THE DIVERSITY AND FAUNISTICS OF BUMBLEBEES FOR POLLINATION IN GREENHOUSES

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SUMMARY

Bumblebees are the most effective pollinators especially in the greenhouses in comparison to other insects including honeybees. Their advantages over other insects are well known. There are different species and subspecies of bumblebees adapted to different ecological conditions. The most common bumblebee species that has been domesticated and used for the pollination of vegetable crops is *Bombus terrestris*. There are several subspecies and ecotypes of *B. terrestris* such as *B.t. terrestris*, *B.t. dalmatinus*, *B.t. sassaricus, B. t. canariensis, B.t. lucitanicus, B. t. audax, B. t. xanthopus, B. t. africanus*. Besides *B. terrestris*, western bumblebees such as *B. occidentalis* and *B. impatients* in the USA, *B. hypocrita* and B. *ignitus* in Japan have been domesticated and used for the pollination purposes.

There are several criteria for selecting a candidate bumblebee species for large-scale production. As being wide spread, being polilectic, isolated to the lower elevations, having strong colonies, and suitable for domestication *B. terrestris* is the best candidate for commercial breeding in many countries in Europe. Moreover other pollen storer species have also potential for breeding and they can even be better pollinators than *B. terrestris* at higher altitudes.

Bumblebee pollination increase the greenhouse crop yield significantly compared to hand pollination or hormone applications in unheated greenhouses in winter seasons. They have food preference in the greenhouses and visit the plant varieties which produce more and high quality pollen. They also have floral preference in the nature and conservation of nature will maintain the biological diversity, disturbance will cause the extinction of some plant and bumblebee species.

INTRODUCTION

Insects play a vital role in the pollination of many plants including some of our most important cultivated horticultural crops. The most common pollinators being used in the greenhouses are the bumblebees (*Bombus* sp) and honeybees (*Apis* sp). In general insects other than bees usually visit only specific crops, only at specific times, and play a minor role in pollination. However bees are dependent upon nectar and pollen for the survival of the colonies and therefore visit numerous flowers as long as they have pollen and/or nectar. The value of honeybees is also limited in the greenhouses especially during the cold seasons or winter months. They do not forage at air temperatures below 15 °C, and at low light intensities. Moreover, greenhouses are frequently treated with insecticides and there is practically no insect activity especially during the winter and early spring seasons. Therefore, there are serious problems in pollination of tomatoes, peppers and eggplants in greenhouse conditions. The growers either use hand pollination or growth regulators (2-4D, 4-CPA and βNOA) extensively for the parthenocarpic fruit set. Using these hormones are increasing labor and the production costs, and impairing the growth of the plants due to herbicidal effect. Moreover it reduces the quality of the crops, and overdoses of these chemicals cause accumulation in the crops and may be harmful to human health.

R. de Jonghe demonstrated in 1987 that bumblebees can be used in the greenhouses for the pollination of tomatoes. This was the revolution for the greenhouse culture. Then bumblebee breeding techniques were developed (Röseler, 1985; Heemert et al, 1990; Eijnde et al, 1991), several breeding companies were established and growers started using bumblebee colonies as pollinators of tomatoes, peppers, eggplants and strawberries in greenhouses in many countries such as The Netherlands, Belgium, France and Israel since 1988 (Ravestijn and Sande, 1991; Banda and Paxton, 1991; Abak et al, 1996; Griffiths and Roberts, 1996). The application of bumblebees for pollination of these crops has led to higher quality classes and increased in revenue for the farmer. As a result there was a great interest to breed bumblebees and to find the best species or subspecies for the pollination of cultivated crops in the greenhouses.

DIVERSITY OF BUMBLEBEES FOR COMMERCIAL BREEDING

There are over 300 species of bumblebees. They live on the northern temperate and subtropical regions extending through Europe, Asia and North America. They are particularly abundant in the high altitudes and cooler parts of the world (Alford, 1975; Sladen, 1912; Prys-Jones and

Corbet, 1987). There are 48 species in Turkey (Kaftanoglu, 1999), 25 species in England (Prys-Jones and Corbet, 1987), 78 species in America including Canada and South America (Milliron, 1971, 1973a, 1973b) 46 species in North America (Stephen et al, 1969; Heinrich, 1979), 27 species in California (Thorp et al, 1983), and over hundred species in Asia. Bumblebees are absent in the deserts and tropical areas. However they have been introduced to different countries for the pollination of field crops or vegetable crops (Hopkins, 1914; Iwasaki, 1995, Dafni and Shmida, 1996).

The most common bumblebee species that has been domesticated and used for the pollination of vegetable crops in Europe, Japan, Australia and Israel is *Bombus terrestris*. There are several subspecies and ecotypes of *B. terrestris* such as *B.t. terrestris*, *B.t. dalmatinus*, *B.t. sassaricus, B. t. canariensis, B.t. lucitanicus, B. t. audax, B. t. xanthopus, B. t. africanus*. Among these subspecies *B.t. terrestris*, *B.t. dalmatinus* and *B. t. canariensis* have been reared by the commercial companies in Europe. Besides *B. terrestris*, western bumblebees such as *B. occidentalis* in Western USA, *B. impatients* in Central and Eastern USA, and Asian bumblebees such as *B. hypocrita* and *B. ignitus* in Japan (Asada and Ono, 1996) have been domesticated and used for the pollination purposes. There are also attempts to domesticate different species especially the long tongued bumblebees such as *Bombus hortorum, Bombus ruderatus* and *Bombus subterraneaus* (Griffin, et al., 1991).

Bombiculture is a rather new technology. There are still some problems in breeding, nutrition of the colonies and disease control. Thousands of colonies are shipped to different countries. Different species or subspecies have been introduced to different ecological regions. Introduction of different species causes the hybridization of native species and subspecies as observed in Japan. Moreover some diseases and parasites may well be transported to different countries. Introduced species may be established as feral colonies as seen in New Zealand and Israel. They may also threaten the local bee fauna especially if the food source is limited and there is competition for food.

BIODIVERSITY OF BUMBLEBEES IN TURKEY

After the development of year-round breeding system and demonstration of using bumblebees in greenhouses there was a huge demand for bumblebee colonies in Europe. However the bumblebee rearing techniques were not sophisticated at that time and thousands of *B. terrestris* queens were collected by the bumblebee breeding companies in countries around the Mediterranean. Turkey was among these countries. Villagers collected bumblebee queens and destroyed thousands of natural nests between 1988 and 1993. Due to heavy destruction of the natural nests, the bumblebee populations greatly declined in the Aegean Region, which affected the agricultural production and wild life in the region (Özbek, 1992 and 1995). Then a NATO SfS Programme project (TU-Pollination) was initiated to study diversity and faunistics of bumblebees, to provide scientific background for the successful introduction of bumblebees in Turkish agriculture and to initiate bumblebee breeding (Kaftanoglu, 1994).

Bumblebees were collected in Cukurova Region, Central Anatolia, North Eastern Anatolia and the Black Sea Coast during the summer of 1995 and 1996. A total of 48 bumblebee species was identified in Turkey and their altitude frequency is summarized in Table 1. The abundance and distribution of bumblebees in the Taurus Mountains were studied. There are 4 altitude levels distinguished for the Bombinae such as low altitude plain level (1-500 m), the hill level (500-1500 m), the mountain level (1500-2500 m) and the Alpine level (over 2500 m). *Bombus terrestris* was the most common species especially at the lower altitudes. It represented about 75 % of the bumblebee specimens below 500 m. elevations in the Taurus mountains. The distribution of *B. terrestris* decreased rapidly at high elevations and disappeared at the mountainous and Alpine elevations (Rasmont and Flagothier, 1996).

Since *B. terrestris* lives in low altitudes there is not much competition for food with other species except Bombus *muscoru,* the breeding and propogation of *B. terrestris* in large numbers does not seem to limit the food resources for the other species.

The floral preference of bumblebees was also studied in the Taurus mountains. *Bombus armeniacus*, *Bombus argillaceus*, *Bombus niveatus* and *Bombus terrestris*, forage on 15-24 different plant species and they seem to be polylectic species. On the other hand *Bombus vorticosus*, *Bombus apollineus*, *Bombus humilis* and *Bombus subterraneus* visit only one or two plant species and they seem to be oligolectic species. Polilectic species were more abundant then the oligolectic species.

There are several criteria for selecting a candidate bumblebee species for large-scale production. First of all the candidate species must be wide spread, must be polilectic, must be suitable for breeding in captivity, must produce large colonies (workers), and survive at low altitudes where most of the greenhouses are located.

As being wide spread, isolated to the lower elevations, being polilectic *B. terrestris* is the best candidate for commercial breeding. *B. niveatus, B. argillaseus, B. cryptarum* and *B. armeniacus* have also potential for breeding. They can even be better pollinators than *B. terrestris* at high altitudes but more difficult to rear them at low altitudes.

VARIATIONS AMONG BOMBUS TERRESTIS DALMATINUS *ECOTYPES*

There are some ecologically adapted populations or ecotypes within the same subspecies of bumblebees. The colony characteristics, performance of the colonies in the greenhouses, tolerance to diseases and parasites may differ among the ecotypes. All these parameters were studied to investigate the variations among the ecotypes of *Bombus terrestris dalmatinus*. Naturally hibernated bumblebee queens were collected from Bodrum (Mugla), Antalya, Alata (Mersin) and Adana provinces in November 1996 and 1997 to find the best candidate for commercial production. The queens were stimulated for colony initiation and all the colony characteristics were studied as described by Duchateau and Velthuis (1983).

There was not much variation in terms of colony initiation, number of egg cups in the 1^{st}, 2^{nd} and 3^{rd} brood, number of worker bees in the 1^{st}, 2^{nd} and 3^{rd} brood, developmental time, the competition point, the total number of worker and male bees among the populations however, the switch point of the Antalya colonies was significantly later than the Bodrum and Adana colonies. Antalya colonies also produced more queens than the Bodrum and Alata colonies (Yeninar, 1997; Yeninar et al., 1999). There was also a variation on the occurrence of bumblebee diseases and parasites among the ecotypes. The average *Nosema bombi* infection rates were 3.4 % in Antalya queens, 11.8 % in Mersin, 15.3 % in Adana and 17.5 % in Bodrum queens. Similarly *Locustacarus buchneri* infection rate was highest in the Bodrum queens compared to other ecotypes or locations (Eldeniz and Kaftanoglu, 1999). Whether the susceptibility of the Bodrum queens to diseases or parasites is genetic or environmental is not known and needs to be investigated.

FLIGHT ACTIVITIES OF B. TERRESTRIS DALMATINUS *IN THE GREENHOUSES*

Bees collect nectar and pollen from the flowers for the nourishment and store them in the nest for the immediate or future consumption. They have a fidelity to the flower, area and time. They usually visit the same plant species as long as they have rewards. Since the greenhouses are covered with glass or plastic there is no access to the outside, and there is usually only one plant species that the bees are forced to visit and pollinate. Therefore bumblebee activities in the greenhouses are very important for the success of pollination.

Bumblebees start foraging early in the morning (e.g. 7 am in January and at 6 p.m. in February and March) during the sunny days. The flight activity changes throughout the day in the greenhouses. The flight activity is highest between 8-11 am, and lowest between 12 to 2 p.m. The decrease in flight activity might be due to high temperature, shortage of nectar and/or pollen or greenhouse effect during the noontime. Foraging activities increase again after 2 p.m. and last until sunset (5 p.m. in January and February 6 p.m. in March).

The foraging activity or the number of foragers in cloudy days decreases about 50 % compared to the sunny days. The bees start foraging around 8 a.m. and continue until 6 p.m. In contrast to the sunny days, they are more active during the noon times (between 11am and 3 p.m.) Production or release of nectar and/or pollen by the plants determines the flight activity in the greenhouses.

Bumblebees are much better pollinators than honeybees or other insects for the pollination of many cultivated crops grown in greenhouses. The use of bumblebees in the greenhouses especially in winter months will increase the quality and quantity of the crops, lower the production cost compared to hand pollination and increase the revenue for the farmers. Breeding native bumblebees will not harm the diversity of other insects as long as there is not much competition between bumblebees and other insects especially during the winter months. The effectiveness of bumblebees can be increased further by the development of breeding techniques, disease control and proper management of the colonies in the greenhouses.

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***Table 1**. Altitude frequency of Bombinae inTurkey (Rasmont and Flagothier, 1996)*

	Number of specimens	Altitude min.-max. (m)	Average Altitude (m)	Altitude median (m)
rupestris rupestris	5	1400-1700	1540	1500
rupestris armeniacus	11	1500-3200	2129	2570
vestalis	8	900-1375	1197	1375
bohemicus	219	900-2570	1595	1550
campestris	24	775-1550	1401	1500
barbutellus	10	600-2200	1725	1850
maxillosus	48	900-2875	1507	1550
quadricolor rossicus	10	1850-2750	1992	1850
sylvestris	5	1240-1740	1544	1500
handlirschianus	292	1790-3000	2416	2470
shaposhnikovi	83	2000-3000	2277	2100
terrestris lucoformis	519	1-2200	885	1010
lucorum terrestriformis	754	230-2855	1513	1550
cryptarum	188	1770-3000	2259	2100
wurfleini wurfleini	140	1600-2570	2015	2000
pratorum pratorum	135	780-2000	1479	1500
pratorum skorikowi	98	320-2000	1683	1900
brodmannicus ssp.	62	1750-2880	2256	2300
haematurus	34	380-1700	1131	900
lapidarius lapidarius	381	775-2390	1421	1500
lapidarius caucasicus	38	1750-2570	2219	2300
sicheli cazurroi	106	2000-2570	2176	2000
alagesianus	158	2200-3000	2797	2855
incertus	1249	850-3000	1898	1870
oezbeki	45	1550-3000	2348	2340
erzurumensis	53	1930-3000	2731	2855
apollineus	174	1300-2855	1989	1950
vorticosus vorticosus	67	900-2250	1349	1400
niveatus niveatus	673	900-3500	1679	1680
sulfureus	9	1250-2325	2035	2200
soroeensis	640	775-2570	1613	1550
argillaceus	807	400-2855	1429	1440
hortorum	552	150-3500	1495	1600
portschinskyi	113	1400-3500	2221	2200
subterraneus	206	775-2855	2047	2070
melanurus	217	1750-3500	2466	2390
fragrans	151	1000-2325	1532	1500
pomorum pomorum	59	1300-2000	1689	1650
pomorum canus	143	1600-3500	2284	2200
mesomelas alboluteus	246	1660-3000	2169	2150
armeniacus	864	800-3000	1829	1800
brodmanni brodmanni	4	2070-2470	2270	2200
sylvarum citrinofasciatus	135	775-1950	1167	1000
sylvarum daghestanicus	767	850-2750	1863	1930
mlokosievitzi	206	850-3500	1770	1700
ruderarius ruderarius	15	775-2100	1748	1930
ruderarius simulatilis	234	1200-2650	1936	1930
velox	67	1750-2855	2384	2340
zonatus	414	150-1950	1349	1330
muscorum	10	300-1600	460	300
humilis quasimuscorum	15	1490-1675	1616	1660
humilis insipidus	85	1350-2500	1835	1850
humilis aurantiacus	38	800-1880	1196	1200
humilis nigrinus	191	600-2390	1409	1500
pascuorum	911	3-2300	1213	1240
persicus eversmanni	562	1200-3500	2072	2000
laesus laesus	160	1190-3500	1604	1200

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