Review Article

HONEYBEES AND OTHER INSECT POLLINATORS OF CULTIVATED PLANTS: A REVIEW

R. B. Thapa
Institute of Agriculture and Animal Sciences (IAAS), Rampur, Chitwan, Nepal

ABSTRACT

Insects are viewed from the harmful perspectives and aimed at killing them through several means including indiscriminate use of deadly chemicals. If good judgment made keeping views on sustainable crop production, natural balance and pollution free environment, they are important component of the ecosystem and their beneficial aspects are immense. One of them is that insects provide pollination service to plants. The study showed that over 50 species of insects visited flowers of 17 different species of selected crops during flowering periods. The visiting preferences of insects to flowers of different crops differed among the crop species and insect species as well. In fact, of the total pollination activities, over 80% is performed by insects and bees contribute nearly 80% of the total insect pollination, and therefore, they are considered the best pollinators. The manmade agro-ecosystem exerted pressure and forced to decline pollinators and their diversity, which resulted in reduced agricultural productivity again threatening biodiversity. Management of wide diversities of honeybees and other beneficial insects and flowering plant species occurring in Nepal help to maintain diversity of flora and bee fauna, pollination and reward hive products in the service of mankind. This paper covers honeybees and other insect species visiting various crop flowers.

Key words : Pollination, honeybees, insect, flower visitors

INTRODUCTION

Co-evolution of flowering plants and their pollinators started about 225 million years ago (Price, 1975). Stone carvings and bricks from the palace of Assyrian kings as early as 800 B.C. depict the significance of pollen and pollination of fruits that pollination enhances quality and yield of seeds and fruits. Lack of sufficient number of suitable pollinators causes decline in fruit and seed production (Partap, 2001). Of the total pollination activities, over 80% is performed by insects and bees contribute nearly 80% of the total insect pollination, and therefore, they are considered the best pollinators (Robinson and Morse, 1989).

Nepal is rich in plant and insect diversities including honeybees well distributed in terai, mid-hills and high-hills (Woyke, 1999). About one-third of the total human diet comes from bee pollinated crops and pollination value worth about 143 times than honey production (Mishra, 1997/98). Honeybees are the center of attraction to mankind from the beginning for their pollination services and beehive products. The wide diversities of honeybee and flowering plant species occurring in the country help to maintain diversity of flora and bee fauna greatly influence crop pollination and reward hive production in the service of nature and human beings as well. The pollinating potential of a single honeybee colony becomes evident when it is realized that bees make up to four million trips per year and that during each trip an average of about 100 flowers are visited (Free, 1993). Therefore, pollinators and pollination activities were overviewed to elucidate significance of honeybees and other crop pollinators for maintaining natural diversity and sustainable crop production through the service of bees and other crop pollinators.

MATERIALS AND METHODS

Insect species including honeybees were recorded visiting flowers of seventeen crops grown at IAAS and its vicinity in 2004/2005. In addition, exhaustive list of over 180 cultivated plants of economic importance was prepared and their important pollinators were searched gleaning through literature and available information arranged systematically. Findings are summarized in tables and briefed in texts. The causes of their decline, research priorities and conservation needs are also provided.

RESULTS AND DISCUSSION

Self-/cross- pollinated crops

The plants fall under the category of being self-pollinated or cross-pollinated for the purpose of reproduction, which are presented in Table 1 (Chaudhari, 2000). Insect and other organisms play major role in boosting agricultural production by significantly increasing the yields of crops, vegetables, fruits and seeds through visiting flowers and helping in pollination. Self-incompatible and cross-pollinated crops require pollinating service of efficient pollinators. Self-pollinated crops also benefit from insect pollination, that increase yield up to 30% from pollinator visits and also collection of nectar or pollen and benefit farmers from pollinators' service. Lack of pollinators causes decline in fruit and seed production (Partap, 2001).

Table 1. Classification of crop species based on their natural mode of pollination aspects

SN	Self-pollinated but benefited by insect visits	Cross-pollinated plants and highly benefited by insect visits
1	*Cereals:* rice, wheat, barley, oat, millet, ragi etc.	*Cereals:* maize, rye, bajra etc.
2	*Legumes/Oilseeds:* pea, groundnut, gram, mung, urid, cowpea, soybean, lentil, khesari, rajma, sunhemp til, linseed etc.	*Legumes:* alfalfa, red/white clover etc.
3	*Vegetables:* tomato, okra, lettuce, brinjal, chilli, parsnip, potato etc.	*Vegetables:* cabbage, carrot, cauliflower, onion, pumpl\kin, radish, turnip, muskmelon, watermelon, squash, sweet potato, bean, broccoli, brussel sprout, parsley, celery, spinach, asparagus, garlic, coriander etc.
4	*Fruit Trees:* apricot, citrus, peach etc.	*Fruit trees:* apple, avocado, banana, cherry, date palm, fig, coconut, papaya, plum, loquat, strawberry, almond, niger, mango, pear, blackberry, raspberry, chestnut, hazelnut etc.
5	*Forage Crops:* burr/subterranean clover, valvet bean etc.	*Forage Crops:* ryegrass, timothy grass, bromegrass, johnson grass etc.
6	*Other Crops:* jute and several other grasses etc.	*Other Crops:* sugarcane, hemp, hops etc.
7	*Often Cross Pollinated Crops:* jawar, cotton, broad bean, jute, tobacco, pigeon pea, rai, yellow sarson, toria, safflower, brinjal, chilli etc.	

Source: Bastola (1998), Chaudhari (2000)

The self-pollinated crop species occupy less than 15% and the remaining are cross-pollinated crops that need help of pollinating agents, wind, water or insects for fertilization. Some crops also exhibit often cross-pollinated nature. The genetic architecture of such crops is intermediate between self- and cross-pollinated species. The self-pollinated crop species also benefit from cross pollination and hybrids grown these days require pollination in order to bear satisfactory marketable crops. Some plants may carry thousands of flowers, but unless there is adequate pollination, little if any fruit will be produced. Pollination is one of the most important factors in fruit production (Partap, 2001).

Insect flower visitors and crop pollinators

The role of pollinators especially honeybees including some other insect flower visitors have been reported in Nepal (Thapa, 2002; Dhakal, 2003; Neupane, 2001; Devkota, 2000). List of insect species visiting flowers of various crops at IAAS and its vicinity is presented in Table 2. The study showed that over 50 species of insects visited flowers of different species of selected crops during flowering periods. The visiting preferences of insects to flowers of different crops differed among the crop species and insect species as well (Table 3). The highest number of insect species (21 species) visited litchi and buckwheat followed by rapeseed, cowpea, radish, broccoli, sponge gourd, cucumber, brinjal, red gram, okra, mango, citrus, squash, bottlebrush, sesame and bottle gourd, respectively (Table 3, 4). In general, out of 17 crops, honeybee species visited 15 different crop species followed by other hymenopterans wasps, other beneficial insects and some insect pests, indicating majority of helpful insects, i.e. flower visitors, pollinators etc.

Table 2. Number of insect species visiting flowers of various crops at IAAS and its vicinity

SN	Crop	Botanical name	Insect species (No)
1	Bottle gourd	*Lagenaria siceraria* (Molina) Standley	3
2	Bottlebrush	*Callistemon citrinus* (Curtis) Skeels	6
3	Brinjal	*Solanum melongena* Lin.	14
4	Broccoli	*Brassica oleracea* Lin. var italica Plenck	16
5	Buckwheat	*Fagopyrum esculentum* Moench	21
6	Citrus	*Citrus* spp.	10
7	Cowpea	*Vigna unguiculata* (Lin.) Walp.	17
8	Cucumber	*Cucumis sativus* Lin.	14
9	Litchi	*Litchi sinensis* Sonner.	21
10	Mango	*Mangifera indica* Lin.	11
11	Okra	*Abelmoschus esculentus* Moench	13
12	Radish	*Raphaus sativus* Lin.	16
13	Rapeseed	*Brassica campestris* Lin. var *toria* Duth. & Full.	20
14	Red gram	*Cajanus cajan* (Lin.) Huch.	13
15	Sesame	*Sesamum indicum* Lin.	4
16	Sponge gourd	*Luffa aegyptiaca* Miller	14
17	Squash	*Cucurbita maxima*Duch. var. *maxima*	9

Source: From field survey and other various studies (Devkota, 2000; Dhakal, 2003; Neupane, 2001; Thapa, 2002)

Table 3. List of honeybees and other insect pollinators visiting different crop flowers at IAAS and its vicinity

SN	Insect species visiting flowers
1	Bottlegourd, *Lagenaria siceraria* (Molina) Standley (Insect species 3) Cowpea borer (*Lampides boeticus* L.), Syrphid fly (*Surphus sp.*), Red pumpkin beetle (*Aulacophora foveicollis* Lucas)
2	Bottlebrush, *Callistemon citrinus* (Curtis) Skeels (Insect species 6) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Golden wasp (*Vespa magnifica* (Smith), Oriental wasp (*Vespa orientalis* (Lin.), Pollen beetle (*Chiloloba acuta* Wied.)
3	Brinjal, *Solanum melongena* Lin. (Insect species 14) Bumble bee (*Bombus* spp.), Rice skipper (*Pelopida mathias* (F.), Mud wasp (*Chlorion* sp.), Golden wasp (*Vespa magnifica* (Smith), Oriental wasp (*Vespa orientalis* (Lin.), Lemon butterfly (*Papilio machon* Lin.), Peacock pansy butterfly (*Presis* sp.), Tabanid fly (*Tabanus* spp), Lady beetle (*Hippolimnus* sp.), Monarch butterfly (*Danaus plexipus* (Lin.), Cowpea borer (*Lampides boeticus* L.), Carpenter bee (*Xylocopa* sp.), Cabbage butterfly (*Pieris brassicae* Lin., *P. canidia* Lin.), Yellow wasp (*Polistes* sp.)
4	Broccoli, *Brassica oleracea* Lin. var *italica* Plenck (Insect species 16) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Fruit fly (*Bactrocera* sp.), Housefly (*Musca domestica* Lin.), Red pumpkin beetle (*Aulacophora foveicollis* Lucas), Flea beetle (*Phylotreta cruciferae* Goeze), Lady beetle (*Coccinella* spp.), Cabbage butterfly (*Pieris canidia* Lin., *Pieris brassicae nepalensis* Doubl.), Syrphid fly (*Eristalis* spp.), Carpenter bee (*Xylocopa* spp.), Bright green carpenter bee (*Ceratina* spp.), Bumble bee (*Bombus* spp.), Rice skipper (*Pelopidas mathias* (F.), Tabanid fly (*Tabanus* spp), Monarch butterfly (*Danaus plexipus* Lin.)
5	Buckwheat, *Fagopyrum esculentum* Moench. (Insect species 21) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Little bee (*Apis cerana* Fab.), Syrphid fly (*Syrphus* sp.), Tabanid fly (*Tabanus* spp), Marsh fly (*Bibilio* sp.), Rice skipper (*Pelopidas mathias* (F.), Lady beetle (*Coccinella* spp.), Carpenter bee (*Xylocopa* sp.), Legume pod bug (*Riptorus lineralis* Fab.), Mud wasp (*Chlorion* sp.), Cabbage butterfly (*Pieris brassicae* Lin., *P. canidia* Lin.), Legume pod borer (*Lampides boeticus* Lin.), Castor butterfly (*Ergolis merione* Cram.), Housefly (*Musca sp*), Oriental wasp (*Vespa orientalis* (Lin.), Yellow banded wasp (*Sphex* sp.), Ichneumonid wasp (*Ichneumonus* sp.), Green bug (*Nezara viridula* Lin.), Yellow butterfly (*Therias* sp.)
6	Citrus, *Citrus* spp. (Insect species 10) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Golden wasp (*Vespa magnifica* (Smith), Oriental wasp (*Vespa orientalis* (Lin.), Red pumpkin beetle (*Aulacophora foveicollis* Lucas), Epilachna beetle (*Epilacanthi pusillanimity* (Muslant), Housefly (*Musca domestica* Lin.), Fruit fly (*Bactrocera* sp.), Lemon butterfly (*Papilio machon* Lin. *P. demoleus* Lin.)

Table 3. Cont. ……

7	Cowpea, *Vigna unguiculata* (Lin.) Walp. (Insect species 17) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Carpenter bee (*Xylocopa* sp.), Rice skipper (*Pelopidas mathias* (F.), Cowpea borer (*Lampides boeticus* L.), Bumble bee (*Bombus* spp.), Oriental wasp (*Vespa orientalis* (Lin.), Tabanid fly (*Tabanus* spp), Syrphid fly (*Eristalis* sp.), Housefly (*Musca domestica* Lin.), Fruit fly (*Bactrocera* sp.), Castor butterfly (*Ergolis merione* Cram.), Cabbage butterfly (*Pieris brassicae* Lin., *P. Canidia* Lin.), Golden wasp (*Vespa magnifica* (Smith), Cyntomid fly (*Cyntomis passalis* (F.), Mustard sawfly (*Athalia lugens proxima* (Klug.)
8	Cucumber, *Cucumis sativus* Lin. (Insect species 14) European honeybee (*Apis mellifera* Fab.), Asiatic honeybee (*Apis cerana* Lin.), Rock bee (*Apis dorsata* Lin.), Lady beetle (*Coccinella* spp.), Red pumpkin beetle (*Aulacophora foveicollis* Lucas), Pollen beetle (*Chiloloba acuta* W.), Fruit fly (*Dacus cucurbitae* (Que.), Carpenter bee (*Xylocopa* sp.), Peacock pansy butterfly (*Presis* sp.), Rice skipper (*Pelopidas mathias* (F.), Lemon butterfly (*Papilio machon* Lin.), Oriental wasp (*Vespa orientalis* (Lin.), Golden wasp (*Vespa magnifica* (Smith), Yellow banded wasp (*Sphex* sp.)
9	Litchi, *Litchi sinensis* Sonner. (Insect species 21) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Pollen beetle (*Chiloloba acuta*), Lady beetle (*Coccinella* spp), Damsel fly (*Agriochemis* spp), Housefly (*Musca domestica* Lin.), Tachinid fly (*Agryrophylax nigrotibitalis* (Baranov), Rice ear head bug (*Leptocorisa acuta* (F.), Syrphid fly (*Eristalis* sp.), Tabanid fly (*Tabanus* spp), Peacock pansy butterfly (*Presis* sp.), Lemon butterfly (*Papilio machon* Lin.), Cowpea borer (*Lampides boeticus* L.), Cyntomid fly (*Cyntomis passalis* (F.), Oriental wasp (*Vespa orientalis* (Lin.), Golden wasp (*Vespa magnifica* (Smith), Yellow banded wasp (*Sphex* sp.), Castor butterfly (*Ergolis merione* Cram.), Monarch butterfly (*Danaus plexpus* Lin.), Crane fly ()
10	Mango, *Mangifera indica* Lin. (Insect species 11) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Syrphid fly (*Syrphus* sp.), Housefly (*Musca domestica* Lin.), Marsh fly (),Oriental wasp (*Vespa orientalis* (Lin.), Yellow banded wasp (*Sphex macula*), Castor butterfly (*Ergolis merione*), Nymphalid butterfly (*Presis atlites* Lin.), Monarch butterfly (*Danus plexpus* Lin.)
11	Okra, *Abelmoschus esculentus* Moench. (Insect species 13) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Bumble bee (*Bombus* spp.), Flower beetle (*Chiloloba acuta* Wied.), Rice skipper (*Pelopidas mathias* (F.), Lemon butterfly (*Papilio machon* Lin.), Oriental wasp (*Vespa orientalis* (Lin.), Peacock pansy butterfly (*Precis lemonias* Lin.), Golden wasp (*Vespa magnifica* (Smith), Syrphid fly (*Eristalis* sp.), Carpenter bee (*Xylocopa* sp.), Yellow banded wasp (*Polistes* sp.)
12	Radish, *Raphaus sativus* Lin. (Insect species 16) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Lady beetle (*Coccinella* spp.), Bumble bee (*Bombus* spp.), Red cotton bug (*Dysdercus koenigii* (Fab.), Rubber fly (*Asilus* sp.), Green stink bug (*Nezara viridula* (L.), Pollen beetle (*Chiloloba acuta* Wied.), Syrphid fly (*Syrphus* sp.), Housefly (*Musca domestica* Lin.), Tabanid fly (*Tabanus* spp), Rice skipper (*Pelopidas mathias* (F.), Cabbage butterfly (*Pieris brassicae* Lin., *P. canidia* Lin.), Cowpea borer (*Lampides boeticus* Lin.)
13	Rapeseed, *Brassica campestris* Lin. var *toria* Duth. & Full. (Insect species 20) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Lady beetle (*Coccinella* spp.), Bumble bee (*Bombus* spp.), Syrphid fly (*Syrphus* sp.), Carpenter bee (*Xylocopa* spp), Tabanid fly (*Tabanus* spp), Rice skipper (*Pelopidas mathias* (F.), Geometrid moth (*Nyctalaemon* sp.), Cowpea pod borer (*Lampides boeticus* Lin.), Cyntomid fly (*Cyntomis passalis* (F.), Mustard sawfly (*Athalia lugens proxima* (Klug.), Peacock pansy butterfly (*Presis atlites* Lin.), Yellow banded wasp (*Sphex* sp.), Mud wasp (*Chlorion* sp.), Short horned grasshopper (*Oxya* spp), Green stink bug (*Nezara viridula* (L.), Pumpkin caterpillar (*Diaphinia indica* (Saund.), Blister beetle (*Mylabris* spp.)
14	Red gram, *Cajanus cajan* (Lin.) Huch. (Insect species 13) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Cowpea borer (*Lampides boeticus* L.), Bumble bee (*Bombus* spp.), Tabanid fly (*Tabanus* spp), Syrphid fly (*Syrphus* sp.), Housefly (*Musca domestica* Lin.), Rice skipper (*Pelopidas mathias* (F.), Castor butterfly (*Ergolis merione* Cram.), Cabbage butterfly (*Pieris brassicae* Lin., *P. canidia* Lin.), Golden wasp (*Vespa magnifica* (Smith), Mustard sawfly (*Athalia lugens proxima* (Klug.)
15	Sesame, *Sesamum indicum* Lin. (Insect species 4) European honeybee (*Apis mellifera* Lin.), Asiatic honeybee (*Apis cerana* Fab.), Rock bee (*Apis dorsata* Fab.), Syrphid fly (*Syrphus* sp.)
16	Spongegourd, *Luf a aegyptiaca* Miller (Insect species 14) Lemon butterfly (*Papilio machon* Lin.), Yellow butterfly (*Therias* sp.), Cabbage butterfly (*Pieris brassicae* Lin., *P. canidia* Lin.), Castor butterfly (*Ergolis merione* Cram.), Bumble bee (*Bombus* spp.), Golden wasp (*Vespa magnifica* (Smith), Oriental wasp (*Vespa orientalis* (Lin.), Epilachna

Table 3. Cont. ……

	beetle (*Henosepilachna pusillanum* (Muslant), Rice skipper (*Pelopidas mathias* (F.), Fruit fly (*Bactrocera* sp.), Mud wasp (*Chlorion* sp.), Cowpea borer (*Lampides boeticus* L.), Red pumpkin beetle (*Aulacophora foveicollis* Lucas), Tabanid fly (*Tabanus* spp.)
17	Squash, *Cucurbita maxima*Duch. var. *maxima* (Insect species 9) European honeybee (*Apis mellifera* Fab.), Asiatic honeybee (*Apis cerana* Lin.), Rock bee (*Helophilus trivittatus*.), Lady beetle (*Coccinella* spp), Syrphid fly (*Syrphus* sp), Red pumpkin beetle (*Aulacophora foveicollis* Lucas), Rubber fly (*Asilus* sp.), Fruit fly (*Bactrocera* sp.), Housefly (*Musca domestica* Lin.)

Source: From field survey and other various studies (Devkota, 2000; Dhakal, 2003; Neupane, 2001; Thapa, 2002)

In the past, genus *Apis* was believed to have four species: *Apis mellifera* Lin. (species native to Europe and Africa with 24 sub-species), *Apis cerana* Fab. (Asian species with 4 sub-species), *Apis dorsata* Fab. and *Apis florea* Fab. In 1980, the largest bee species in the world, *Apis laboriosa* Smith was reconfirmed from higher altitudes of Nepal and in 1987, the world's smallest bee, *Apis andreniformis* Smith having black body color and living in Southeast Asia was reconfirmed as an independent species from *Apis florae* Fab. Similarly, in 1988, a red honeybee, *Apis koschevnikovi* Enderlein discovered in Sabah, East Malaysia was another independent species from Apis cerana Fab. Then in 1996, *Apis nigrocinta* Smith in Sulawasi Island, Indonesia and *Apis nuluensis* Lin. in same area as the habitat of *Apis koschevnikovi* Enderlein were described as two new species. Hence, among these nine species, eight species are distributed in Asian countries and more than 50% are in Nepal (Table 4). Beekeepers and crop farmers need to realize their commercial importance. Then, they could be exploited for pollination different under different agro-climatic conditions. In addition, there are 20,000-40000 species of honeybees in the world that have to be conserved and utilized their services in pollination.

Table 4. Races of honeybees and their native habitat

SN	Scientific Name	Common Name	Native habitat
1	*Apis dorsata* Fab.	Rock Bee	Asia
2	*Apis florea* Fab.	Little Bee	Asia
3	*Apis laboriosa* Smith.	Largest Bee	Asia
4	*Apis cerana* Fab.	Asiatic Hive Bee	Asia
5	*Apis andreniformis* Smith.	Smallest Bee	Asia
6	*Apis mellifera* Lin.*	European Bee	Europe
7	*Apis koschevnikovi* Enderlein	Red Bee	Malaysia
8	*Apis nuluensis* Lin.	Malaysian Bee	Malaysia
9	*Apis nigrocinta* Smith	Black Bee	Indonesia

Source: Sakagami *et al.* (1980), Partap (1997); * Introduced species

Over 180 plant species of economic importance and their pollinators have been listed in Table 5. It is clear that bees pollinate almost all crops and very few crops are dependent on other insect species for their pollination requirements. Self-incompatible and cross-pollinated crops require efficient pollination services of honeybees and other pollinators. Even self-pollinated crops benefit from insect pollination because thus pollinated crops produce higher yields with good quality seeds showing their hybrid vigor without any desertion in the innate properties of fruits and seeds. Thus, honeybees are unquestionably the primary pollinating agents of many crop plants. Honeybees visit flowering plants and collect both pollen (if it is produced) and nectar from flowers. The flower is so constructed that if the bee has visited a previous pollen-producing flower, some pollen is likely to be transferred to the next stigma visited. Other pollinating insects are minor although their role in pollinating vast array of wild flowering plants and maintaining natural diversity is the reality but beyond the imagination of our thinking because of their miniature forms. Thus, there continues an uninterrupted natural phenomenon for co-existence of the insects and flowering plants for our selfish interest.

Table 5. Pollination of cultivated crops by honeybees and other insect species

SN	Crop	Scientific Name	Family	Major Pollinators	Other Pollinators	Reference
1	Akee	*Blighia sapida* Koenig	Sapindaceae	Honeybees	Wasps	Free (1993)
2	Alfalfa	*Medicago sativa* Lin.	Leguminosae	Honeybees	75 wildbee spp. visit flowers	Ahmed *et al.* (1989); Bohart (1957); Tasei (1972)

Table 5. Cont. ……

3	Allspice	*Pimenta dioica* Lin.	Myrtaceae		Solitary bees	Chapman (1966)
4	Almond	*Prunus dulcicis* (Miller) D.A. Webb	Rosaceae	Honeybees	Solitary bees	Tufts (1919)
5	Alsike clover	*Trifolium hybridum* Lin.	Leguminosae	Honeybees	Large bees	Fischer (1954)
6	American ginseng	*Panax quinquefolius* Lin.	Araliaceae	Halictid bees		(Duke, 1980)
7	Anise	*Pimpinella anisum* Lin.	Umbelliferae	Honeybees	Solitary bees	Free (1993)
8	Apple	*Malus domestica* Borkh	Rosaceae	Honeybees	Solitary bees, wasps, flies	Kurennoi (1969)
9	Apricot	*Prunus americana* Lin.	Rosaceae	Honeybees	Solitary bees	Kobayashi (1970)
10	Artichoke	*Cynara scolymus* Lin.	Compositae	Honeybees	Other bees	Frediani and Pinzauti (1983)
11	Asparagus	*Asparagus officinalis* Lin	Liliaceae	Honeybees	Other bees	Jones and Robines (1928)
12	Avocado	*Persea americana* Mill.	Lauraceae	Honeybees	Wasps, flies	Vithanage (1986, 1988)
13	Bambara groundnut	*Voandzeia subterranean* Thou	Leguminosae	Honeybees	Other bees	Doku and Karikari (1971)
14	Banana	*Musa* spp.	Musaceae	Bats	Bees, humming bird	Mahadevan and Chandy (1959)
15	Barbados cherry	*Malpighia glabra* Lin.	Malpighiaceae	Solitary bees		Raw (1979)
16	Basil	*Ocimum* spp.	Labiatae	Honeybees		Darrah (1974)
17	Betel nut	*Areca catechu* Lin.	Palmae	Honeybees	Ants, flies, thrips	Murthy (1977)
18	Birdfoot-trefoil	*Lotus corniculatus* Lin.	Leguminosae	Honeybees	Other bees	Morse (1958)
19	Bitter gourd	*Memordica charantia* Lin.	Cucurbitaceae	Honeybees	Other bees, beetle	Grewal and Sidhu (1978)
20	Blueberry	*Vaccinium* spp.	Ericaceae	Honeybees		Brewer et al. (1969a,b); Hensels (1983)
21	Bottle gourd	*Lagenaria siceraria* Standl.	Cucurbitaceae	Honeybees	Bugs	Alam and Kadir (1986)
22	Brazil nut	*Lecythis* spp.	Lecythidaceae		Large bees	Nelson *et al.* (1985)
23	Breadfruit	*Artocarpus altilis* Fosb	Moraceae	Stingless bee		Brantzes (1981)
24	Broccoli	*Brassica oleracea* var *italica* Lin.	Cruciferae	Honeybees	Flies other bees	Radcehenko (1966)
25	Buckwheat	*Phagopyrum esculentum* Moench	Polygonaceae	Honeybees	Wasps	Elagin (1953)
26	Cardamom	*Elettaria cardamomum* (L.) Maton	Zingiberaceae	Honeybees	Solitary bees, wasps	Verma (1987)
27	Carrot	*Dacus carota* Lin.	Umbelliferae	Honeybees	Solitary bees, flies	Hawthorn *et al.* (1960)
28	Cashew nut	*Anacardium occidentale* Lin.	Anacardiaceae	Honeybees	Bees, flies, butterflies	Phoon *et al.* (1984)
29	Castor	*Ricinus communis* Lin.	Euphorbiaceae	Wind	Bees	Alex (1957a)
30	Cauliflower	*Brassica oleracea* var *capiata* Lin.	Cruciferae	Honeybees	Flies, other bees	Free (1993)
31	Celery	*Apium graveolens* Lin.	Umbelliferae	Flies	Solitary bees	Warakomska *et al.* (1982)
32	Chestnut	*Castanea* spp.	Fagaceae	Honeybees	Other bees	Free (1993)
33	Chick pea	*Cicer arietinum* Lin.	Leguminosae		Various bees	Howard *et al.* (1916)
34	Chicory	*Cichorium intybus* Lin.	Compositae	Honeybees	Other bees	Marletto *et al.* (1988)
35	Chilli	*Capsicum* spp.	Solanaceae	Honeybees	Solitary bees, wasps, thrips	Tanksley (1985)
36	Chinese cabbage	*Brassica pekinensis* Lin.	Cruciferae	Honeybees	Flies, other bees	Free (1993)
37	Chrysanthemum	*Chrysanthemum cineraria-efolium* (Trev) Bocc	Compositae	Honeybees	Beetles and flies	Smith (1958)
38	Cinchona	*Cinchona* spp.	Rubiaceae	Honeybees	Butterflies, flies	Ochse *et al.* (1961)
39	Cinnamon	*Cinnamomum zeylanicum* Breyn	Lauraceae	Flies		Purseglove (1968)
40	Citron	*Citrus medica* Lin.	Rutaceae	Honeybees	Bumble bees, thrips, mites, flies	Hassanein and Ibrahim (1959)
41	Clementine	*C. aurantium* x *C. reticulata*	Rutaceae	Honeybees	Bumble bees, thrips, mites, flies	Priore and Sannio (1977)
42	Clove	*Eugenia caryophyllus* Bul & Harr	Myrtaceae	Honeybees		Wit (1969)

Table 5. Cont. ……

43	Cluster bean	*Cyamopsis tetra-gonooloba* (L.) Taub	Leguminosae	Honeybees	Other bees	Free (1993)
44	Cocoa	*Theobroma cacao* Lin.	Sterculiaceae	Midges	Ants, thrips, aphids	Free (1993)
45	Coconut	*Cocos nucifera* Lin.	Palmae	Honeybees	Earwigs, wasps, ants	Sholdt and Mitchell (1967)
46	Coffee	*Coffea arabica* Lin.	Rubiaceae	Honeybees	Other bees, wasps	Nogueira-Neto *et al.* (1959)
47	Common bean	*Phaseolus vulgaris* Lin.	Legunminosae	Honeybees	Other bees	Webster *et al.* (1982) Mackie and Smith (1935)
48	Common vetch	*Vicia sativa* Lin.	Leguminosae	Honeybees	Other bees	Free (1993)
49	Coriander	*Coriander sativum* Lin.	Umbelliferae	Honeybees	Flies, other bees	Shelar and Suryanarayana (1981)
50	Cotton	*Gossypium* spp.	Malvaceae	Honeybees	41 insect spp visit flowers	Sidhu and Singh (1961)
51	Cowpea	*Vigna unguiculata* (Walp.)	Leguminosae	Honeybees	Bee, ant, flies	Rawal *et al.* (1978)
52	Crimson clover	*Trifolium incarnatum* Lin.	Leguminosae	Honeybees	Large bees	Free (1993)
53	Crown vetch	*Coronilla varia* Lin.	Leguminosae	Honeybees	Other bees	Anderson (1959)
54	Cucumber	*Cucumis sativus* Lin.	Cucurbitaceae	Honeybees	Other bees	Alex (1957b)
55	Cumin	*Cuminum cyminum* Lin.	Umbelliferae	Honeybees		Sihag (1986)
56	Currant	*Ribes* spp.	Grossulariaceae	Honeybees	Other bees	Free (1968)
57	Custard apple	*Abbona squamosa* Lin.	Annonaceae		2 beetles and black ants	Thakur and Singh (1965)
58	Date palm	*Phoenix dactylifera* Lin.	Palmae	Honeybees		McGregor (1976)
59	Dill	*Anethum graveolens* Lin.	Umbelliferae	Honeybees	Solitary bees	Warakomska *et al.* (1982)
60	Egg plant	*Solanum melongena* Lin.	Solanaceae			Levin (1989)
61	Egyptian clover	*Trifolium alexandrinum* Lin.	Leguminosae	Honeybees	69 insect spp visit flowers	Wafa and Ibrahim (1959)
62	Eucalyptus	*Eucalyptus* spp.	Myrtaceae	Honeybees		Ibrahim and Salim (1962)
63	Faba bean	*Vicia faba* Lin.	Leguminosae	Honeybees	Other bees	Kogbe (1972)
64	Feijoa	*Feijoa sellowiana* Berg.	Myrtaceae	Honeybees		Schroeder (1947)
65	Fennel	*Foeniculum vulgare* Mill.	Umbelliferae	Honeybees	Flies	Sagar (1981)
66	Fig	*Ficus carica* Lin.	Moraceae	Fig wasp		Ramirez (1969)
67	Flax	*Linum usitatissimum* Lin.	Linaceae	Honeybees	Other bees, flies, thrips	Alles (1977)
68	Garden pea	*Pisum sativum* Lin.	Leguminosae	Honeybees	Other bees	Free (1993)
69	Gooseberry	*Ribes uva-crispa* Lin.	Grossulariaceae	Honeybees	Other bees	Glushkov (1958); Jefferies *et al.* (1982)
70	Grape	*Vitis vinifera* Lin.	Vitaceae	Honeybees	Solatary bees, flies	Steshenko (1958)
71	Grapefruit	*Citrus paradise* Macf.	Rutaceae	Honeybees	Bumble bees, thrips, mites, flies	Burger (1985)
72	Greater yam	*Dioscorea alata* Lin.	Discoreaceae		Small night flying insects	Free (1993)
73	Guava	*Psidium guajava* Lin.	Myrtaceae	Honeybees	Other insects	Purseglove (1968)
74	Guayale	*Parthenium argentatum* A. Gray	Compositae	Honeybees	Beetles, flies	Mahmood *et al.* (1989)
75	Gurana	*Paullinia cupana* HBK	Sapindaceae		Wild bees	Prance (1985)
76	Hairy vetch	*Vicia villosa* Lin.	Leguminosae	Honeybees	Other bees	Weaver (1956a)
77	Horse bean	*Canavalia ensiformis* (L.) DC	Leguminosae		Other bees	Sastrapradja *et al.* (1979)
78	Horse gram	*Dolichos biflorus* Roxb.	Leguminosae	Honeybees	Other insects	Free (1993)
79	Indian mustard	*Brassica juncea* Lin.	Cruciferae	Honeybees	Flies, other bees	Sihag (1986)
80	Jackfruit	*Artocarpus heterophyllus* Lam.		Moraceae	Flies, beetles	Purseglove (1968)
81	Java indigo	*Indiofera arrecta* Hochst	Leguminosae	Honeybees	Other bees	Howard *et al.* (1915)
82	Jujube	*Zizyphus jujube* Mill.	Rhamnaceae		Bees, wasps, flies	Singh (1984)
83	Jute	*Corchorus capsularis* Lin.	Tiliaceae		Bees	Kundu *et al.* (1959)
84	Kenaf	*Hibiscus cannabinus* Lin.	Malvaceae	Honeybees	Wasps, other bees	Jones and Tamargo (1954)
85	Kiwifruit	*Actinidia deliciosa* (A. Chevalier)	Actinidiaceae	Honeybees	> 150 insect spp, spiders, mites	MacFarlane (1981; MacFarlane and Ferguson, 1984)
86	Lavender	*Lavandula* spp.	Labiatae	Honeybees	13 bee spp visit flowers	Herrera (1987)

Table 5. Cont. ……

87	Lemon	*Citrus limon* Lin.	Rutaceae	Honeybees	Bumble bees, thrips, mites, flies	Moffett and Rodney (1971)
88	Lespedeza	*Lespedeza* spp.	Leguminosae	Honeybees	Other bees	Graetz (1951)
89	Lettuce	*Lactuca sativa* Lin.	Compositae	Hoverflies	Wild bees	Watts (1958)
90	Lima bean	*Phaseolus lunatus* Lin.	Leguminosae	Honeybees	Other bees, thrips	Mackie and Smith (1935)
91	Lime	*Citrus aurantifolia* Swing.	Rutaceae	Honeybees	Bumble bees, thrips, mites	Hassanein and Ibrahim (1959)
92	Litchi	*Litchi chinensis* Sonn.	Sapindaceae	Honeybees	Wasps, flies, ants,	Pandey and Yadava (1970)
93	Locust bean	*Ceratonia siliqua* Lin.	Leguminosae	Honeybees	Flies	Linskens and Scholten (1980)
94	Loquat	*Eriobotrya japonica* (Thun.) Lind	Rasaceae	Honeybees	Bumble bees	Mann and Sagar (1987)
95	Lupin	*Lupinus* spp.	Leguminosae	Honeybees	Other bees	Forbes *et al.* (1971)
96	Macadamia	*Macadamia* spp.	Proteaceae	Honeybees	Beetles, wasps	Heard (1987)
97	Mandarin	*Citrus reticulata* Blanco	Rutaceae	Honeybees	Bumble bees, thrips, mites, flies	Hassanein and Ibrahim (1959)
98	Mango	*Magnifera indica* Lin.	Anacardiaceae	Honeybees	80 insect spp	Anderson *et al* . (1982); Wolfenbarger (1977)
99	Mesquit bean	*Prosopis* spp.	Leguminosae	Solitary bees	Honeybees	Habit *et al.*(1980)
100	Milk vetch	*Astragalus cicer* Lin.	Leguminosae	Honeybees	Other bees	Richards, (1987)
101	Muskmelon	*Cucumis melo* Lin.	Cucurbitaceae	Honeybees	Other bees, lady beetle	McGregor and Todd (1952)
102	Natal plum	*Carissa grandiflora* A. DC.	Apocynaceae		Some insects visit flowers	(Free, 1993)
103	Niger	*Guizotia abyssinica* Cass.	Compositae	Honeybees	Other bees	Panda *et al.* (1988)
104	Nutmeg	*Myristica fragrans* Houtt.	Myristicaceae	Beetle		Armstrong and Drummond (1986)
105	Oil palm	*Elaeis guineensis* Jacq.	Palmae	Honeybees	12 insect spp visit flowers	Syed (1982)
106	Okra	*Abelmoschus esculentus* (Lin.)	Malvaceae	Honeybees	Other bees, flies, beetles	Mishra *et al.* (1988)
107	Olive	*Olea europaea* Lin.	Oleaceae	Honeybees		Griggs *et al.*(1975)
108	Onion	*Allium cepa* Lin.	Alliaceae	Honeybees	267 insect spp collected from flowers	Caron *et al.* (1975; Bohart *et al,* 1970)
109	Opium	*Papaver somniferum* Lin.	Papaveraceae		Insects	Free (1993)
110	Papaya	*Carica papaya* Lin.	Caricaceae	Skipper, hawk moth	17 insect spp. visit flowers	Allan (1963)
111	Parsley	*Petroselinum crispum* (Mill) Nym.	Umbelliferae	Honeybees	Flies	Burgett (1980)
112	Parsnip	*Pastinaca sativa* Lin.	Umbelliferae		Solitary bees	Treherne (1923)
113	Passion fruit	*Passiflora* spp.	Passifloraceae	Honeybees	17 insect spp visit flowers	Cox (1957); Nishida (1958)
114	Peach	*Prunus persica* Lin.	Rosaceae	Honeybees	Solitary bees	Bulatovic & Konstantinovic (1962)
115	Peanut	*Rachis hypogea* Lin.	Leguminosae	Honeybees	Other bees	Rashad *et al.* (1978)
116	Pear	*Pyrus communis* Lin.	Rosaceae	Honeybees	Solitary bees	Weiss (1957)
117	Pepper	*Piper nigrum* Lin.	Piperaceae		Springtails	Free (1993)
118	Peppermint	*Mentha × piperita*	Labiatae	Honeybees	Flies	Free (1993)
119	Persian clover	*Trifolium resupinatum* Lin.	Leguminosae	Honeybees	Other bees	Weaver and Weihing (1960)
120	Persimmon	*Diospyros kaki* Lin.	Ebenaceae	Honeybees	Wasp, flies	McGregor, 1976)
121	Phalsa	*Grewia asiatica* Lin.	Tiliaceae	Honeybees	Flies, wasps	Parmar (1976)
122	Pigeon pea	*Cajanus cajans* (L.) Mill.	Leguminosae	Honeybees	Other bees	Williams (1977)
123	Pineapple	*Ananas sativus Schult.* f.	Bromeliaceae		Humming birds	Free (1993)
124	Plum	*Prunus domestica* Lin.	Rosaceae	Honeybees	Solitary bees	Mann and Singh (1981)
125	Pomogranate	*Punica granatum* Lin.	Punicaceae		Insects	Nath and Randhawa (1959)
126	Potato	*Solanum tuberosum* Lin.	Solanaceae		Bumble bees, bees	Sanford and Hannemann (1981)
127	Pumelo	*Citrus grandis* Osbeck	Rutaceae	Honeybees	Bumble bees, thrips, mites, flies	Hassanein and Ibrahim (1959)

Table 5. Cont. ……

128	Pumpkin	*Cucurbita moschata* (Duch)	Cucurbitaceae	Honeybees	Other bees	Free (1993)
129	Quince	*Chaenomoles* spp.	Rosaceae	Honeybees		Kim and Choi (1987)
130	Radish	*Raphanus sativus* Lin.	Cruciferae	Honeybees	Flies, other bees	Muhammad *et al.* (1973) Hussein and Abdel-Aal (1982)
131	Rambutan	*Nephelium lappaceum* Lin.	Sapindaceae	Honeybees	Wasps, files	Phoon (1984)
132	Rape	*Brassica campestris* Lin.	Cruciferae	Honeybees	Other bees, flies	Kapil *et al.* (1971)
133	Raspberry	*Rubus* spp.	Rosaceae	Honeybees	Solitary bees, thrips, flies	Johanston (1929) Hippa *et al.* (1981)
134	Red clover	*Trifolium pretense* Lin.	Leguminosae	Honeybees	Other bees	Hills (1941)
135	Rhubarb	*Rheum rhaponticum* Lin	Polygonaceae		Flies	Hawthorn and Pollard (1954)
136	Ridge gourd	*Luffa acutangulata* Lin.	Cucurbitaceae	Honeybees	Other bees	Free (1993)
137	Rocket cress	*Eruca sativa* Lam.	Cruciferae	Honeybees	Flies, other bees	Kapil *et al.* (1971)
138	Rubber	*Hevea brasiliensis* Muell-Arg.	Euphorbiaceae	Midges	36 insect spp visits flowers	Warmke (1952); Rao (1961)
139	Saffflower	*Carthanus tinctorius* Lin.	Compositae	Honeybee	Bumblebees, syrphid flies	Boch (1961); Deshmukh *et al.* (1985)
140	Sago palm	*Metroxylon sagu* Rottb.	Palmae	Honeybees	Trigona	Utmi (1986)
141	Sanfoin	*Onobrychis viciifolia* Scop.	Leguminosae	Honeybees	Other bees	Bogoyavlenskii (1976)
142	Sapindus	*Sapindus emarginaties* Vahl.	Sapindaceae	Honeybees	37 insect spp visit flowers	Reddi *et al.* (1983)
143	Sarson	*Brassica compestris* var *sarson* Lin.	Cruciferae	Honeybees	Flies, other bees	Mishra et al. (1988)
144	Scarlet bean	*Phaseolus coccineus* Lin.	Leguminosae	Honeybees	Large bees, humming bird	Free (1966)
145	Sesame	*Sesamum indicum* Lin.	Pedaliaceae	Honeybees	Wasps, flies	Panda *et al.* (1988); Rashad *et al.* (1979)
146	Silk cotton	*Ceiba pentandra* Gaertn.	Bombaceae		Bats and insects	(Free, 1993)
147	Sour cherry	*Prunus cerasus* Lin.	Rosaceae	Honeybees	Solitary bees	Free (1993)
148	Sour orange	*Citrus aurantium* Lin.	Rutaceae	Honeybees	Bumble bees, thrips, mites, flies	Hassanein and Ibrahim (1959)
149	Soybean	*Glycine max* Lin.	Leguminosae	Honeybees	Other bees	Erickson *et al.* (1978)
150	Spinach	*Spinacia oleracea* Lin.	Chenopodiaceae			
151	Squash	*Cucurbita pepo* Lin.	Cucurbitaceae	Honeybees	88 insect spp visit flowers	Girish (1981); Nevkryta (1953)
152	Starfruit	*Averrhoacarambola* Lin.	Oxalidaceae	Honeybees	Other bees, ants	Phoon (1983)
153	Straberry	*Fragaria × ananassa* Duch	Rosaceae	Honeybees	108 insect spp visit flowers	Free (1993)
154	Strawberry clover	*Trifolium fragiferum* Lin.	Leguminosae	Honeybees	Large bees	Morley (1963)
155	Sugarbeet	*Beta vulgaris* Lin.	Chenopodiaceae	Thrips	129 insect spp visit flowers	Shaw (1914); Free *et al.* (1975)
156	Sumatra indigo	*Indiofera sumatrana* Gaertn.	Leguminosae	Honeybees	Other bees	Howard *et al.* (1919)
157	Sunflower	*Helianthus annus* Lin.	Compositae	Honeybees	31 bee spp visit flowers	Sanchez and Ranera (1987)
158	Sunnhemp	*Crotalaria juncea* Lin.	Leguminosae	Other bees	Honeybees	Grewal and Singh (1979)
159	Swede rape	*Brassica napus* Lin.	Cruciferae	Honeybees	Flies, other bees	Mesquida and Renard (1987)
160	Sweet cherry	*Prunus avium* Lin.	Rosaceae	Honeybees	Solitary bees	Free (1993)
161	Sweet clover	*Melilotus alba* Desr.	Leguminosae	Honeybees	Other bees	Free (1993)
162	Sweet lime	*Citrus limettoides* Lin.	Rutaceae		Bumble bees, thrips, mites, flies	Nijjar and Sandhu (1971)
163	Sweet orange	*Citrus sinensis* Osbeck	Rutaceae	Honeybees	Bumble bees, thrips, mites, flies	Lange and Vincent (1972)
164	Sweet potato	*Ipomoea batatas* Lin.	Convolvulaceae		Wild bees	Thompson (1925)
165	Sweet vetch	*Hedysarum coronarium* Lin.	Leguminosae	Honeybees	54 bee spp visit flowers	Free (1993)
166	Tea	*Camellia sinensis* (Lin.) O. Kuntze	Theaceae	Flies	Bees, wasps	Free (1993)

Table 5. Cont. ……

167	Temarind	*Temarindus indica* Lin.	Leguminosae	Honeybees	Other bees	Bhaskar and Mahadevaiah (1990)
168	Thyme	*Thymus vulgaris* Lin.	Labiatae	Honeybees		(Ricciardelli D'Albore, 1988)
169	Tobacco	*Nicotiana tabacum* Lin.	Solabnaceae	Honeybees	Bumble bees	Free (1993)
170	Tomato	*Lycopersicon esculentum* Mill.	Solanaceae	Honeybees	Bumble bees	Free (1993)
171	Toria	*Brassica compestris* var *toria* Lin.	Cruciferae	Honeybees	117 insect spp visit flowers	Mohammed (1935)
172	Tree lucerne	*Chamaecytisus palmensis*	Leguminosae	Bumble bee	Honeybees	Webb and Shand (1985)
173	Turnip	*Brassica rapa* Lin.	Cruciferae	Honeybees	Flies, other bees	Sihag (1986)
174	Vanilla	*Vanilla* spp.	Orchidaceae	Humming bird	Other bees	Free (1993)
175	Watermelon	*Citrulus lanatus* (Thunb.)	Cucurbitaceae	Honeybees	Other bees	Free (1993)
176	White clover	*Trifolium repens* Lin.	Leguminosae	Honeybees	Other bees	Free (1993)
177	White mustard	*Sinapis alba* Lin.	Cruciferae	Honeybees	Flies, other bees	Hussein and Abdel-Aal (1982)
178	Wils	*Aleurites montana* (Lour.)	Euphorbiaceae		Aphids, thrips	Angelo *et al.* (1942)
179	Winged bean	*Psophocarpus tetragonolobus* (L.) DC.	Leguminosae	Xylocopa	Other bees	Erskine (1980)
180	Yellow clover	*Melilotus officinalis* Lin.	Leguminosae	Honeybees	Other bees	Sano (1977)

Source: Compiled from various sources

Crop pollination and yield increment

There are very few studies conducted to assess yield increment and impact of insect pollination in Nepal (Table 6, 7). But it is clear that insect pollinators play vital role in producing high yield due to their service in crop pollination. Importance of insects visiting flowers and pollination has been recognized in various crops in many countries (Free, 1993; Atwal, 2000; Crane and Walker, 1984; Verma and Jindal, 1997; McGregor, 1976). From the study, it seems essential to survey and collect insect species in various crop plants during their flowering periods, identify them and explore their potentiality as crop pollinating agents for managing production and productivity of various crops.

Table 6. Yield increment of different crops with natural and managed pollination over control in Chitwan

SN	Crop	Seed yield (kg/ha)			
		Control	Natural	*Apis cerana*	*Apis mellifera*
1	Broccoli	13	333	417	425
2	Rapeseed	68	623	1081	845
3	Buckwheat	50	361	583	481

Source: Devkota (2000); Dhakal (2003); Verma and Partap (1993)

Table 7. Impact of *A. cerana* pollination on vegetable seed production in hilly areas

SN	Crop	Increased in pod setting (%)	Increased in seed setting (%)	Increased in seed weight (%)
1	Cabbage	28	35	40
2	Cauliflower	24	34	37
3	Radish	23	24	34
4	Indian mustard	11	14	17
5	Lettuce	12	21	9

Source: Verma and Partap (1993)

Pollinators decline

Pollinators are products of millions of years of evolution and eroding at fast rate from the globe. The ecological consequence of contemporary agriculture can be viewed from various angles analyzing each component

of agriculture- deforestation for expanding agriculture, soil, irrigation, fertilizer, pesticide, and agronomic practices with their influence on the environment of plants and thereby pollinators.

Declining biodiversity

Decline biodiversity results decline in pollinators and *vis-à-vis*. About 75% of the genetic diversity of agricultural crops lost since the beginning of 20th century from the earth and 25% of the world's species present in the mid 1980 will be lost by 2015 (Raven, 1988; WRI/IUCN/UNEP, 1989; FAO, 1993). Over 85% of the 7000 or so apple varieties grown in last century are now extinct in the USA (FAO, 1993). In 1970, genetic uniformity of maize in USA, caused almost $ 1000 million loss and yield reduced by as much as 50%. Similarly, the broad breast turkey accounting for 90% of all turkeys in the US today would be extinct without AI. In Europe, half of the breeds of domestic animals that existed in the beginning of the century have been extinct and one-third of remaining in danger. Irish potato famine in 1840s is the result of genetic uniformity causing million people to die and million more to immigrate. Rice, one of the most important cereal crops in south east Asia, only 10 varieties cover third-fourth of rice area, over 30,000 grown before in the same areas in India. The apicultural problems are severe in the developing countries like Nepal. The word biodiversity is often spelled out by many people but pollinators are quite new to Nepal. The cost of conserving biodiversity is far less than the penalty of allowing its degradation. Global extinction rate of species are accelerating at an alarming rate (Table 8). Wilson (1988) estimated that 0.2-0.3% of all species are lost every year. Range of 5-10% of the tropical forest species may become extinct within the next 30 years (UNEP, 1993). It is estimated that 60,000 species will be eliminated in the foreseeable future and 50,000 species will be at risk of extinction in the next half of the century.

Table 8. Estimate loss of species on earth

SN	Species loss	Global loss per decade (%)
1	1 Million species (1975-2000)	4
2	15-20% of species (1980-2000)	8
3	25% of species (1985-2015)	9

Habitat loss

Natural forests that play a vital role in maintaining ecological balance, providing energy, animal fodder and timber and recharging water tables, are being degraded day by day causing habitat loss of other life system and ultimately threatening biodiversity and associated pollinators in Nepal. A constant rise in the population, higher rate of deforestation, and over-exploitation of resources with expansion of farm lands for agriculture and rearing livestock, cause a continuous depletion of the forest resources (Tables 9). The lowland and mid-hill fauna are more endangered than mountain fauna (Table 10). Kaiser -I-Hind is the rear species of butterfly listed in IUCN Red Book. This is mainly due to greater human activity in lowland and mid-hills. Since 1945, 17% of the earth's vegetative land (1.2 billion ha) degraded, to an area equivalent to China and India together. To meet the need, the agriculture is expanding and pollinators' habitat is being lost so rapidly that sustainable agriculture is in jeopardy.

Table 9. Changes in forest and shrub-land cover in Nepal

SN	Year	Forest (% of total land area)	Shrub-land (% of total land area)	Total
1	1978/79	38.0	4.7	42.7
2	1990/91	29.0	10.6	39.6

Source : HMGN/MFSC (2002)

Table 10. Number of threatened butterfly species according to physiographic zone

SN	Threatened Category	Lowland	Mid-hill	Mountain
1	Endangered	0	12	0
2	Vulnerable	7	28	11
3	Susceptible	31	63	7
	Total	38	103	18

Source : BPP (1995)

Honey hunting

Visit and observation trip of Khandarjung and Dalambhir, and discussion with a honey hunter (Mr. Min Bahadur Gurung) revealed that there were no colonies of *A. laboriosa* honeybees from 1985 to 1995 as a result of destructive honey hunting methods followed by the local honey hunters and in fact, only one two colonies appeared in 2000 (Thapa, 2006). Similarly, as a result of habitat destruction and honey hunting, the wild honeybees, *A. dorsata* has been declining in Chitwan by more than 50% in the year 2004 as compared to 2003 (Pokhrel, 2006).

Introduction of new species

Apis mellifera Lin. is the exotic honeybee of European origin and imported in the country for honey production. Partap *et al.* (2000) in the field study in Kathmandu valley reported that worker bees of *A. mellifera* carried significantly heavier pollen loads from both peach and plum flowers than those of *A. cerana* worker bees. However, studies conducted on the pollination of strawberry showed that *A. cerana* collected heavier pollen loads during morning and noon hours showing time and crop specificity. But the introduced species, *A. mellifera* completely replaced domesticated native *A. cerana* bees as indicated by the absence of worker bees during early, mid and late hours under Chitwan condition (Figure 1). In addition, beekeepers in terai regions are keeping *A. mellifera* and slowly replacing the native honeybee *A. cerana*, and thus a decline of *A. cerana* bees has been recorded in the terai regions.

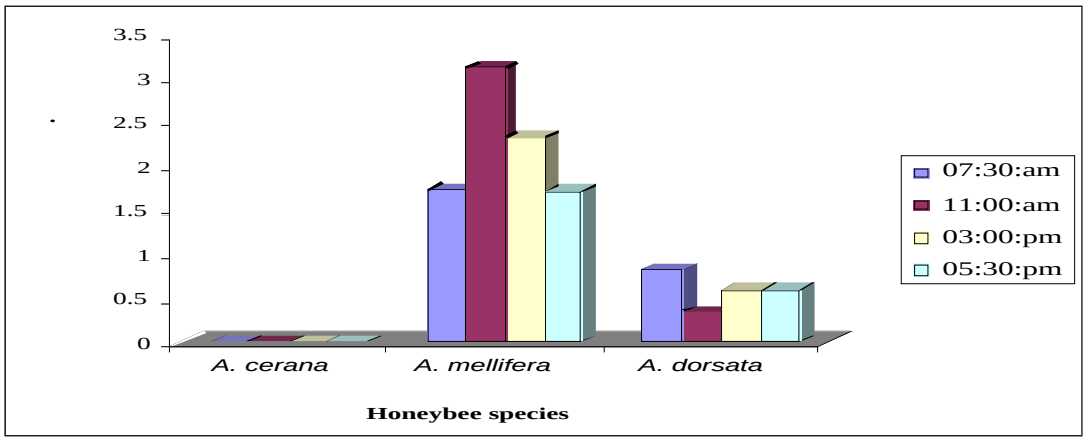

Figure 1. Interactions of honeybee species while foraging radish flowers during different time of the day in Chitwan

Diseases and pests

Nepal did not know any serious bee disease until 1980, when the serious outbreak of the sacbrood disease caused by the Thai sacbrood virus, occurred first along the eastern border areas. The disease spread so fast that within four years it covered the entire length of the country, and reached to peak in western border areas within three years. During the time, almost 90% of the colonies lost (Kafle, 1992; Shrestha and Shrestha, 2000). By 1984, the disease started to subside and the bees started to regain normal condition again from the eastern border. The Asian mite, *Varroa jacobsoni* is associated with *A. cerana* and *A. dorsata* bees but causes no serious problem to them, but it is fatal to *A. mellifera* colonies. *A. mellifera* colonies may collapse in the near future unless timely precautionary measures taken. Farmers' training to beekeeping in modern hives, regular supervision and seasonal management seem necessary to establish good apiaries free of disease and pests.

Pesticide pollution

Insects are viewed from the harmful perspectives and aimed at killing them through several means including indiscriminate use of deadly chemicals. The demand of pesticides increased in Nepal with the introduction of high yielding varieties of crops, massive input of chemical fertilizers and irrigation facilities which improved the agricultural productivity considerably but also created multi-faced problems resulting in a large amount of crop losses and turning ecological sound farming into pest problems, crop loss and pesticide pollution (Thapa, 1994; Thapa *et al.*, 1995). The use of chemical pesticides is concentrated in standing crops and post harvest loss

protection in agriculture, and control of malaria and black fever in public health sectors. Several studies estimate that the use of pesticides in agriculture worth of over 50 million rupees and this guess could be as high as 500 million rupees in agriculture, agro-forestry, and human health. Among the crops, cotton receives the highest amount of pesticides (2560 g/ha) followed by tea (2100 g/ha) and then vegetable farming (1450 g/ha) as compared to the national average of 142 g/ha (Table 11).

Table 11. Consumption of pesticides in commercial farming in Nepal

SN	Commodity	Pesticide use
1	Cotton	2560 g/ha
2	Tea	2100 g/ha
3	Vegetable	1400 g/ha
4	National Average	142 g/ha

Source: Sharma (1994); Thapa (1994, 1999).

Regarding the type and volume of pesticide used by the farmers both the types and volumes decline from terai to mountain sharply (Thapa *et al.*, 1995; 2003). Commercial farmers have no sufficient understanding of pesticide handling, safe application and pollution to the environment.

Both the misuse and excessive use of pesticides disturb the natural ecosystem and produce serious environmental problems adding costs in four ways to the people: i) health related expenses, ii) environmental pollution, iii) yield loss due to non-target pesticide application resulting in pesticide induced pest resurgence and destruction of natural enemies and iv) financial burden both to poor farmers and the country as a whole (Baker and Gyawali 1994). Pesticide problem on pollinators is severe in the developed country like USA (loss of about 320 million US$/year) and is equally important for other countries as well. After the heavy use of chemical pesticides all domesticated bees were wiped out in Ilam and Nuwakot and many colonies were destroyed in Chitwan (Sharma 1994; Thapa, 1994; 1999).

A survey conducted very recently to record flower visitors in insecticide sprayed and non-sprayed mustard crop is presented in Table 12. The insect flower visitors in non-sprayed mustard field were recorded over three times higher (19 insects species) than those in sprayed field (6 insects species only). It is clear that pesticide spray has been one of the various factors for pollinators decline. Therefore, it is essential to survey and collect insect species in various crop plants during their flowering periods, identify and conserve them, and explore their potentiality as crop pollinators.

Table 12. Insect flower visitors in sprayed and non-sprayed mustard crop in Chitwan

SN	Common name	Scientific name	Sprayed field	Non-sprayed field
1	Lady beetle	*Coccinella* spp.	-	+
2	Bumble bee	*Bombus* spp.	-	+
3	Yellow banded wasp	*Xylocopa* spp.	-	+
4	Rice skipper	*Pelopidas methias* (F.)	-	+
5	Tiger moth	*Nyctemers lactinia*	-	+
6	Cowpea pod borer	*Lampides boeticus* L.	-	+
7	Cynthomid fly	*Cyntomis passalis* (F.)	-	+
8	Mustard sawfly	*Athalia lugens proxima* (K.)	-	+
9	Nymaphalid butterfly	*Presis atlites*	-	+
10	Mud wasp	*Chlorion labatum*	-	+
11	Short horned grasshopper	*Oxya* sp.	-	+
12	Green stink bug	*Nezara viridula* (L.)	-	+
13	Blister beetle	*Mylabris* spp.	-	+
14	European honeybee	*Apis mellifera* L.	+	+
15	Asiatic honeybee	*Apis cerana* F.	+	+
16	Rock bee	*Apis dorsata* F.	+	+
17	Syrphid fly	*Milesia* sp.	+	+
18	Tabanid fly	*Tabanus* spp.	+	+
19	Hymenopteran wasp	*Sphex macuta*	+	+

+= present; - =absent

Global warming and climate change

Global warming is caused by something known as the green house effect, brought about by the ability of the atmosphere to be selective in its response to different types of radiation. CO_2, (56%) CH_4 (14%), CFCs (23%) and N_2O (7%) are main green house gases of which, CO_2 accounts more than 50% for global warming (Table 13). Atmospheric temperature increased by 1.5 to 5.5^{0}C by the year 2030, causing loss of 10-15% arable productive costal land due to melting of polar ice caps and raise of sea level and CO_2 concentration increased from 290 ppm 100 year ago to 350 ppm today and likely to go up 440-500 ppm by 2100.

Table 13. Human activity releasing key green house gases

SN	Effects	CO_2	CH_4	CFC	N_2O
1	Increase in a atmospheric concentration				
	Pre-industrial to 1990	26	115	-	8
	Post-industrial : 1990 to 2025	23	51	-	10
2	Concentration to the change in heat trapping				
	Pre-industrial to 1990	61	23	12	4
	Post-industrial : 1990 to 2025	81	17	10	5

Source : APP (1995)

European scientists have warned that a long-term two degree Celsius or more increase in the average global temperature could threaten Latin America water supplies, reduced food yield in Asia and rise in extreme weather condition in the Caribbean. Global warming alters precarious habitats or eliminates food supplies. Based on the sample of 1,103 land plants and animals, it has been estimated that 15% to 37% would eventually become extinct as a result of climate change expected by 2050. Similarly, Californian scientists analysing 9,787 living and 129 extinct bird species, reported that tenth of all bird species could be extinct by 2100 and by then another 15% could be on the brick of extinction. The vulture population of India has crashed down by 95% in the last decade. These birds keep down insect populations, spread seeds, and pollinate flowering plants and scavenge on carrions.

More intense and erratic rainfall events are expected to be a feature of climatic change. The fate of agriculture of Nepal lies on rainfall, early rainfall in April, May in the hills and mountain to sow the seed of corn with some rainfall in June and heavy rainfall in July for rainy season crops. If this does not happen then entire hills become famine stricken area. Similarly, agriculture in terai area starts with early rainfall in July and heavy but discontinuous rainfall up to the end of September (some time up to December). First rain helps paddy plantation and second rain helps wheat plantation. If one failed the second crop is also likely to be failure unless artificial pumping ground water or irrigation water provided. Climatic changes have been realised for past few years. Hills are getting more landslides and glacial lakes out burst and more of cloud burst brought in scattered rain. Terai is experiencing heavy rain in some area and drought condition in other areas. It appears that country's modulation capacity to absorb heavy flood and increase low flow has now changed because of environment degradation which directly influence habitat and its biotic flora and fauna.

Level of knowledge/ awareness

Two studies (Partap and Partap, 2002; Thapa, 2002) reveal that level of knowledge about biodiversity conservation, pollination and pollinators in Nepalese farmers are inadequate. Majority of farmers are not aware of biodiversity conservation and natural pollinators or managed pollination of crops (Tables 14, 15). Farmers survey revealed that more than 90% of the citrus farmers had no idea of pollinator and pollination of citrus and very few farmers (15%) had local bees in hive which is just for honey production and not for managed pollination, neither they were aware of biodiversity conservation and environment protection (ICIMOD, 2003).

Table 14. Farmers response related to biodiversity conservation

SN	Particular	Response (No)	Percent
1	Aware of biodiversity and their conservation	2	4
2	Unaware of biodiversity and their conservation	53	96
	Total	55	100

Source : Field survey

Table 15. Farmers awareness on pollinators visiting citrus flowers

SN	Particular	Response (No.)	Percent
1	Aware	2	4
2	Unaware	53	96
	Total	55	100

Source : Field survey

National policy on pollinators

It is clear that insects including honeybees are unquestionably the main pollinating agents for many crop plants. Their role in pollinating vast array of flowering plants and maintaining biological diversity is beyond the imagination of poor farmers, politicians, policy makers and even scientists are in dilemma. Beekeeping is known for honey production as well as pollination services to crops, but the later has received no attention in research and development activities in Nepal. Beekeeping important service of pollination has not only been underplayed by the planners, government authorities and also the agriculturists have ignored altogether.

Conservation and utilization of pollinators

Honeybees show preference to more attractive floral rewards neglecting the less attractive ones (Free, 1980). When two or more species of bees compete for the same floral sources, the stronger and more competitive species displace the weaker one from the resources and geographic areas affecting crop pollination. Presence of *Apis mellifera* Lin. displaced and reduced the number of *Apis cerana* Fab. honeybees from the resources (Neupane, 2001; Mishra, 1997/98). It has become increasingly clear that the pollination needs of a crop species varies greatly with the locality and cultivar concerned, so ideally pollination investigations are necessary in each general locality where crop is grown. Plant species are now grown for food, or other uses, in many parts of the world far from where they originated, and sometimes in absence of their natural pollinators. In such circumstances, careful consideration should be given to import natural pollinators with the introduced plant species.

In addition, increased need for hybrid seed production has often posed several pollinating problems and indeed the breeders of insect pollinated crops should always ensure that the quality and quantity of pollen and nectar produced will attract sufficient pollinators even when competitive sources are nearby. Pollinator's distribution is not systematic; some areas overcrowded with bees and others having practically none. Proper placement of the pollinators and even their attraction to pollinating crops is necessary for good result for ensuring effective pollination. If placed properly, honeybees worked equally well in all directions and were evenly spread in flowers (Ingram *et al.,* 1996).

For several decades, bee researchers and beekeepers have tried to conserve pollinating insects like honeybees providing nesting sites and good forage, and protecting them from pesticides. Managed pollination of crops that has been largely neglected part of agriculture requires due attention to increase productivity and quality. In this regard, little work has been done on the number of bee visits per flower, or the effect of cross-visitation between cultivars in relation to fruit set on crop cultivars either dependent upon or benefited by bee pollination. Some recommendations have been made, without support or data, on colonies per hectare and suggested placement. There is no indication given as to the relative bee population per unit of flowers and also no relation is shown between colonies per hectare and bees per flower. Studies on the foraging preference and effect of foraging competition of different honeybee species to crop pollination should find priority in future research for different ecological regions of Nepal.

In the developed countries, insect pollination has increased considerably during the past few decades and arrangements for insect pollination are now part of standard management practices when growing many crops. For example, in the USA alone, over million honeybee colonies are rented annually for pollination services. With hybrid seed production, it is likely that demands for pollination will become greater still in the near future. In the developing countries like Nepal, pollination by honeybees and other pollinators is completely neglected by everyone- policy makers, naturalists, researchers, extension workers and farmers. Rather it is just opposite that farmers are complaining loss of crops due to bees and other pollinators considering them as crop pests.

Knowledge about pollinators among university researchers exist to some extents, and as a result of realization of importance of this subject, university curricula, particularly at M.Sc. level (Botany, Entomology, Zoology)

have included pollination, pollinators, biological resources, palynology, useful insects, etc.). As far as conservationists are concerned they have given emphasis to large mammals, birds, and reptiles, and almost nil to insect pollinators. Honeybees have been definitely concerned for honey production and Nepal is rich in traditional knowledge of beekeeping and honey production.

Over 66 laws, 38 rules and regulations, 39 executive orders and 39 by-laws in Nepal are of direct concern to agriculture. Out of these, 17 laws are agriculture specific addressing agricultural issues, agricultural trades and agro-industries. Reviews of these acts and regulations in the country reveal that none of them spell out the word pollinators and their conservation. Biodiversity can not be isolated from pollinators' diversity, and therefore, there is a need to address pollinators and their conservation issues in existing acts and regulations to take care of pollinator issue. Community members as users of local resources should be aware about importance of wild bee conservation for environment improvement, and benefit sharing.

At the present day, there is now a general increased environmental awareness for sensible habitat management that may help pollinators likely to increase. Discovering potential pollinators, devising management techniques, and increasing their population for commercial exploitation will take several years. Research studies are needed in this direction to conserve honeybees and other natural pollinators, exploit their potentiality in crop pollination and allow them to develop in the pollution free environment.

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