorikov, 1912, 1914a (6), Vogt, 1911 (1), Popov, 1927a, 1931 (2), Richards, 1928a, 1929a, 1934 (4), Frison, 1933, 1935 (4) and Tkalcu, 1968a (2).

With the immense economic importance of these anthophilous insects and their association with entomophilous flowering plants, their species
diversity and altitudinal distribution has already been well studied in the advanced countries. Some important works include: Smith, 1852a, 1854, 1861, 1878a, 1879; Bingham, 1897; Friese, 1905, 1909, 1913, 1916, 1918, 1924, 1931; Skorikov, 1910a, 1912, 1914a, 1914b, 1933a, 1938a; Richards, 1928a, 1929b, 1930, 1931, 1934; Frison, 1933, 1935, Cury, 1984; Morse, 1982; Williams, 1989, 1991; Abrol, 1991; Williams and Cameron, 1993; Rasmont, 1995; Buchmann and Nabhan, 1996; Westrech, 1996; Kumar and Lall, 1998, 1999; Abak et al., 2000; Walter-Hellwig and Frankl, 2000, Kevan and Philips, 2001; Mand et al., 2002; Kumar and Chandel, 2002; Tscharntke et al., 2002; Pywell et al., 2004; Sepp et al., 2004; Quaranta et al., 2004; Goulson et al., 2005; Semida and Elbanna, 2006; Turnock et al., 2006; Sabir et al., 2008, 2011; Burger et al., 2009; Ahmad et al., 2009; Williams, et al., 2009, 2010. They not only enlisted these insects, but provided comprehensive account on their associations with the host plants.

Whatever work on these insects is documented, has been carried out mainly by foreign workers who either took the study material from various Indian museums or collected it at the time of British Rule. When viewed in totality, it becomes very clear that the present state of taxonomic studies on this economically important insect group is far from complete.

Earlier, bumblebee studies from Kashmir Himalaya are based merely on a couple of hundred specimens. The first important collection of bumblebees from Kashmir was made by Lt. Col. C.G. Nurse in 1901. A complete inventory of this material was never published, although it provided the specimens that have since been described as the types of many nominal taxa (Friese, 1909, 1918; Richards, 1928a, 1930; Tkalcu, 1974a). Other important collections were carried by A. Jacobson in
Kashmir and Ladakh during 1912 (Skorikov, 1914a) and by Col. R. Meinertzhagen in Ladakh during 1925 (Richards, 1928b). Skorikov (1933a) compiled a preliminary list of the fauna of Kashmir and discussed the fauna of the entire Himalaya, though his work was based on different concept of the species than what it is presently. The only recent revision of some part of the large Himalayan fauna has been conducted by Tkalcu (1974a, 1989), and included description of 73 bumblebees from Nepal. Although there are many elements in common between the faunas of Nepal and Kashmir, 16 species that are known from Kashmir are not represented in this collection. Recently he has described several new taxa from the region. In addition to his outstanding contribution in the field of taxonomy, Skorikov (1922) also studied the general biology of bees, their morphological features, genitalic characters and DNA analysis. The only key that has been intended to cover any part of the Himalayan fauna is that published by Bingham (1897). The only commendable job on the bumblebees from Kashmir Himalaya is done by Williams (1991), where he reported 29 species of bumblebees including some from Pakistan occupied Kashmir.

The earlier records show that genus *Bombus* was represented by 26 species from Kashmir Himalaya and 47 species from India as a whole (Williams, 1991, 1998). Bingham (1897) compiled 23 species in the Fauna of British India that included some records from the neighboring countries such as Myanmar, Bhutan, Nepal etc. Though after this work, 149 species got associated with this list, raising the total to 172, but due to lot of synonymy as put forth by Williams (1998) only 47 species have been declared as valid. The reason being most of the species were
erected merely on the basis of unstable morphological features and some differences in colour pattern. It is only recently that another species has been inducted into this list thus raising the total to 48 (Table 1).

Various workers have contributed 108 species of bumblebees from the Oriental region, the main works include that of Linnaeus, 1758, 1761 (2); Fabricius, 1775, 1793 (3); Schrank, 1802 (1); Illigier, 1806 (1); Dahlbom, 1832 (1); Lepeletier, 1832, 1836 (2); Seidl, 1837 (1); Nylander, 1848 (2); Eversmann, 1852 (1); Smith, 1852a 1852b, 1854, 1861, 1869, 1871, 1878, 1879 (19); Morawitz, 1875, 1880, 1881, 1883, 1886, 1887, 1890 (11); Radoszkowski, 1859, 1860, 1877, 1888, 1893 (5); Dalla Torre, 1890(1) Gribodo, 1892 (1); Bingham, 1897 (1); Perez, 1905 (1); Friese, 1905, 1909, 1916, 1918, 1931 (6); Schulz, 1906 (1); Vogt, 1908, 1911 (2); Skorikov, 1910a, 1910b, 1912, 1914a, 1914b, 1915, 1922, 1923, 1933a, 1933b, 1938 (16); Cockerell, 1910 (1); Sparre Schneider, 1918 (1); Richards, 1928a, 1928b, 1929a, 1929b, 1934, 1968 (5); Popov, 1927a, 1931 (2); Frison, 1933, 1934, 1935 (8); Yasumatsu, 1934 (1); Bischoff, 1936 (1); Reinig, 1940 (1); Chiu, 1948 (1); Pittioni, 1949 (1); Tkalcu, 1968a, 1968b, 1989 (7); Wang, 1979(1).

There are over 250 different species of bumblebees that can be found right across the world. Williams et al. (2008) proposed a simplified subgeneric classification of genus Bombus and reduced the number of subgenera from 38 to 15 using new strongly supported estimate of phylogeny for almost all bumblebee species (Table 2). They have recognized 10 new subgeneric synonyms as well. The table 3 makes, the situation all the more clear.

There is no dearth of studies carried out on the pollinating activity, colony size, nest structure, and foraging behaviour of these bees.
Tremendous work on bumblebee and their role in pollination of various crops, orchards and wild flowers has been carried. They accentuated the urgency of this work as the massive induction of high technology in the high altitude ecosystem was threatening to cause the impoverishment of biodiversity.

Bumblebees are increasingly used in glass house cultivation, where a honeybee hive would be too large, e.g. cabbage, kiwi fruit and tomatoes pollination in Holland (Free & Butler, 1959). So bumblebees are of great economic importance, and with the increase of glass house cultivation, and the spread of mite, *Varroa jacobsoni* causing a decline in honey bee population, their importance has increased many fold. A decrease in the honeybee population would probably lead to an increase in the population of short tongued bumblebees, as happened in Colorado recently (Plowright & Laverty, 1984).

In general, adequate pollination requires an approximate match between the size and shape of the flower and that of the pollinator. For some plants, honeybees are ineffective at pollen transfer (Westerkamp, 1991 and Wilson and Thomson, 1991). Thus, for example, on cranberry (*Vaccinium* spp.), alfalfa (*Medicago sativa*) and delicious apples (*Pyrus malus*), honeybees gather nectar while making little or no contact with the reproductive structures, and thus are poor pollinators (Gray, 1925; Roberts and Struckmeyer, 1942; Farrar and Bain, 1946; McGregor, 1976; Robinson, 1979). Similarly, bumblebees have been demonstrated to be better pollinators than honeybees for watermelon (*Citrullus lanatus*), cucumber (*Cucumis sativus*) (Stanghellini *et al.*, 1997, 1998) and for apples (Thomson and Goodell, 2001). Bumblebees are hairier than honeybees, which may contribute to their efficacy in transferring more pollen; for example when visiting raspberry flowers, bumblebees deposited significantly more
pollen on the stigmas than did honeybees (Willmer et al., 1994). In Europe and North America, bumblebees are among the most important wild pollinators of crops (Corbet, 1987; Plowright and Laverty, 1987; Corbet et al., 1991). At least 25 major crops grown within the European countries are visited and pollinated by bumblebees, including field beans, red clover, alfalfa, oilseed rape and various hard and soft fruits (Corbet et al., 1991). There are almost certainly more crops that benefit from bumblebee pollination, but as noted earlier, the pollination requirements of most crops have not been investigated.

A broad variety of crops depend on insect pollinators. Some, such as alfalfa (Medicago sativa) and clovers (Trifolium spp.), set no seed unless they are cross pollinated. Crops such as oil seed rape (Brassica napus), brown mustard (Brassica juncea) and tomato (Lycopersicon esculentum) are capable of self pollination, but insect visits are needed to move pollens from the anthers to the stigma. In oilseed rape, adequate pollination further benefits the grower by ensuring an early and uniform ripening of seeds; otherwise, seed ripening is staggered and some seeds are shed before harvest (Williams et al., 1987). Morandin et al., (2001) studied the effect of bumblebee pollination on the quality and yield of green house tomatoes. Some crops, notably sunflower (Helianthus annuus), are partially self fertile, but produce better quality seed when cross pollinated. Even fully self fertile crops can benefit from cross-pollination through improved quality of the offspring; for example, field beans (Vicia faba) will set seeds in the absence of pollinators, but the offspring produced will themselves set few or no seed without insect visitors (Stoddard and Bond, 1987). In fruits such as strawberry (Fragariax ananassa), melon (Cucumis melo) and kiwi fruit (Actinidia deliciosa), fruit size is related to the number of seeds produced (and hence to the number of ovules fertilized).
Adequate pollination ensures maximum fruit size. Thus, for example, in glasshouse conditions, providing captive *B. terrestris* colonies doubles the number of marketable fruit produced by strawberries (Dimou *et al.*, 2008). In Europe, a region better studied than most, about 250 plant species are grown as crops. Of these, about 150 are thought to be insect pollinated, but for most we do not know which insects pollinate them, or whether yields are being limited by inadequate pollination (Williams, 1995; Corbet *et al.*, 1991). The current drive to diversify arable production is leading to the introduction of yet more crops, many of which require insect pollination (*Lupinus* spp.), yet whether we have sufficient appropriate insects to pollinate them is unknown. It is exceedingly hard to estimate the total value of bee pollination (Gill, 1991), but various estimates have been produced and all agree that the economic contribution made by bees is vast. The most recent estimates for the United States suggest a value of US $14.6 billion for honeybees alone (Morse and Calderone, 2000; Levin, 1983; Robinson *et al.*, 1989; Southwick and Southwick, 1992; Ghazoul, 2005). Gill (1991) estimated the value to be US $103 million for Australia, while Winston and Scott (1984) put the value for Canada at US $1 billion. A comparable estimate for the EC suggests that insect pollination was worth US $6.6 billion in 1989, of which US $5.5 billion was ascribed to honeybees (Borneck and Merle, 1989). More than a third of all human food is thought to depend on insect pollination (McGregor, 1976). The honeybee, *Apis mellifera*, is overwhelmingly the most widely managed pollinator of crops, and many farmers are entirely unaware that there are other insects that are capable of pollination. The economic value of pollination is often credited entirely to honeybees (Parker *et al.*, 1987), and is often used to justify public subsidizing of honeybee keeping. Even the scientific literature is frequently blinkered in this
respect (Richards, 1993; Batra, 1995). For example, honeybees were promoted for pollination of alfalfa up until the 1980s even though Henslow noted in 1867 that honeybees were incapable of tripping the flowers (Olmstead and Wooten, 1987; Robinson et al., 1989; Batra, 1995). In 1909, it was discovered that other species of bee, notably those belonging to the Megachilidae, did trip the mechanism and provide efficient pollination (Brand and Westgate, 1909), but through a combination of inertia and poor advice to farmers it was not until the 1970s that use of Megachilidae for alfalfa pollination became widespread. There is now growing appreciation that there are alternatives to the honeybee and that in some situations the alternatives may be better (Westerkamp, 1991).

Honeybees do have a number of advantages as pollinators: they form vast colonies that can pollinate large areas of crops; there is a substantial body of expertise in the management of these colonies; and they provide honey. However, they also have disadvantages. First, honeybees are fair weather foragers (Willmer et al., 1994). In cold conditions, and when it is raining, they will not forage. In an unpredictable climate such as that of the United Kingdom this can be important, particularly when growing crops such as apples that flower early in the year when a spell of poor weather is likely. Second, honeybees are not able to adequately pollinate some crops. They have short tongues, and so are not keen to visit crops with deep flowers such as red clover (Trifolium pratense). In some plants, such as Solanaceae (which includes tomatoes and potatoes) the pollen is presented in poricidal anthers. These are essentially similar to an inverted salt cellar; to obtain the pollen an insect has to shake the anthers (buzz pollination). Honeybees are not able to do this, and thus cannot efficiently pollinate these crops (Rick, 1950). Finally, reliance on a single species for pollination of crops is an inherently risky strategy. This has
been made all too clear during the recent epidemic of the mite *Varroa destructor*, which all but exterminated wild honeybees through vast parts of their range, and causes substantial loss of managed hives. Most recently, in North America ‘Colony Collapse Disorder’ a somewhat mysterious phenomenon probably attributable to viral diseases, has devastated commercial hives and threatens yields of bee pollinated crops such as almonds. In contrast, bumblebees are hardy and will forage in very cold conditions and even when it is raining (Corbet *et al.*, 1993). Tomano and Sota (1997) worked on the life history and pollination ecology of bumblebees in alpine zone of Central Japan. In North America, bumblebee queens have been seen foraging when the air temperature was below freezing, while in the Scandinavian summer they will forage for 24 hrs each day. Because of their greater cold tolerance, bumble bees begin foraging earlier in the day than honeybees; for example on curcubit crops, *B. impatiens* begin foraging 15–40 min before honeybees (Stanghellini *et al.*, 2002). Under the same conditions, bumblebees tend to forage faster than honeybees, and so pollinate more lowers per bee (Poulsen, 1973; Free, 1993; Stanghellini *et al.*, 2002; Fuchs and Muller, 2004). Thus they provide a reliable pollination service despite the vagaries of the weather. Because different bumblebee species differ in their tongue lengths, between them they can pollinate a range of crops. For example, short tongued bumblebee such as *B. terrestris* is important pollinator of oilseed rape, particularly in poor weather when honeybees are inactive (Delbrassinne and Rasmont, 1988). Species with medium or long tongues (*B. pascuorum* or *B. hortorum*) are needed to pollinate crops with deep flowers such as field beans and red clover (Fussell and Corbet, 1991). Bumblebees are capable of buzz pollination, and make excellent pollinators of Solanaceae such as tomatoes (Van den Eijnde *et al.*, 1991). The
anthers of these flowers only release pollen when vibrated, which bumblebees achieve by placing their thorax close to the anthers and contracting their flight muscles at a frequency of about 400 Hz (King, 1993). Members of the Ericaceae such as cranberries and blueberries (*Vaccinium* spp.), and also kiwi fruit (*A. deliciosa*) benefit from buzz pollination (Buchmann, 1985), and so are more effectively pollinated by bumblebees than by honeybees (Kevan and Gadawski, 1984; Mohr and Kevan, 1987; Cane and Payne, 1988; Mac Kenzie, 1994). *B. ruderatus* is pollinating field beans and is one of many long tongued species that have declined in recent years, threatening the pollination service for deep flowered crops. Sianturi *et al.* (1995) did an outstanding work on behavioural ecology. They studied the nest structure, colony composition and foraging activity of tropical mountain bumblebees. This is not the end; a lot of work is still going on concerning various other aspects of these anthophilous insects. In fact the advanced countries realized the role of these conservators of vegetation biodiversity quite earlier.

Regarding ecological and behavioural studies there is hardly any work on Indian bumblebees. In spite of the fact that bumblebee diversity can be exploited for the purpose of pollination of various crops, green house farming, floriculture, fruit trees, various vegetables and medicinal plants, no body made any effort in this direction. In the present work some observations have been taken with regard to their food preference, foraging range, colony size, visiting timings and ecological distribution patterns of some dominant bumblebee species prevalent in various areas of Kashmir Himalayan belt. Similarly the role of high altitude region has also been evaluated and a separate list of plants and their bumblebee pollinators has also been provided.