The Scope for Managed Crop Pollination

Economic Effectiveness of Managed Crop Pollination

To determine the economic effectiveness of bee pollination within the limits of an individual farm or an administrative region, experimental data on the increase in yield for soil types on a certain farm or the average for an entire region are necessary. To carry out such work, it is necessary to know the average increase in yield for different soil types in a district, province, or the whole country. It is appropriate to use the average data on the increase in yields after bee pollination over a number of years. These data should be expressed in percentages of total yield per hectare rather than in natural values. The basis for determining the economic effectiveness of managed crop pollination is provided by data on the increase in yield. Unfortunately, these data are not yet available for the HKH Region, but data are available from other parts of the world for most of the crops responsive to bee pollination.

The promotion of managed crop pollination has been a common practice in the State owned and community farms in the former USSR for the past three decades and more. Therefore, the method and the subject matter are exemplified here by studies carried out in the former USSR (Saldatov 1976). The average indices for increase in yield, which are expressed in percentages of the total yield per hectare, were: fruit crops-35, lucerne-65, red clover-82, sunflower-35, buckwheat-39, mustard-56, rape-30, coriander-35, cucurbits-25, cotton-28, cucumber-11, grapes-29, and linseed-19. This increase in productivity is converted into net gains of production countrywide, using the total area under crops pollinated by bees and the total production of grains, seeds, or fruits and calculating the additional production.

The expenses incurred in establishing apiaries are set off by the economic benefits accruing from the pollination of crops, depending on the crops pollinated. These expenses include the work of the apiarists and a certain degree of depreciation and mortality, nominal expenses for feeding the bees, and so on. The annual expenditure for managing beehives for pollination has been estimated at about 30 per cent of the total direct and indirect expenses, indicating a high degree of economic efficiency for this process (Soldatov 1976).

The expense of rearing bees for crop pollination, in spite of substantial returns, unfortunately, is not included in the cost of production of pollinated crops. This harms not only the bee industry but also crop husbandry. The extremely profitable cottage industry in bees is considered to be a part of the agricultural economy operating on minor gains in income.

Further, the economic effectiveness of managed crop pollination with bees is characterised by the cost evaluation of the additional yield and expenditure and also by the impact on the cost of producing the main products.

Primacy of Honeybees for Crop Pollination

Pollination of crops by honeybees is one of the most practical and most promising methods of increasing crop production. Honeybees have flower fidelity/constancy, have a potential for long working hours, and can be managed in sufficient numbers where and when required. Bees collect pollen and nectar to supply to the next generation, whereas other insects collect for their individual needs only. Bees, therefore, make more flower visits. Their long tongues, coats of long collecting hairs, and the ability to warm themselves and to work in cool weather make them generally more efficient pollinators than most other insects.

The practical use of honeybees for this purpose began in 1895 in the U.S. when honeybees were used as pollinators to avoid crop failure in Virginia (Waite 1895) and used for apple pollination in other states of the USA (Benton 1896). Therefore, over the past few decades, researchers have included other agricultural and horticultural crops within the scope of honeybee pollination (Sakharov 1958; Radchenko 1966; Kozin 1976; McGregor 1976; Manzoor et al. 1978; Adlakha and Dhaliwal 1979; Manzoor and Muhammed 1980; Crane and Walker 1984; Kevan 1984; Deshmukh et al. 1985; Dulta and Verma 1987; Verma 1990).

HKH Experiences of Managed Crop Pollination

Realising the valuable role honeybees play in increasing yield and improving the quality, beekeeping is now being promoted as an essential component in the pollination of fruit crops and in vegetable seed production in the HKH Region. Farmers in Himachal Pradesh now use honeybees to pollinate apples and other fruits. The government of Himachal Pradesh has created an institutional infrastructure for rearing and managing bee colonies, and it rents these to farmers at a nominal cost of one US$ per colony per season as an encouragement to farmers. Some of the farmers have started bee-rearing on a large scale for rental purposes also. The use of honeybees for crop pollination is also increasing in the Chinese Himalayas (ICIMOD 1996a; 1996b; 1996c).

The results of ICIMOD's research on vegetable and fruit crop pollination reconfirm the usefulness of bee pollination and its role in increasing crop productivity and improving the quality of fruits and seeds (Partap and Verma 1992; 1994; Verma and Partap 1993; 1994). Table 3 sums up the findings of experiments carried out by ICIMOD staff on popular vegetable cash crops in the Kathmandu Valley.

Table 3: Honeybee (*A.cerana*) Pollination Impacts on Vegetable Seed Productivity in the Hills

Crop	Increase in Pod Setting (%)	Increase in Seed Setting (%)	Increase in Seed Weight (%)
Cabbage	28	35	40
Cauliflower	24	34	37
Radish	23	24	34
Indian Mustard	11	14	17
Lettuce	12	21	9

Source: Verma and Partap 1993

Box 1: Economic Value of Bee Pollination: Some Experiences

Many economic estimates of the value of managed honeybee pollination to crop production in different countries have been worked out. For example, the value of bee pollination in crop production is estimated at US$ 20 billion per year in the USA (USDA-ARS 1991); Canadian Dollars 1,200 million in Canada (Winston and Scott 1984); and about 3,000 million dollars in the EEC (Williams 1992). Cadoret (1992) worked out bee pollination inputs to crop productivity for 20 countries in the Mediterranean region to be almost US$5.2 billion annually; of this, US$3.2 billion is estimated to go to agricultural production in the developing countries of the region.

The value of bee pollination for New Zealand's economy has been calculated at about US$ 2,253 million per year (Matheson and Schrader 1987), almost 113 times more than the bee products sold by New Zealand's beekeepers. This also includes the value of nitrogen-fixing on New Zealand's pastures by honeybee pollinated legumes.

In the former USSR, researchers have shown that, given the constancy of other conditions, bee pollination gives an additional yield of buckwheat on an average of 3q/h. For the whole of eastern Siberia, this increase would amount to 90,000 quintals of additional grain.

In China, the economic values of honeybee pollination on four major crops, viz., rape, cotton, tea, and sunflower, have been estimated to be more than 6 billion *yuan* (US$ 0.7 billion), which is six to seven times more than the direct income from bee products (Chen 1993). Though attempts have not been made to estimate the value of bee pollination in the countries of the Hindu Kush-Himalayan Region, it is undoubtedly considerable.

Scientific evidence confirms that bee pollination also improves the yield and quality of other vegetable crops grown by mountain farmers such as asparagus, carrots, onions, turnips, and so on (Deodikar and Suryanarayana 1977). When bees are used for the pollination of popular fruit crops in mountain areas, it improves the fruit set, reduces fruit drop, and improves fruit quality in apples, almonds, apricots, cherries, citrus, guavas, litchis, peaches, pears, plums, persimmons, and strawberries (McGregor 1976; Ahmad 1987; Dulta and Verma 1987; Free 1993). Experimental evidence also indicates the positive effect of bee pollination on productivity of forage crops (Deodikar and Suryanarayana 1977); of cardamom, a high-value spice crop from Sikkim and Ilam (Chandran et al. 1983); of buckwheat (Suryanarayana and Deodikar 1977); and of the main oil seed crops such as mustard, sesame, safflower, niger, and sunflower (Rao et al. 1984).

Simplicity of Crop Pollination Technology

After years of research and experimentation, scientists have developed farmer-friendly techniques of honeybee pollination for a number of agricultural and horticultural crops (Kozin 1976; Free 1993; Verma 1990). For example, a simple and very effective method of pollinating vegetable crops with honeybees is by introducing large bee colonies (each colony consisting of at least 7-8 frames covered with bees) in the field when flowering is about five to ten per cent. The colonies are kept in the field until the flowering period ends. Large, strong colonies are better pollinators because large colonies usually have more older bees as foragers. The number of colonies required depends upon the number of flowers and the strength of the bee colonies. In general, two colonies of *A. mellifera* per hectare of crops in bloom are recommended. Keeping in mind the small size and shorter flight range of *A. cerana*, three to four colonies per hectare are recommended (Verma 1990).

Table 4. Increase in Crop Productivity due to Bee Pollination

Increase in Fruit Production (x times)		Increase in Seed Production (x times)	
Production (x times)			
Apples	x24	Large Cardamom	x10
Lemons	x15	Mustard	x1.4 - 1.6
Litchis	x2	Turnips	x1.2
Peaches	x2	Sesame	x1.3
Pears	x14	Sunflower	x1.5
Persimmons	x1.2	Onions	x1.7
Plums	x6		

Source: Eva Crane 1991

Eva Crane (1991) has summed up the experimental findings and experiences of crop pollination with honeybees. Table 4 illustrates the key findings of her work.

Factors Controlling the Quality of Pollination

The quality of pollination is presumably determined by the strength of the colonies participating in the pollination of crops. Years of research and experiment attest the effectiveness of managed crop pollination (Baga 1976). Research also indicates that the greatest efficiency can be achieved by bringing the requisite number of healthy and strong beehives to crop areas in order to ensure complete pollination, or saturation. The value of achieving saturation is that crop yields are 15-20 times greater (Baga 1976). Experiences from pilot experiments and practical farming have shown that the best results are obtained by using large bee colonies, each of which contains 50,000-70,000 worker bees (*A. mellifera*). A small bee colony performs four to five times less pollination work than a large one.

Actual guidelines for the saturated pollination process have to be worked out by researchers for each area and region. For example, in the Ukraine, scientists have set the following conditions; in spring, keeping the bees in multi-framed hives, a strong bee colony may occupy 10 or more frames, a moderate colony seven to nine frames and a weak colony fewer than six frames (Baga 1976). During summer, this number is reduced to four, three, and two, respectively. As an incentive to good management on the part of apiarists and satisfactory pollination of agricultural crops, Russian scientists practised a system of Crop Certification Ratings of Bee Pollination. This certificate indicated the number of bee colonies in the field for the pollination of a particular crop and specified the colony strength. The impact on quality and quantity of crop produce was estimated from these two factors.

The arrangement of colonies in crop fields is important in order to ensure uniform distribution of foraging bees and, thus, uniform pollination of crops. Honeybees primarily visit those sources of pollen or nectar that are within a 300-500m radius from the apiary. At a distance of over 500m, the number of foragers decreases, and thus the pollination activity diminishes significantly. Therefore, for effective pollination of crops it has been recommended to distribute the bee colonies inside the field instead of placing them into groups.

Box 2: Role of Insect Pollinators on Yield and Quality of Apple Crops

Most of the commercial varieties of apples give good yields only after cross-pollination. Cross-pollination is carried out by insects, because the role of wind in cross-pollination of apple bloom is negligible; this is because of the sticky nature of apple pollen. The results of experiments carried out in the Shimla hills of Himachal Pradesh show that bee pollination provides a major contribution to improving fruit set in apple orchards. In the absence of insect pollination, particularly in self incompatible varieties of apples such as the Royal and the Red Delicious (the two most popular types with farmers from a commercial point of view), fruit set does not take place. Although some varieties, such as Golden Delicious, may require bee pollination to contain the percentage of fruit drop, experiments also ascertained that bee pollination significantly improves the quality of apples in terms of weight and size.

_____Dulta and Verma 1987

The findings of experimental research carried out in the Kullu and Shimla hills of Himachal Pradesh also suggest that in apple orchards with 20 per cent pollinizer*, placing bee colonies in groups of four, each group separated by 50m, gives maximum fruit set. In apple orchards having only three per cent pollinizer, better fruit set is possible by keeping three colonies in a group than by distributing them singly. Under the ideal pollinizer ratio of 30 per cent, farmers can achieve a better fruit set of 30-44 per cent by keeping four bee colonies per hectare.

_____Gupta et al. 1993

* Refers to the plant supplying the pollen

Efficiency and Complementarity between A. cerana and A. mellifera

There are at present five species of honeybees found in the Hindu Kush-Himalayan Region. Among these, *A. cerana, A. dorsata, A. florea,* and *A. laboriosa* are native to the region, but only *A. cerana* are kept in hives in order to collect honey. The European hive bee, *A. mellifera,* was introduced into this region over the last few decades because it produces more honey. It is already popular with lowland and hill farmers in countries of the Hindu Kush-Himalayan Region. Also, the institutional support for beekeeping is mostly directed to the promotion of *A. mellifera* for honey production only.

So far, attempts to keep other species of honeybees in hives have not succeeded. These species make their single comb nests in the open air on branches of trees or on rock overhangs on vertical cliff faces, and local communities collect honey through traditional honey hunting methods.

The Asian hive bee, *A. cerana,* and the European hive bee, *A. mellifera,* are comparable in many ways, and both have their advantages under different mountain farming conditions. Under the low and mid-hill subtropical conditions of the HKH region, it is observed that *A. mellifera* performs better than *A. cerana* in terms of honey production and has prolific queens. It is also observed to have less swarming and absconding tendencies. However, scientists have warned against the trend of replacing *A. cerana* with *A. mellifera* which has led to the near extinction of several races of *A. cerana* from these areas of the HKH (Verma 1994). This is an unwelcome process of erosion of genetic diversity.

In addition, there are reports about the comparative advantages *A. cerana* has over *A. mellifera* in the cooler mountain climates of the HKH Region, in terms of both honey production and pollination purposes. In fact, this point can be used as a basis of the strategy for saving *A. cerana* through proper use.

While searching for complementarity between the two species, one finds that they differ in some of their behavioural aspects, particularly in terms of foraging behaviour and habitat preference. From the point of view of crop pollination, these are the key attributes of honeybees; these characteristics differ between the two species vis a vis efficiency in pollinating crops in different agroecological zones. Whereas *A. mellifera* is successful at lower altitudes and in the plains, *A. cerana* has a broader ecological coverage and is therefore used by farmers from the plains to the high mountains. Its more productive strains are, however, found in high mountain areas, e.g., Jumla in Nepal, Himachal Pradesh and Kashmir in India (ICIMOD 1994a; 1994b), and Yunnan in China (Bangyu and Tan 1996).

Studies on the comparative effectiveness of *A. cerana* and *A. mellifera* in pollinating different vegetable and fruit crops in the hills/mountains have shown that *A. cerana* is a better pollinator of vegetable and fruit crops flowering during early spring (Partap and Verma 1992; 1994; Verma and Partap 1993; 1994). Compared to *A. mellifera, A. cerana* begins foraging earlier in the morning and ceases late in the evening. *A. cerana,* thus, continues pollinating for a longer period of time on a particular day. It also visits and pollinates more flowers per minute than *A. mellifera* (Table 5).

Table 5. Comparative foraging behaviour of *A. cerana* and *A. mellifera*. (Values are mean±SE)

Parameter	Peaches		Plums		Pears	
	cerana	*mellifera*	*cerana*	*mellifera*	*cerana*	*mellifera*
Commencement of foraging activity (time of day)	0701 ± 3	0734 ± 3	0710 ± 2	0740±3	0655 ± 5	0720 ± 4
Cessation of foraging activity (time of day)	1806 ± 2	1745±5	1801±5	1740±3	1803±5	1803±4
Total duration of foraging activity (hrs)	11.1 ± 0.8	10.11±0.9	10.5±0.2	10.00±0.3	11.35±0.8	10.43±0.9
Peak hours of foraging activity (time of day)	1100 - 1400	1100-1300	1100-1400	1000-1300	1100-1400	1000-1300
Duration of foraging trip	20.2 ± 2.7	25.3±3.1	21.4±1.3	24.9±2.5	19.8±1.5	22.6±1.8
Number of flowers visited per foraging trip	187.1 ± 3.5	205.1±2.8	168.3±3.8	273.5±3.7	229.2±8.8	282±5.2
Number of flowers visited per min.	TW 9.74 ± 1.2 SW 4.1 ± 0.9	8.9±1.5 3.4±1.0	8.8±1.1	15.0±2.2	13.6±1.3	12.5±0.9
Time spent (s) per flower	TW 4.8 ± 1.6 SW 12.6 ± 1.3	5.4±1.5 16.4±1.7	6.8±2.9	4.6±1.8	3.4±0.9	3.2±0.7
Ratio of top workers (TW) versus side workers(SW)	9:1	2:8	10:0	9:1	10:0	9:1
Weight of pollen loads	14.5 ± 2.2	15.4±2.4	13.1±1.7	17.1±2.0	13.5±1.8	24.8±3.4
Number of bees/1,000 flowers at a distance of 0-250m 250-500m	11.8 ± 2.4 5.6 ± 1.9	11.0±1.6 5.5±1.3	9.4±3.5 5.5±1.1	7.1±1.2 4.2±1.8	8.5±1.0 5.3±0.8	6.3±1.0 3.1±1.5

Source: Partap 1996

In the Hindu Kush-Himalayan Region, both species are being used for crop pollination. *A. mellifera* has been found to be more suitable for beekeeping in the low hill areas. Beekeepers produce more honey from these bee species and the farmers benefit from their pollination services. However, under the agroecological conditions prevailing in mountain areas, beekeeping with *A. mellifera* is not viable. This species is very susceptible to cold, and this results in high mortality during winter. Therefore, as a management strategy, the colonies need to be transferred to the low hill/plains during winter, i.e., from November to March. In the

Gilgit area of the North West Frontier Province of Pakistan, where *A. mellifera* has been introduced on a large-scale, reports are that it is not effective in pollinating fruit crops that flower during late winter or early spring.