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The Role of Honey Bees *Apis mellifera* L. (Hymenoptera: Apidae) in Pollination of Apple

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Abstract: Five varieties of apple trees were tested against the concentration of honey bees at their blooming stage. Most of the apple varieties require cross-pollination with another compatible variety. The role of honey bees foraging activities in apple fruit production was significantly enhanced. The fruit quality (Fruit size and number of seeds) were also found superior when main commercial varieties were benefited with pollinizers. Closely related pollinizer varieties were less benefited from each other. Bees prefer to work up and down rows rather than across rows. There was a significantly high yield (140-170 kg) in un-caged Starkrimson and Kala kulloo as compared with caged Starkrimson and Kala kullo (35-42 kg). The foraging honey bees and Bumble bees preferentially visit umbels that bear large number of open male phase flower. Individual bees restrict their foraging to limited areas. The inter-planting pollinizer varieties with main commercial old trees can only maximize the fruit setting. Majority of natural pollinators were not found due to the delayed winter during bloom period. Only the honey bees were proved to be the practical pollinators for majority of the apple varieties.

Key words: *Malus domestica,* honey bee pollinators, foraging, pollinizers, nectars

INTRODUCTION

Honey bees and the plants have a special relationship. Each of them benefits the other. Flowering plants provide food for honey bees, in turn, bees provide pollination for many plants, enabling them to reproduce. The apple (*Malus domestica* L.) is an indigenous fruit plant of Azad Jammu and Kashmir, growing from 2500 to 6500 ft. above sea level. It gives the flowers during the spring and the flowers occur in clusters at the end of a 1-3 year old woody shoot called a spur. Each flower has five stigmas that join into a style that leads to the ovary. The ovary has five divisions, each with two ovules, which means that a fully-pollinated fruit will have ten seeds. Surrounding the style are 20-25 pollen-bearing stamens. Nectar is excreted at the base of the central style. Five pinkish-white petals surround the sexual parts (Fig. 1). Each flower cluster has a primary bud called the *king bloom* that opens first and produces the best fruit. Production of nectar and pollen is marginal to good and bees readily visit the blossoms. At least 6-7 ovules must be fertilized. If this threshold is not met then the fruit will be misshapen[1], small, or may not stay on the tree until harvest[2]. Inadequate pollination can also reduce calcium concentrations in fruit[3] which can create the fruit storage problems[4].

Most apple varieties require cross-pollination with another compatible variety. With some exceptions such as Golden delicious and Rome beauty, many varieties show a degree of self-fruitfulness, but not enough to allow solid-block plantings. So orchardists must interplant main varieties with compatible pollinizer varieties. Generally, closely related varieties as, for example, Golden delicious do not cross-pollinate with each other well. Likewise, spur types do not pollinate the parent variety well. The bloom periods of the main and pollinizer varieties must overlap. To optimize pollination, it is necessary to plant both early and late blooming pollinizers so that the main variety blooms in between. In this way, ample pollen will be available for the early-blooming king bloom on the main variety and if frost kills the king blooms the late-bloomining pollinizers will provide pollens for remaining flowers.

Growers can use pollinizers instead of another commercial variety. This is warranted if other candidate pollinzers produce inferior fruit, take up too much orchard space, have conflicting pesticide requirements, or produce fruit that pickers cannot distinguish from the main variety. The flower color of a crab variety should match the color of the main variety since bees do not readily switch to a different-colored blossom during a foraging trip[5]. Crabapples can be planted in existing space between main

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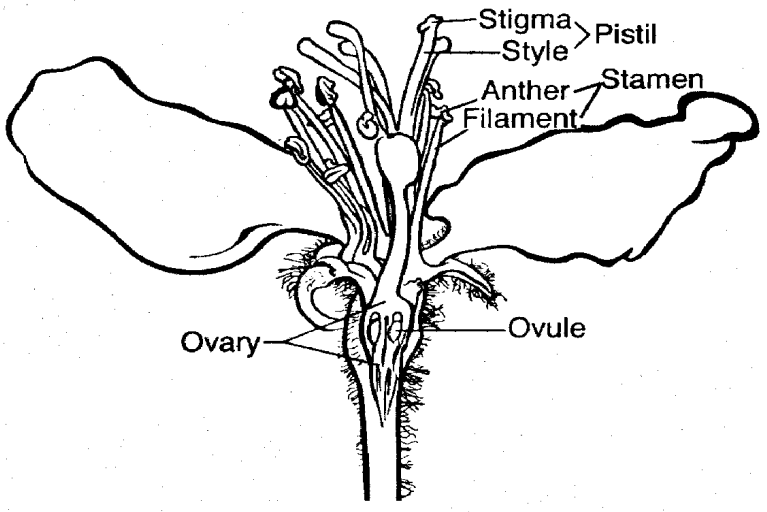

Fig. 1: Apple flower showing the reproductive parts

variety trees or grafted on to them; this makes crabapples an attractive remedy for old orchards that were not inter-planted with pollinizers.

MATERIALS AND METHODS

The experiment was carried out at a farmer's orchard near the University College of Agriculture, Rawalakot. Four healthy colonies of *Apis mellifera* with enough comb space were placed inside one acre apple orchard consisting of five different varieties (Kala kuloo, Starkrimson, Golden delicious, Queeta Amri and Kashmir Amri). To secure the even coverage, the colonies were placed on different part of the orchard at equal distance. For possible and full utilization of the pollinating capacity of the bees, the colonies were placed in the orchard about 5% in bloom when first king blooms started open. The pollinizer trees were marked to observe the bee visitation. Randomized complete block design with two treatments (caged and un-caged) was applied. Randomly selected trees from each row were caged with nylon net to avoid the access of bees and other insects. The trees were caged one week before the flowering. Observations were taken twice a day for entire flowering time of two weeks. The insects other than bees visiting apple florets were also counted. Analysis of variance (ANOVA) and χ^2 test were applied to compare the yield of the treatment means.

RESULTS

The treatment means (Table 1) indicated that the foraging activities of bees significantly increase the fruit yield in un-caged trees. There was a significant difference in total fruit yield of un-caged and caged Kala-kuloo. A least difference in fruit size among the treatments was due to the foraging activities of bees, although less number should be bigger in size as compared with dense fruit setting.

The frequency distribution of number of bees and other pollinators' visits indicated the flowers of apple varieties. The Golden delicious variety was preferably visited by honey bee pollinators (Table 2) but the pollinators other than bees showed least response to Golden delicious, a pollinizer. The Hymenopteran insects on the whole were the highly dominating pollinators among all. The bumble bees and other large wasps were more thorough than other visitors when the flower number was constant. The medium wasp appeared in the apple orchard when the flowering time was almost over.

DISCUSSION

Honey bees visit flowers to collect pollen and nectar for their food requirement. Pollen is essential to bees because it is their only natural source of protein. Without it, colonies would be unable to produce new bees and would eventually die. Nectar is the carbohydrate portion of the honey bee's food and is the raw material of honey. Bees convert nectar into honey by adding an enzyme which breaks down the complex sugars into simple sugars. During this time bees reduce the moisture content of nectar to less than 18% by fanning air through the hive. A mechanical power pollen duster device was shown to have no effect on fruit set, fruit size, seed number, or yield[6].

Table 1: Treatment means of yield of five apple cultivars (caged) to avoid bee access and (un-caged) to expose for bees access

	Total yield tree^{-1} (Kg)		Fruit size (cm radius)		No. of fruits (Kg^{-1})		No. of seeds fruit^{-1}	
Apple varieties	Un-caged	Caged	Un-caged	Caged	Un-caged	Caged	Un-caged	Caged
Kala kuloo	170a	35b	13.0a	1.04a	9.0a	8.5a	10.0a	4.0b
Starkrimson	150a	42b	13.3a	14.5a	8.5a	7.5a	12.0a	5.0b
Golden delicious	133a	17b	11.7a	12.6a	6.0a	5.2a	14.0a	6.5b
Queeta Amri	144a	64b	10.5a	11.5a	6.5a	4.4a	11.5a	6.4b
Kashmir Amri	138a	59b	11.5a	12.3a	5.5a	5.4a	15.5a	5.2b

Means followed by same letters in one column are not significantly different (P<0.05: LSD)

Table 2: Visiting frequencies of honey bees and other field foraging pollinators on stratified selected trees on hourly basis.

Apple varieties	No. of visits by bees tree^{-1} h^{-1}	Fraction of multiple visits	No. of other pollinators h^{-1}	Fraction of multiple visits
Kala kuloo	123	0.30*	34	0.11***
Starkrimson	98	0.34	13	0.13*
Golden delicious	160	0.23***	21	0.12**
Queeta Amri	144	0.28**	29	0.12**
Kashmir Amri	103	0.32	10	0.15

*** denote the visit frequencies of pollinators at P<0.05 by χ^2 test

Bees usually work in apple blossoms entirely, but some apple varieties are not always the richest available forage and competing blooms can be a problem. Although honey bees pollinate apple well and are considered as most efficient apple pollinators[7,8]. They sometimes rob an apple flower of its nectar without pollinating it; this happens most often with the `Delicious' apple variety. Honey bees make fewer contacts with the sexual column of the apple flower, compared to certain solitary bees[9]. Partab[10] working on pollinators management concluded that bees play very important role in the pollination of apple trees in the Himalayas and in this way the results of the present study are very much resembling with that of Partab[10]. Researchers have increased apple visitation by honey bees with pheromone-based bee attractants[11,12].

Honey bee colony strength standards: In time for apple bloom there is always low temperature and very few insect pollinators are available in fields. As with any early blooming crop, it can be difficult to get strong bee colonies. As much as possible, colonies should have large adult populations and plenty of brood. Mayer *et al.*[13] and Ambrose[14] recommend a minimum strength standard of six frames of brood covered by adult bees. Such a colony will have about 20,000 bees.

Managing honey bee hives for apple pollination: Colonies should not be kept at the apple orchards year-round. Instead, they should be moved in after about 5% of the orchard is in bloom or when the first king blooms open. Such a delay will encourage bees to focus on the crop rather than learn to visit competing plants. In small orchards like at Rawalakot, colonies should be placed in groups of 4-6 at 137 m intervals. With larger orchards, colonies should be placed in groups of 8-16 at 183-275 m intervals, starting about 92 m from the edges. Young trees, with fewer blossoms, are less attractive to bees than older trees, so in young orchards the grower may have to increase hive numbers in order to compensate[13].

Pollen dispensers (hive inserts) are devices that fit at the entrance of bee hives and hold pollen of desirable pollinizer varieties in such a way that bees dust themselves with the pollen as they leave the hive. Although dispensers have a questionable record[15,13], many apple growers use them. The pollen dispensers are an attractive remedy for old solid-block orchards with no pollenizers planted nearby[16]. In general, inserts are warranted when weather restricts the blooming of pollenizers and the activity of the bees.

It is necessary to use only pure, hand-collected apple pollen in dispensers; cured, pollen-laden anthers are even better[13]. Bee-collected pollen pellets will not pollinate apple flowers, even though they are easily obtained from pollen traps at hive entrances. *Lycopodium* powder is sometimes used to dilute pollen, but it agitates bees and is no longer recommended. High-quality pollen for inserts is available commercially. Pollen should be kept refrigerated until use and inserts should be replenished with about a teaspoon of pollen every few hours while bees are actively flying. A bee density rate of two bee hives per acre (5 ha^{-1}) is recommended if one is relying on inserts for pollination[16].

Orchard mason bees (*Osmia cornifons, O. lignaria lignaria and O. lignaria propinqua*) are potential apple pollinators. *O. lignaria lignaria and O. lignaria propinqua* land directly on the anthers and stigma of the blossom, thus maximizing the chance of successful pollination[17]. Honey bees, on the other hand, sometimes land on the flower petals before approaching the sexual column. In a comparison of orchard bees and honey bees in Japan, orchard bees visited more apple flowers per minute and contacted the sexual column 26 times more frequently[18]. Orchard bees are most promising in cases where honey bees are not available or in those varieties

that honey bees work inefficiently, such as `Golden delicious'. In North Carolina, *O. lignaria lignaria, O. lignaria propinqua and O. cornifrons* improved fruit-set, seed number and fruit shape in 'Delicious' apples, even in areas of orchards that already had honey bee hives[19]. In spite of these favorable studies, orchard mason bee management has not reached practical large-scale levels. Recurring problems include the timing of bee emergence with apple bloom, the dispersal of females away from the orchard after release and disease contamination in nest materials.

Other bees as apple pollinators: Populations of non-managed bees range from abundant to insignificant. Some soil nesters are also good apple pollinators where they occur in large numbers. In Maryland, the introduced *Andrea pilipes villosula* is active during apple bloom. It forages in cool, damp weather and works from before dawn to after dusk[20]. Managed leaf cutting bees (*M.egachile rotundata*) visits apple blossoms in Washington, but they fly only at higher temperatures and the bees must be incubated starting 21 days before bloom (which is not easy to predict).

During apple bloom there is always low temperature in apple growing zones of Azad Jammu and Kashmir. The emerging technology of managed honey bees' and their large populations may serve to fully compensate the relative inefficiencies of apple pollination. No apple variety is sufficiently self-fruitful to be dependably productive when planted alone and with out the foraging activities of pollinators.

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