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A REVIEW

Role of honeybees in horticultural crop productivity enhancement

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Abstract : Pollination is vital to conserve the planet's vast wealth of biodiversity.The pollinator is a living organism transporting pollen grains from the male part to the flower's fertilizing stigma.Fruit and seed set mainly in cross-pollinated crops dependon honeybees since their bodily parts have been engineered to capture the most pollen grains possible andhavea rapid reproductive rate. Insects are responsible for about 80% of all pollination activity, with bees accounting for over 80% of all insect pollination.Every day, a given bee colony may pollinate about 300 million flowers.Honey bees are considered the finest pollinators among all that contribute to pollination and generate honey and other hive products that add to farm income. The benefits of growing crops yield much more than the income generated by selling honey and other products.Many studies also demonstrate that pesticide application became a significant issue in most crops and antagonistically influence the honey bee population. Hence, great care must be taken to safeguard insect pollinators, particularly honey bees, against pesticide poisoning.The importance of pollinator species richness in their natural environment and function in crop improvement must be recognized. This review provides a broad overview of pollination difficulties that farmers face and an explanation of the importance of pollination in boosting food and nutritional security by improving the productivity of horticultural crops.

Key Words : Crop improvement, Honeybees, Pollination, Productivity, Horticultural crops

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INTRODUCTION

Pollination is the process of transferring pollen grains from a blossom's male anther to its female stigma.The process of pollination incorporates all events from maturation to zygote division. Camerarius, in 1964 first discovered that Pollination is necessary for seed production (Sharma, 2006). Cross-pollination of insect-pollinated crops by a honey bee is one of the most successful and cheapest methods to improve horticultural crop yields. Other horticultural practices like manuring, seed treatment, seed sowing, fertilizer application, insecticides, pesticides, and irrigation are also essential.

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Still, the desired outcomes may not be acquired without using honey bee pollination (Chadha, 2001). Bees visit flowering plants regularly for nutrition, nectar, and pollens. Bees' floral constancy is owing to their predilection for sugar-containing nectars and pollen with better nutritional contents.When one considers that a single honeybee colony may make up to 4 million journeys each year and that each trip visits an average of 100 flowers, the pollination potential of the colony becomes clear (Free 1993). This is due to their abundant body hair and distinct behavioural habits (Du Toit, 1988).

Flowering species of plants provide nectar and pollen to honeybees, while honeybees fulfill their responsibility by pollinating flowers, maintaining genetic variety, and ensuring the survival of that plant species. However, honeybees are still more important to farmers because of their pollination service, which increases crop yields qualitatively and quantitatively (Sharma *et al.,* 2015). Honeybee pollinators are responsible for providing 30 per cent of the world's food supply, either directly or indirectly (Greenleaf and Kremen, 2006).This remarkable work of the honeybee plays a significant role in its position as an effective insect pollinator. The value of extra yields obtained by honeybee pollination services is 15-20 times more than the value of all hive products combined. However, Pollination services provided by honey bees have not been recognized and overestimated by farmers and policymakers, resulting in a decrease in agricultural yield (Pratap and Pratap, 2000).

Honeybees species in India:

In India, generally,four species of honey bees of commercial importance are found, *i.e., Apisflorae* little bee*, Apisdorsata*rock bee*, Apisceranaindica* Indian bee*, Apismellifera* Italian bee. Among these first three are indigenous to India, but *Apismellifera* was introduced to India in the 19th century, which is highly suitable for domestication in India (Chadha, 2001). *Apiscerana indica* takes flight only up to 1-2 km, so it is not effective for pollination, while *Apismellifera* and *Apisdorsata* take flight or visit flower upto 5-6km. Still, Apis dorsata is difficult to be domesticated. At the same time, the Italian bee has been used extensively to enhance the yield because it is easy to rear, highly suitable for pollination in India. It is estimated that pollination by this bee increases yield upto 25% compared to the other crop pollinated through other means of pollination or pollinated through other bees species (Sharma, 2006).

Table 1: Pollination of fruit crops by honey bees

Fruit crop	Type of pollination	Major pollinator	Required number of beehives /ha	Reference
Apple	Cross-pollination	Honeybees, bumblebees	> 2	Sharma (2006); Chadha (2001)
Apricot	Cross-pollination	Honeybees, Solitary bees	2-3	Sharma (2006)
Grapes	self-sterile to self-fertile	Honeybees, solitarybees, and flies	1	Steshenko (1958); Chadha (2001)
Pear	Self to cross-pollinated	Honeybees	-	Sharma (2006)
Kiwi fruit	Cross-pollination	Honeybees	-	Mac Farlane (1981)
Litchi	Cross-pollination	Honeybees, wasp, and houseflies	4-5	Sharma (2006)
Loquat	Cross-pollination	Honeybees	-	Mann and Sagar (1987)
Mango	Cross-pollination	Houseflies honeybees	8-15	Chadha (2001); Sharma (2006)
Passion fruit	Cross-pollination	Honeybees	-	Cox (1957)
Persimmon	Some var show self-pollinated and some show cross-pollination	Honeybees, bumblebees	2-3	Sharma (2006); McGregor (1976)
Peach	Male sterility, cross-pollination	Honeybees	1-3	Sharma (2006); Chadha (2001)
Plum	Cross-pollination	Honeybees	2-5	Sharma (2006); Chaddha (2001)
Cherry	Cross-pollination	Honeybees	2-3	Sharma (2006); Chaddha (2001)
Strawberry	Self-pollination, cross-pollination is also advantageous	Honeybees	25 or more	Sharma (2006); Free (1993); Chadha (2001)
Almond	Cross-pollination	Honeybees	5-8	Sharma (2006); Chaddha(2001)
Citrus	Self-sterile to self-fertile	Honeybees	1-2	Sharma (2006)
Avocado	Cross-pollination	Honeybees, Wasps	-	Vithanage (1986, 1988)

Table 2: Pollination of vegetable crops by honey bees

Crops	Botanical name	Type of pollination	Major pollinator	Reference
Tomato	*Solanumlycopersicon*	Self-pollination	Honeybees and bumblebees	Free (1993)
Pumpkin	*Cucurbita moschata*	Cross-pollination	Honeybees	Free(1993)
Bitter gourd	*Momordicacharantia*	Cross-pollination	Honeybees	Grewaland Sidhu (1978)
Bottle gourd	*Lagenariasiceraria*	Cross-pollination	Honeybees and bugs	Alam and Kadir (1986)
Carrot	*Dacuscarota*	Cross-pollination	Honeybees, solitary bees, and flies	Hawthorn *et al.*(1960)
Cauliflower	*Brassica oleraceavarcapitata*	Cross-pollination	Honeybees and flies	Free(1993)
Chilli	*Capsicum annum var annum*	Often cross-pollination	Honeybees and solitary bees	Tanksley (1985)
Cluster bean	*Cyamopsis tetra-gonoloba*	Self-pollination	Honeybees	Free (1993)
French bean	*Phaseolus vulgaris*	Self-pollination	Honeybees	Webster *et al.* (1982)
Cowpea	*Vignaunguiculata*	Self- pollination	Honeybees	Rawal *et al.*(1978)
Garden pea	*Pisumsativum*	Self-pollinated	Honeybees	Free (1993)
Okra	*Abelmoschusesculentus*	Often cross-pollinated	Honeybees, flies, and beetle	Mishra *et al.*(1988)
Onion	*Allium cepa*	Cross-pollination	Honeybees	Caron *et al.*(1975)
Radish	*Raphanussativus*	Cross-pollination	Honeybees, flies	Muhammad *et al.*(1973)

There are different kinds of pollinators found in nature like a wasp, flies, butterflies, birds, beetles, moths and bees, etc. from which honey bees are the most efficient pollinators of all agronomic crops due to possessingthe following characteristics:

– Modification in their body structure in a way that they can pick several pollen grains at a time.

– Presence of body hair in their body.

– They areadapting to adverseand harsh climatic conditions.

– Bees can work for a long time.

– Their reproduction rate is very high.

Table 3: Effect of honeybee pollination on productivity of fruit crops

Crops	Fruit set increase (%)	Fruit weight increase (%)	Fruit size increase (Length, Diameter) (%)	References
Citrus	24	35	9, 35	Partap, 2000
Apple	10	33	15, 10	Verma and Dulta, 1998
Plum	13	39	11, 14	Partap *et al.*2000
Peach	22	44	29, 23	Partap *et al.*2000
Strawberry	112	48	Decrease in misshaped fruits by 50 per cent	Partap, 2000

Table 4: Increase in total yield due to bee pollination

Crop	Increase yield (%)
Apple	15-20
Cherry	5-15
Citrus	5-15
Mango	3-5
Plum	10-15
Almond	15-20
Cashew	5-15
Coconut	3-5
Grapes	10-20
Guava	5-10
Litchi	20-25
Papaya	5-10
Pear	10-15

Source: Chadha, 2001

– Bees possess a unique communication system (Chadha, 2001; Sharma, 2006).

Honey bee as a pollinator:

Pollination is the most crucial benefit of honey bees and beekeeping, whereas hive products like honey and beeswax are secondary. Honey bees improve the productivity level of different crops by cross-pollination. This is evident from the fact that when honeybees are used in cross-pollination, the income from farming is several times higher than itsas worth as production of products like beeswax and honey. Furthermore, cross-pollination is not required for self-sterile types; self-fertile plants will produce higher-quality seeds if pollinated by honey bees and other insects (Verma and Pratap 1993). Research conducted in the Kathmandu valley found that *A. mellifera* worker bees transported much more pollen from peach and plum blossoms than *A. cerana indica* worker bees (Partap *et al.,* 2000).

Role of honey bees in boosting horticultural productivity:

Pollination by honeybees has enhanced the yield and quality of apples and strawberries. Pollination by bees enhances the fruit quality and reduces fruit drop in peach, apple, citrus, and plum trees (Verma and Dulta, 1987; Partap *et al.,*2000). It was reported that in strawberries, the malformed fruit is significantly reduced by bees pollination (Partap, 2000b). Studies have also shown that sugar and fruit juice content significantly increased (Partap, 2000a).According to reports, the direct cost of honeybee pollination to boost agriculture productivity in 20 Mediterranean countries was US$ 5.2 billion per year, 3.2 billion in developing countries, and 2 billion in other countries (Cadoret, 992). Appropriate pollinator location and a good amount of pollinizer trees are required for a better outcome and successful pollination. Honeybees, when put correctly, functioned equally effectively in all directions and were uniformly distributed throughout flowers (Ingram *et al.,*1996). Animal pollinators, notably bees, are thought to be responsible for pollinating more than three-quarters of the world's crops and more than 80% of all blooming plants (Kenmore and Krell, 1998).

Impact of the honey bee in vegetable seed production:

Table 5 shows the influence of honeybee pollination on vegetable seed production. Honeybee pollination enhanced seed output and quality in a variety of vegetable crops, including cabbage, cauliflower, radish, mustard, and lettuce, according to the studies (Partap 1992; Verma 1994).

Following research have shown yield and quality increment due to bee pollination :

Litchi:

Honey bee pollination is adequate in litchi, as shown by many researchers. Badiyala and Garg (1990) introduced four honeybees colonies into litchi orchard where inflorescence open to honey bee and some inflorescence are begged at the beginning of the flowering stage and found that the fruit set and yield is 2-3 times greater in open inflorescences for honey bee compared to the bagged inflorescence. Du Toit (1994) in South Africa did the same experiment after four years of the above investigation and found that the inflorescence open to honey bees set fruit three times higher than bagged inflorescences.

Apple:

Several studies indicated that apple pollination through bees enhances productivity (Sharma *et al.,* 2012). Several experimentsshow that the more bees visit and the installation of bee colonies in apple orchards resulted in more fabulous fruit set and a decreased level

Table 5:Effect of honeybee (*Apiscerana*) pollination on seed production of vegetables

Vegetable crop	Pod setting increment (%)	Seed setting increment (%)	Seed weight increment (%)
Cabbage	28	35	40
Cauliflower	24	34	37
Lettuce	12	21	9
Radish	23	24	34
Broad leaf mustard	11	14	17

Source: Partap 1992; Verma 1994

of apple fruit loss Gupta *et al.* (1993); Sharma and Gupta 2001 and Sharma *et al.* (2004) also reported lesser fruit drop and increased fruit set in apple orchards with proper care and pollination management.

Guava:

In guava, 20-40% of pollination is due to honey bees. Fruit characteristics like length and width were also substantially improved through bees pollination treatment compared to without bee pollination. (Anonymous, 2011; Sehgal, 1961).The fruit set and quality of guava fruit weresignificantly improved by honey bee pollination (Rajagopal and Eswarappa, 2005).

Banana:

Honeybees were the dominant visitors in the banana inflorescence; the major species of honey bee *A. cerana, A. mellifera* and A *dorsata* were visiting with 77.50, followed by a wasp (15.53%) (Kaushik *et al.,* 2012).

Strawberries:

In strawberries, insect pollination increases fruit yield and quality (Williams, 1994). Bee pollination increases strawberry weight shape and quality improved through bee pollination (Chagnon *et al.,* 1993; Zebrowska, 1998). An experiment conducted by Kakutani *et al.* (1993) on comparing stingless bees and *Apis mellifera* showed that one visit of the *Apis mellifera* pollinated 11% of achenes of strawberry and one-stop of the stingless bee-pollinated 4.7%. It was concluded that strawberry per flower at tains regular berries required 11 visits of the honey bee or 30 visits of the stingless bee. The rate of misshapen berries in the *Apis mellifera* are (51%), and the stingless bee is (73%) was higher than *Apis mellifera.*

Pomegranate:

In an experiment conducted in California, farmers placed honey bee colonies in pomegranate orchards and thought that honey bees increase the yield of pomegranate their less efficiency of honey bees were seen McGregor (1976). Other researchers found that in comparison to self-pollination, bee pollination may improve the quality of pomegranate fruit (Derin and Eti, 2001; Tao *et al*., 2010). The Department of Agriculture and Food in Western Australia (2005) estimated that 10% of pomegranate pollination is carried out by honey bees.

Ber:

A study has shown that honey bee was observed foraging on both nectar and pollen among many insect visitors (1990). Singh (1984) noticed that honeybees and other hymenopterans insects were plentiful and active on the top branches of the ber (*Zizyphus mauritiana* L.). In contrast, houseflies and other dipterans insects were prevalent on the centre and lower branches.

Aonla:

Gravity and honeybees are critical for efficient pollination of the Aonla crop. According to the research, using honey bees as pollinators and pollinizers in aonla orchards is crucial for boosting fruit output and quality(Allemullah and Ram, 1990).

Plum:

Most European plums set fruit with their pollen but produce superior crops with pollinizers, but most of the Japanese plums require pollinizer cultivars for pollination and fruit set. (Halder *et al.,* 2019). Department of Agriculture and Food in Western Australia (DAF 2005) in prune and plum orchard honey bee enhance yield and quality of plum and prunes and showed differences in yield in Japanese plum 150% open field condition and bees restricted plots. In another experiment with French prunes, trees with open pollination set 3.6-21.8% fruit;the tree was caged with honey bees give 15-19% fruit set, but when a tree with restricting beesset 1.3% fruit only. Heres, we can easily compare that by which pollinators fruit plant get benefitted.

Diclining of honey bees population:

The recent decades have seen an alarming decrease in insect pollinators, particularly honey bees;this could prove a considerable challenge to global food production shortly (Klein *et al.,* 2006). Declining honey bee numbers and biodiversity is posing a significant danger to agricultural productivity.Natural habitat loss, parasite and pesticide exposure, loss of floral richness, and low genetic variety owing to increasing land usage, long-distance transportation of colonies, exotic plants and bees, and climate change might all be factors contributing to a significant reduction in the bee population.

According to a survey of citrus farmers, more than 90% had no knowledge of citrus pollinators or pollination. Only 15% of them had local bees in the hive for honey production rather than controlled pollination. They also did not know about biodiversity conservation or

environmental protection (ICIMOD, 2003). Studies at the International Centre for Integrated Mountain Development (ICIMOD) indicate a reduction in the local populations of bees in their natural growing places (Joshi *et al.,* 2003). The extinction of native bees has had a negative impact on the income of underprivileged groups that used to make a living from beekeeping and honey gathering. It also poses a significant threat to agricultural growth and biodiversity protection in many regions of the nation.

Protective measures: Save the bees:

– Createpollinator gardens with wildflowers.

– Increase the number of nesting spots.

– Pesticides that have a less residual effect on honey bees should be selected and not be applied during the blooming period.

– The importance of crop pollination should be made known to the general public.

– The legal protection of honeybees and other insect pollinators, particularly the conservation of honeybees against chemical poisoning, should be emphasized.

– The central focus should be on developing conservation policies for pollinators.

Conclusion:

Reduced pollination is a key cause of declining horticultural production, which can be attributed to several reasons.One can utilise better agricultural technology like high-quality seed, high-yielding varieties, and high-quality agronomic techniques like timely irrigation and fertilisers. Still, without pollination, no fruit or seed will be produced.Almost all the food that we consume results from the pollination activity done by insects, especially honeybees. The Formation of a seed is the essential and crucial step for the start of new life. Honey bee accomplishes this activity throughout their life. A decrease in their number will have a pessimistic effect on our life as well as on nature also.Both beekeepers and farmers will benefit from encouraging the use of beekeeping for the pollination of horticultural crops.To protect honeybees and other natural pollinators, increase their ability for agricultural pollination, and allow them to develop in a pollution-free habitat, research studies are necessary.Extension experts can also help extend the use of honey bee rearing to pollinate the crop and spread awareness among the farmers to promote and enhance its value.

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