DISCUSSION

Insect pollination of plants involves a co-evolutionary process that has been proceeding perhaps for 220 million years. Fossil records show that insects were already existing when the flowering plants first appeared. The development of self-incompatibility in the Angiosperms during the course of evolution led to the establishment of the close interaction between insects and plants: Entomophily. The variety of floral forms and colours around us are the outcome of this highly dependent relationship.

Scientists in some of the advanced countries of the world had long recognized the contribution of insect pollinators in conservation and maintenance of biodiversity and in sustainable plant production.

The foraging behaviour of insect pollinators was regarded as a highly useful system for study of plant-insect interactions. It was used as a model system in optimal foraging theory (Levin and Kerster, 1974; Pyke 1978; Dukas and Real, 1993) and in evaluating plant gene flow (Levin and Kerster, 1974; Schmitt, 1980; Rasmussen and Broedsgaard, 1992). Although the foraging strategies of pollinators were complex, it was proposed that pollinators, particularly bees followed nearest neighbour pollination rule (Levin and Kerster, 1974; Zimmerman, 1981; Rasmussen and Broedsgaard, 1992).

The insect visitors of a variety of crop plants have been studied and the role of individual species emphasized in some instances (Wilson, 1926,

It was, however, certain that bees (Apoidea) played a very important role as a group of insects biologically related to flowers, hence carrying the main weight of pollination. Urban development and contemporary agriculture, with practices like raising of concrete jungles, extensive monocultures, were leading to habitat destruction and loss of niche. Use of hazardous chemicals, introduction of exotic species, were further adding to the problem and there were quantitative falls in the populations of these useful insects (Sihag and Singh, 1999; Kumar, 2000; Kumar and Kumar, 2000; Verma et al., 2000; Partap and Partap, 2002).

horticultural ecosystem. Banaszak (1992) further emphasized the need to solve the many problems of contemporary farming and the necessity to carry out total analysis of ecosystem function with determination of the role of insect communities and fauna impoverishment.

According to Borges (1999), although evaluation of pollinator services for individual plant species required experiments that consisted of comparing fruit/seed set in the presence and absence of the pollinator, even a record of visitors to the flowers of different species could help at a preliminary level to determine pollinator importance. Identification of important pollinators or guilds of pollinators could then serve to prioritise conservation efforts.

Examination of the world literature on crop pollination and pollinator crop relations revealed that there were major short falls in current understandings. Much of the literature even for well-known crops was now outdated because new and improved cultivars that have not been adequately studied, dominated modern agriculture and horticulture. The principle of the most effective pollinator has become very central to discussions of plant pollinator relationships (Baker and Hurd, 1968). In India, the agro-forest pollinator scenario has undergone a major change after the introduction of exotic A. mellifera. There was an urgent need for reliable information with respect to monitoring, identification, systematics, pollinating efficiency and declining diversity of the pollinating species.

The chapter discusses some of these issues in the light of information generated during the present investigations.

POLLINATOR DIVERSITY

**Sunflower**: Popularly known as ‘Surajmukhi’, Sunflower is a familiar plant in India that was traditionally grown for its ornamental value. Presently, however, it has gained economic importance as an oil seed crop. The oil is used for culinary purposes, in the preparation of
vanaspati and in the manufacture of soaps and cosmetics. Seed yield and oil content have been shown to be influenced by insect pollination (Free, 1964; Langridge and Goodman, 1974; Palmer Jones and Forster, 1975; Parker, 1981; Arya et al., 1994b; Kumar et al., 1994a; Swaminathan and Bhardwaj, 1998). Hence, it was included in the present study.

Seven species of insects were observed visiting sunflower in bloom during the present investigations (Table 1). This is in sharp contrast to the situation in United States, the country of its origin where more than 100 species have been observed visiting the bloom (Parker, 1981).

Sunflower is a comparatively recent introduction in India and its pollinators in different regions have not been fully characterized (Arya et al., 1994a). The diversity and adaptability of insect pollinators varied under different agroclimatic conditions in this sub-continent. Swaminathan and Bhardwaj (1982) observed nine species of insects visiting sunflower heads in Rajasthan while twenty insect species were found visiting sunflower crop at Hisar (Arya et al., 1994a). According to Kumar et al. (1994a) six species of flower visitors were observed on sunflower heads at Latur (Maharashtra).

Native honey bees were relatively abundant on sunflower crop (A. cerana : 4.73 and A. dorsata : 2.00 bees/m²/5 min.) during the present study and a similar situation has been reported from other locations. Seetharam (1981) pointed out that insects were the only suitable agents that could bring about adequate pollination in Sunflower. According to him (Seetharam, 1981) honey bees were of particular importance though dipterans and bumble bees also played an important role. A. dorsata alone constituted more than 80% and A. florea, Trigona and Ceratina were other important species at Rajasthan (Swaminathan and Bhardwaj, 1982). Honey bees were predominant visitors (96.9%) to the floral heads of sunflower at Latur (Maharashtra), other insect pollinators comprising flies
and butterflies were present in very small (3.1%) proportion (Kumar et al., 1994a).

The pollen grains carrying capacity with respect to sunflower pollen was observed to be significantly high in case of A. cerana (97500.00) as compared to A. mellifera (34166.66), A. dorsata (28333.33) and other insects (Table 5) during the present studies. Free and Williams (1972) and Parker (1981) reported lower loads for A. mellifera being 9858 and 28814 respectively as compared to the other pollinators. According to Parker (1981) though Diadasia enuata carried about one million pollen grains, Melissodes bees were the most important pollinator because of their incessant activity around the flower heads.

Apis mellifera was observed to be the most efficient pollinator of sunflower heads in the present study. It showed significantly high foraging rate (2.13 flowers/min.) and ability to manipulate the flowers in the shortest duration of time (28.06 secs., Table 4). This is to be expected keeping in view its longer association and adaptation to the flower (Parker, 1981).

Arya et al. (1994a) and Kumar et al. (1994a) also observed that A. mellifera followed by A. dorsata was the most important pollinator of sunflower. It is interesting to note that A. dorsata was the predominant pollinator in the studies of Panchbhavi and Rao (1978) and Swaminathan and Bhardwaj (1982) which was due to non-availability of A. mellifera in that region.

**Okra**: Abelmoschus esculentus (L.) Moench, Okra (Bhindi) is grown throughout the tropical and warm temperate regions of the world for its fibrous pods full of seeds, which when picked young are eaten as vegetables.
Discussion

Results of investigations carried out on *Abelmoschus esculentus* showed that the crop was visited by ten species of insects. There are very few reports available on the pollination requirements and pollinators of Okra. The data available suggested that though the flowers were self fertile, there was improvement in seed and fruit set as a result of cross pollination by insects (Tanda, 1984, 1985; Mishra *et al.*, 1987; Njoya *et al.*, 2005).

According to Partap (1997) the crop was a good source of nectar and pollen and was benefited by both *A. cerana* and *A. mellifera*. Partap (1997) further observed that the large corolla of Okra attracted honeybees and other insects which facilitated the pollination of this crop.

A wasp, *Polistes hebraeus* was observed to be the most abundant pollinator during the present study (1.48/m²/5 min.) and *A. cerana* (1.00/m²/5 min.) was next in abundance. Dipteran flies, butterflies and a variety of hymenopterans including all the four species of honey bees were the other pollinators observed during the present study. Mishra *et al.* (1987) reported that ants constituted the most abundant (44.35%) pollinators on Okra followed by native honey bee *A. cerana* (21.56%). Beetles were also present in their study in addition to dipteran flies and hymenoptera. Sharma (2004) in his studies conducted in Himachal Pradesh, observed *Ceratina sexmaculatus*, *Megachile* sp., *Xylocopa* sp. and *Bombus* sp. to be foraging on Okra bloom. Njoya *et al.* (2005) have, however, reported that though *Xylocopa* visited Okra bloom, it did not contribute to pollination.

Significantly high foraging rates were exhibited by *A. cerana* (16.0 flowers/min.) and *Papilio demoleus* (15.73 flowers/min.) during the present study. However, *A. mellifera* carried more loose pollen grain on its body (74166.66) and proved to be the most efficient pollinator. Loose pollen grains were also abundant on the bodies of *A. dorsata* (14166.66)
Discussion

and A. cerana (9166.66). These species were therefore important for the pollination of Okra. Tanda (1985) emphasized the role of honeybees in pollination of Okra. Megachile sp. and Halictus sp. were rated as efficient pollinators by Njoya et al. (2005).

**Apple**: *Malus domestica* Borkh, is an important cash crop of India and is extensively grown in Himachal Pradesh, Jammu and Kashmir and Uttarakhand. Most apple cultivars are self incompatible and require cross pollination to produce good crop. Most pollination is brought about by insects because of the hairy and sticky nature of pollen that cannot be dispersed by wind.

Ten species of insects belonging to eight different families in four orders were observed during the present investigations. This is in close agreement with the report of Mishra et al. (1976) who recorded seven species and Singh and Mishra (1986) who observed nine species in apple orchards in Himachal Pradesh.

*A. cerana* was significantly more abundant in this study whereas *A. mellifera* was conspicuous by its absence because there were no maintained colonies of *A. mellifera* nearby. *A. cerana*, on the other hand, being indigenous was available in nature and was also kept in traditional wall hives by the rural people (Kumar and Kumar, 1997a; Kumar and Kumar, 2000). It maintained good numbers (Table 21) and was actively foraging throughout the day (8.0 to 10.2 flowers/min.).

Most surveys have shown that honey bees form a high percentage of insects visiting apple and constituted 60–87% of the total pollinator population in different studies (Menke, 1952; Smith, 1952; Free, 1966; Rai et al., 1988).

Predominance of *A. cerana* on apple bloom observed during the present study is supported by the studies of Sharma (1961) and Mishra et al. (1976) who recorded this bee to be the chief pollinator of apple in Himachal Pradesh.
This finding is also consistent with that of Kumar (1988) who reported that *A. cerana* constituted 33.80% of the total insect visitors on apple.

*Halictus* sp. and *Andrena* sp. were other important hymenopterans found to visit apple flowers during the present investigations.

Many other insects like bumble bees and solitary bees (Hooper, 1931; Menke, 1951; Singh and Mishra, 1986; Kanwar, 1987) and various dipterans e.g., Syrphidae, Calliphoridae, Bibionidae and Muscidae (Hutson, 1926; Brown, 1951; Lewis and Smith, 1969; Verma and Chauhan, 1985; Kumar and Kumar, 1997a) have previously been found in abundance on apple bloom.

Foraging speed and rate at which bees visit flowers depends on the amount of nectar and pollen present, foraging behaviour of the insects and climate conditions (Free, 1995). During the present investigations it was found that the foraging rate of *A. cerana* (9.26 flowers/min.) was significantly higher than the other species and it spent comparatively shorter time on the flower (5.53 secs.). Zander (1936) noted about 720 apple flowers visited by single honey bee per day.

Free (1955, 1970) and Free and Butler (1959) observed that although bumble bees were less in population but in comparison to honey bees they worked faster, for longer hours and under inclement weather conditions.

According to Verma and Rana (1994), *A. mellifera* visited significantly more apple flowers than *A. cerana* during a single foraging trip.

Higher loose pollen grains were carried by *Andrena* sp. (115833.33) as compared to *A. cerana* (56666.66) in the present study. Pollen gatherers of *Apis* spp. packed all the pollen sticking to their body into corbiculae. However, the amount of pollen in excess of the corbiculae load remained uncombed.
On the basis of pollinating index, *A. cerana* was the most efficient pollinator during the present study.

The present results were compared with those obtained during a similar study at Nauni, Solan (Kumar and Kumar, 1997a) where colonies of *A. mellifera* were being maintained for the last over ten years. While *A. cerana* was predominant in the present study with complete absence of *A. mellifera* the latter comprised about 15% of the total population of insect visitors at Solan (Kumar and Kumar, 1997a) with a concomitant decrease in the diversity of pollinators that declined to seven species. The influence of exotic introduction is thus highlighted.

**Litchi:** *Litchi chinensis* Sonn. is a medium sized, round topped, evergreen subtropical tree bearing pendent clusters of rosy pink fruits. The aromatic succulent flesh around the seed forms the relished edible part. India is now second largest producer of litchi being next only to China. The plant bears three types of flowers male, female and bisexual. The flowers require transfer of pollen by insects (Morton, 1987).

The Litchi fruit crop was studied at Pinjore garden near Chandigarh. The inflorescence was observed to be visited by nine species of insects.

Calliphorid and screw worm flies, soldier beetles, ants, wasps, honey bees, hover flies and other hymenopterans have previously been reported to visit litchi blossom (Dass and Chaudhry, 1958; Chaturvedi, 1965; Pandey and Yadava, 1970; Phadke and Naim, 1974; Morton, 1987).

The little honey bees *Apis florea* was the most abundant pollinator (6.26/m of branch/5 min.). Scelionid bee (3.93/m of branch/5 min.), *Episyrphus balteatus* (3.2/m of branch/5 min.) and *A. cerana* (1.53/m of branch/5 min.) were the other important visitors observed during the present investigations. *Pieris canidia* and *Coccinella septempunctata* were
infrequent visitors. Assessment of parameters related to role as pollinators revealed that *C. punctata* was merely a visitor and was not contributing to pollination (Table 30).

According to Pandey and Yadava (1970) the honey bees *A. dorsata, A. cerana, A. florea* and *Melipona* sp. constituted 98–99 percent of the total insect visitors but hoverflies, black ants, *Musca* sp. and *Vespa* sp. were also regular visitors of litchi flowers. *Apis cerana* and *A. florea* constituted about 18 and 60 percent of flower visitors to litchi in Bihar (Phadke and Naim, 1974) and 50 and 26 percent respectively in valley areas of Himachal Pradesh (Dhaliwal and Adlakha, 1977). This is in accordance with the present observations. Lower percentage of *A. florea* in comparison to *A. cerana* in the report of Dhaliwal and Adlakha (1977) is only to be expected in view of the fact that *A. florea* is a bee of the plains only (upto 300m a.m.s.l.).

A six week survey in Florida revealed 27 species of litchi flower visitors. *Apis mellifera* was the most abundant followed by the soldier beetle *Chauliognathus marginatus*. The rest were present only in insignificant numbers (Morton, 1987).

Morton (1987) has also reported that eleven species of bees, flies, wasps and other insects were recorded on litchi bloom in India. But honey bees, mostly *A. cerana indica, A. dorsata* and *A. florea*, constituted 78% of the litchi pollinating insects working on the flowers from sunrise to sundown.

Significantly higher number of foragers were present on litchi flowers during the early hours as compared to later in the day (Table 26). This is because nectar is secreted only in the morning which is highly attractive to bees. Anther dehiscence occurs between 0630 and 1200 hrs. Higher activity of insects during this period as also reported by Dass and
Chaudhry (1958) is a mutualistic adaptation benefiting both the partners of the ecosystem.

During the present study, it was further observed that *A. cerana*, *A. florea*, *A. dorsata*, *Episyrphus balteatus* and *Eristalis* sp. did not differ significantly from each other with respect to foraging rate. This was the only parameter for which a variety of insects had almost equal scores (Table 27). No reports on relative abundance and for detailed foraging behaviour of insect visitors on litchi are, however, available. The Scelionid bee carried largest number of free pollen grains (42500). The honey bees *A. mellifera*, *A. cerana* and *A. florea* were next in order with 16666.66, 13333.33 and 11666.66 pollen grains respectively. The pollen grain carrying capacity of litchi foragers is not previously reported. Honey bees as well as flies have been reported as good performers on litchi by Butcher (1957a,b). Badiyala and Garg (1990), Partap (1997), Sharma and Jindal (1997) have emphasized the importance of honey bees particularly *A. cerana* and *A. mellifera* in the pollinator complex of litchi. On the basis of pollination indices *A. florea* and *A. cerana* were rated the best performers on litchi flowers during the present study.

_Eucalyptus_ is an economically important agro-forestry tree that was introduced into India from Australia. It is a very important honey plant and is one of the highest nectar yielding species. Colonies of honey bees are migrated to _Eucalyptus_ to tap surplus amounts of honey.

The production of seeds in _Eucalyptus_ is mainly dependent on pollen transfer between flowers and the _Eucalyptus_ breeding system favours outcrossing.

Very little work has been done on the pollinator complex of this tree in India though most studies report that it is visited by both species of domesticated honey bees _A. mellifera_ and _A. cerana_ as a major honey source.
Five species of insect pollinators were observed to be regularly associated with *Eucalyptus* flowers in the area of present study. A few dipterans (Muscidae, Calliphoridae) were observed as casual visitors. All the four species of honey bees were present and *A. dorsata* was observed to be significantly more abundant. Hingston *et al.* (2004a,b) and Hingston and Potts (2005) reported seventy one species of insects on *Eucalyptus* bloom in the country of its origin. In their study *A. mellifera* was the dominant species followed by native colletid bees. Hingston and Potts (2005) found several species of calliphorids, syrphids and tabanids in their study.

An interesting observation was that parrots were frequent and abundant visitors of *Eucalyptus* under the present set of conditions. Other workers have reported that birds, mammals and insects were important for the pollination of *Eucalyptus* with birds being more important on the top flowers and during the cold and rainy conditions when it is not possible for the insects to forage (Hingston *et al.*, 2004c; Hingston and Potts, 2005).

The foraging rate of *A. dorsata* (7.80/min.) was the highest during the present study and it also spent significantly less time per flower for foraging (6.86 secs./flower).

The number of loose pollen grains obtained from the body were the highest 13333.33 for *A. dorsata*. On the basis of pollinating index observed from pollinating behaviour it was rated the best pollinator of *Eucalyptus* under Indian conditions.

**POLLINATOR DECLINES**

**Sarson** : *Brassica campestris* L. var. sarson is a typical winter season crop of the sub-tropical to temperate regions. It is cultivated for its seeds that yield oil and leaves that are used as vegetable. It is a major
source of nectar for honey bees. It is a good bee plant and is visited by honey bees both for nectar and pollen (Partap, 1997).

Reports on the pollinator diversity of *Brassica* in India are well spread over a period of time (Mohammad, 1935; Rahman, 1940; Latif et al., 1965; Kapil et al., 1971; Bhalla et al., 1983a) and provided valuable information for studies on decline particularly under the changed agro-forest scenario following advent of *A. mellifera* (Atwal and Goyal, 1973).

During the present studies on pollinating species of *Brassica campestris* var. sarson near Chandigarh, the crop was observed to be visited by eight species of insects. Greater diversity of pollinators has been associated with this crop in earlier studies. Twenty four species were recorded by Rahman (1940) and Batra (1967). Kapil et al. (1971) reported that the crop was visited by twenty species of wild bees.

On related toria crop (*Brassica campestris* L. var. toria) these workers (Rahman, 1940; Kapil et al., 1971) observed 19 species of insect visitors while 22 were reported by Latif et al. (1965). Declining trends in pollinator diversity are evident in subsequent studies on toria whereby Bhalla et al. (1983a) recorded seven species and Kumar et al. (1994a) reported five species visiting toria bloom. The present studies indicated a similar pattern on sarson.

It is important to note that *A. mellifera* outnumbered all other species during the present study and was significantly higher in abundance (6.4 bees/m²/5 min.) as compared to the native honey bees (1.80, 1.66 and 0.80 bees/m²/5 min. for *A. dorsata*, *A. cerana* and *A. florea* respectively). Similar observations were made by Kumar et al. (1994b) on related toria crop. In their studies *A. mellifera* predominated the wild bees and made 58.94 percent of total visits, whereas *A. ilerda*, *H. catullus*, one solitary bee and *H. spendidulus* constituted 20.40, 11.92, 4.88 and 3.80 percent of total bees respectively (Kumar et al., 1994b). Wild bees were
conspicuous by their absence during the present studies while dipterans were present. Dipterans were the most abundant pollinators constituting 47.08% of the population in the studies of Bhalla et al. (1983a).

It is noteworthy that besides other factors that might have been responsible for the decline in pollinator diversity observed during the present and other recent investigations (Bhalla et al., 1983a; Kumar et al., 1994b), one major change in the agro-forest ecosystem scenario was the introduction of the European honey bee *Apis mellifera* in the Punjab plains during the late 1960s (Atwal and Goyal, 1973).

This observation is supported by the findings that the exotic bee was the preponderant species (Table 8) on this crop during the present investigations in contrast to the native honey bees *A. cerana*, *A. florea* and *A. dorsata* reported by other workers (Rahman, 1940; Kapil et al., 1971; Bhalla et al., 1983a) before *A. mellifera* entered the scene.

A significant finding during the present studies was that the native honey bees *A. dorsata* and *A. cerana* were better performers than *A. mellifera* with respect to foraging rate (Table 9) and pollen carrying capacity (Table 11). Further *A. cerana* and *A. dorsata* are cold hardy (Verma, 1991) and were therefore observed to become active on these winter season flowers earlier in the day (0900–1100 hrs, Table 8) as compared to *A. mellifera* which started foraging comparatively later (1200–1400 hrs). However, the exotic honeybee *A. mellifera* outscored the native bees in pollinating efficiency on the basis of abundance (Table 8). The area around Chandigarh particularly, the *Brassica* fields are extensively exploited for honey harvesting by beekeepers who migrate *A. mellifera* colonies to the plains for this purpose. This accounts for the high population of *A. mellifera* leading to its higher pollinating index.
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Similar trend is also evident in the studies of Kumar et al. (1994b). According to them *A. mellifera* was the most abundant visitor to toria bloom in the mid hills. Based on pollination indices they reported *A. mellifera* followed by *A. ilerida* to be the most efficient pollinator on toria bloom.

**CROP HEALTH VIS-À-VIS POLLINATORS**

Experiment was carried out to assess the role of pollinating insects on health of the studied crop, as indicated in fruit set, with litchi crop. It was observed that the inflorescences on bagged branches of litchi set comparatively less fruit (63/m long branch) as compared to the open pollinated branches (179). The single report (Anonymous, 2007) available in this respect indicated that 95% of bagged panicles did not set any fruit. In contrast 92% of open pollinated inflorescences bore an average of 9 fruits per panicle.

The size of the fruits was reduced by 15 and 12% for length and diameter respectively as compared to the open pollinated fruits. There are no previous reports with which this data can be compared. Data are, however, available for increase in production parameters for different fruit crops under the impact of honey bee pollination as tabulated below:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Increase in fruit set (%)</th>
<th>Increase in fruit weight (%)</th>
<th>Increase in fruit size (length, diameter) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>10</td>
<td>33</td>
<td>15, 10</td>
</tr>
<tr>
<td>Peach</td>
<td>22</td>
<td>44</td>
<td>29, 23</td>
</tr>
<tr>
<td>Plum</td>
<td>13</td>
<td>39</td>
<td>11, 14</td>
</tr>
<tr>
<td>Citrus</td>
<td>24</td>
<td>35</td>
<td>9, 35</td>
</tr>
<tr>
<td>Strawberry</td>
<td>112</td>
<td>48</td>
<td>Misshapen fruits decreased by 50 percent.</td>
</tr>
</tbody>
</table>

On the basis of the present (Table 37) and previous findings (Table 38) on the negative (in the absence) and positive (in the presence) effects of pollinators it is suggested that the integration of pollinating insects as a non-conventional agricultural input is essential for the health of the system.

MANAGEMENT AND RESTORATION OF POLLINATORS

Perusal of the results obtained during the present investigations carried out to study the diversity of pollinators associated with a variety of crop plants (Brassica, Okra, Sunflower, Apple, Litchi, Eucalyptus) indicated that the trend is towards a decline in the number of flower visiting insect species. The reasons for these declines are attributable to factors like habitat, deterioration, destruction of niche, fragmentation, extensive and intensive monocultures, use of pesticides, exotic introductions and environmental pollution, as observed by conservation biologists the world over (Borges, 1999; Kumar, 2000; Kumar and Kumar, 2000; Verma et al., 2000; Richards and Kevan, 2002; de Ruijter, 2002)

The decline in pollinator population and diversity has created two important needs (i) Conservation of the available resources in order to restore the diversity and (2) Management of efficient pollinators so that the crop yields and quality can be maintained.

CONSERVATION OF AVAILABLE POLLINATORS

It is evident from the data collected during the present studies that honey bees and A. mellifera in particular, where present, were dominating the pollinator scene. The native honey bee population had undergone a massive decline to points of near extinction in the 1980s when it was inflicted with an epidemic of the TSBV (Verma, 1991). A.
Discussion

*mellifera* is similarly being threatened by the parasitic mite *Varroa jacobsoni* (Akratanakul and Burgett, 1975). Conservation of the native honey bee *A. cerana* which has co-evolved with the flora and fauna of its native land can be achieved by adopting the low cost, eco-friendly technologies recently developed (Kumar and Verma, 1996; Kumar and Kumar, 1997c, 2000; Verma et al., 2000).

Many of the pollinators observed during the present study do not offer themselves for manipulation by man (atleast till such techniques are developed and standardized). An initial step towards restoration of these insects would be to save them from the harmful effects of pesticides. This could easily be done by timing the application of pesticides so as to avoid periods of insect activity and avoiding the use of pesticides when the crop is in bloom.

**MANAGEMENT OF EFFICIENT POLLINATORS**

The results of the pollinating efficiency ranking of the insect visitors of studied crops (Table 1 to 36) revealed that for Sunflower, Brassica, Okra, Apple, Litchi and Eucalyptus the honey bees were the most efficient pollinators. They are morphologically adapted to carry large amounts of pollen, have high foraging rate, are fast in manipulating flowers and can adapt to different climates.

Further in case of Sunflower, Brassica and Okra, it was the domesticated honey bee *A. mellifera* that bagged the first position. Fortunately *A. mellifera* can be managed by man. The population of these insects can be maintained at will in order to saturate the environment with pollinators so as to compensate to some extent atleast the decline in population of wild bees. On the basis of the present studies, therefore, it is suggested that managed honey bee colonies need
Discussion

to be integrated into conventional agricultural practices (e.g., manuring, fertilizer application, irrigation, use of pesticides) for the health of the ecosystem.