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# Impact of pollination by European honey bee, *Apis mellifera* L. on the yield and quality of litchi (*Litchi chinensis* Sonn.) fruits in India

**RAJESH KUMAR and VINOD KUMAR**

ICAR-National Research Centre on Litchi, Muzaffarpur - 842 002, Bihar, India
Email: rajeshkr_5@yahoo.com; vinod3kiari@yahoo.co.in

**ABSTRACT:** Studies were conducted at National Research Centre on Litchi (NRCL), Muzaffarpur, Bihar during 2010 and 2011 to understand foraging behaviour of bees and non-bee pollinators in litchi, and to investigate the influence of pollination by Italian honey bee, *Apis mellifera* on fruit set, yield and quality of litchi fruits. The results revealed that insects visiting litchi flowers were mainly bee species (*Apis mellifera, A. dorsata*, *A. cerana indica* and *A. florea*), flies, wasps and beetles. *Apis mellifera* was recorded as the dominant forager on litchi flowers (48.13%) followed by *A. cerana indica* (37.16%).The maximum foraging activity of *A. mellifera* was at 08:00 AM followed by 10:00 AM in both open and controlled pollination conditions, while non-bee insect pollinators showed maximum foraging at 12:00 noon followed by 02:00 PM. The data indicated that fruit set increased gradually with increased number of visits/panicle/hour in close vicinity to bee colonies.The maximum fruit set (2.41-1.68%) was recorded in the trees which were nearest to the *A. mellifera* bee colonies. The maximum increment in fruit yield (160.82%) compared to open pollination without bee hives was recorded in trees nearest to *A. mellifera* bee colonies. There was considerable enhancement in quality parameters like fruit mass and pulp: seed ratio. The results conclusively proved the role of *A. mellifera* as efficient pollinator of litchi.

**Keywords** : Bees, fruit quality, fruit set, litchi, pollination

## INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is an important commercial fruit crop grown extensively in Bihar, West Bengal, Assam, Jharkhand,Uttarakhandand Odisha states of India. It is a highly entomophilous fruit crop (Dhaliwal *et al.* 1977) and honeybees have been reported as the most outstanding beneficial insects on litchi (Groff, 1943). Pollination of entomophilous crops by honey bees is considered as one of the effective and inexpensive method for improving the yield and its qualitywith more relevance to perennial nature of fruit crops.The value of the honey bees as principal pollinators and its significant role in enhancing fruit set, fruit yield and quality of litchi has also been advocated by many workers (Butcher, 1956, 1957; King *et al.* 1989). Hermaphrodite litchi flowers are highly self-sterile requiring insect pollination for proper fruit set (Pandey and Yadava, 1970). Several bee species have been reported in different parts of India visiting litchi flowers for nectar and pollen collection. Honey bees forage during daylight and are unlikely to carry pollen grains viable to effect fertilisation beyond 1200 hours (Kraai, 1962). The number of flowers visited per minute by any bee species depends upon a number of factors including instinctive foraging behaviour, length of proboscis and floral structure (Free, 1993), particularly the corolla depth, type and quantity of floral rewards, density of flowers of particular cultivar of the crop grown and the time of the day.

Honey bee pollination has become one of the important inputs for assured pollination resulting in higher yield and quality fruits. Assured pollination can only be achieved by managing optimum levels of pollinators. Till recently, Indian honey bee (*Apis cerana indica* Fabricius.) had been the dominant pollinator for litchi. RecentlyEuropean honey bee (*Apis mellifera* Linnaeus) is being widely used in commercial beekeeping and hence needs to be systematically investigated for the pollination benefits and other related activities. The present study was undertaken with two objectives namely, to understand foraging behaviour of bee and non-bee pollinating insects in litchi, and to study the influence of pollination by *A. mellifera* under open and controlled condition on fruit set, yield and quality of litchi fruits so that quantifiable recommendations could be made.

## MATERIALS AND METHODS

Studies were conducted at National Research Centre on Litchi (NRCL), Muzaffarpur, Bihar during 2010 and

2011. The foraging activity in terms of number of visits/ panicle/hour of all honey bees and non-bee pollinating insects on litchi cultivar 'Shahi' were recorded manually as well as by analysing videography data taken during different hours of the day from various experimental blocks at NRCL. The mean of the observations recorded for a week was then computed. During foraging study, the total count of other bee species (*Apis dorsata*, *Apis cerana indica* and *Apis florea*) and non-bee insect pollinators (Hymenopterous and Dipterous) were also recorded in case of treatments having open pollination in different hours of day. For studying the effect of planned pollination, the experimental orchard adjacent to the apiculture shed having about 100 litchi trees of cv. 'Shahi', 10 years age and planted at a distance of 8.25 m were selected. During the experimental period, forty *A. mellifera* colonies/hives, each with nine frames and excess of unsealed brood were placed at the apiculture shed. There were six treatments each having five trees at marked distances. Out of these six, four were open pollination *viz.*, $T_1$- trees located at 25m from apiculture shed; $T_2$-trees located at 250m from apiculture shed; $T_3$: trees located at 500m from apiculture sheds, and $T_4$- a selected farmers' orchard distantly located (25 km away) having no *A. mellifera* or other bees colonies/hives in the near vicinity. The other two treatments were$T_5$-pollination under controlled conditions in insect proof nylon net cage having only one *A. mellifera* bee colony placed inside, and $T_6$-control, having insect proof nylon net cage without honey bees or any open pollination. During the period of litchi bloom, five selected panicles/ tree (different directions and branches/tree) were observed for recording data by counting number and types of flowers per panicle, fruit set (%), fruit retention (%), fruit yield and quality.

## RESULTS AND DISCUSSIONS

The panicles in litchi (cv. Shahi) started bearing flowers from the first week of March,which continued in phases having particular types of flowers (male, hermaphrodite and female). The period of flowering ended in the first week of April, with its peak bloom during middle of March. The results revealed that insects visiting litchi flowers were mainly bee species (*Apis mellifera, Apis dorsata*, *Apis cerana indica* and *Apis florea*), flies, wasps and beetles. Italian honey bee (*A. mellifera*) was recorded as the dominant forager on litchi flowers in both the cases *i.e.*, in exclusively managed and the open pollination conditions. The data on bee foragers/panicle/hour showed that maximum foraging activity was by *A. mellifera* (48.13%) followed by *A. cerana indica* (37.16%), *A. dorsata* (11.33%) and *A. florea* (3.38%).

The foraging activity of honey bee pollinators depended on the time of the day. The foraging activity recorded for *A. mellifera* at different hours of the day showed that maximum activity was at 08:00 AM followed by 10:00 AM and 06:00 AM in both open and controlled pollination conditions (Fig. 1). The maximum mean count of visits/panicle/ hour was 228.33 at 08.00 AM in ($T_1$-) *i.e.* trees located at 25m from apiculture shed and the number of visits decreased with furthest distance. In case of controlled pollination in nylon net cage, mean no. of visits at 08.00 AM was 128.83 per panicle/hour. In contrast to bee pollinators,non-bee insect pollinators showed a different trend of foraging activity, maximum of which was recorded at 12:00 noon followed by 02:00 PM and 10.00 AM (Fig. 2). The maximum mean count of visits of insect pollinators/hour/panicle was 76.00 in $T_1$ at 12.00 noon. Similar trend was observed in other treatments also.

The minimum visits were recorded at 6.00 PM for *A. mellifera* as well as other pollinators. Comparatively, the lower number of visits of other insect pollinators was recorded showing the situation of low population in unmanaged conditions. Foraging activity during 0800 to 1000 hr results in effective pollination leading to fertilization and fruit set in litchi, hence *A. mellifera* is an important pollinator. The foraging behaviour of bees is a complex phenomenon which depends upon several factors. Besides the physical features of flowers such as colour, shape, and odour, the diversity of environmental factors such as temperature, humidity, light, solar radiation time of the day and nectar flow decisively shape the behaviour of pollinating insects (Visscher and Seeley, 1982; Corbet *et al.* 1993).

It was observed that all the panicles of a single tree bore particular type of flowers at a time in one phase, rarely showing overlapping phases with different types of flowers. This particular phenomenon of flowering necessitates the cross pollination function for fruit set. Data revealed that inspite of occurrence of flowering in different phases, self-pollination and fruit set was almost nil in the treatment $T_6$, having enclosed nylon net-caged trees without honey bees and any other insect pollinators. This confirmed the self-sterile/self-incompatible nature of flowers in litchi. Insects are required to transport pollen from anthers to stigmas conforming cross pollination for fruit set in litchi. Stern and Gazit (1996) observed that

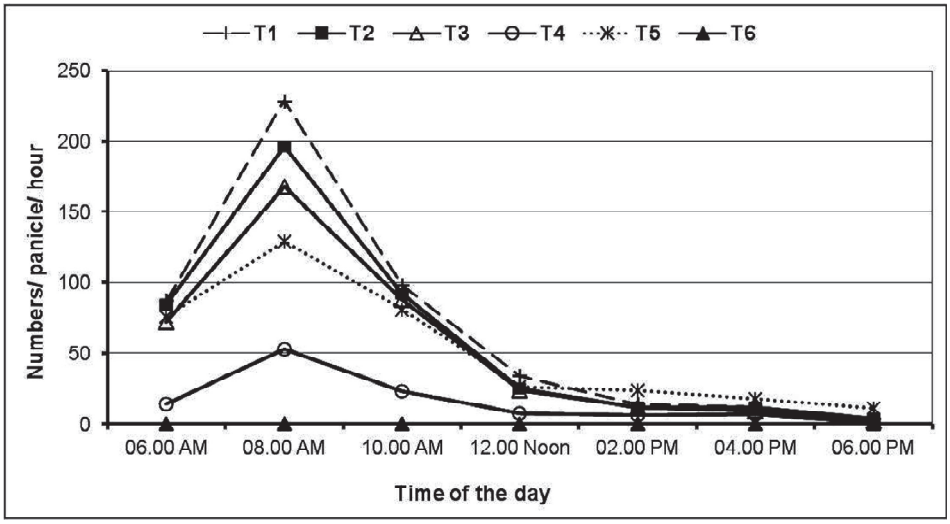


**Fig. 1. Visits of Italian honey bees on litchi flowering panicles (Numbers/panicle/hour) (Mean of 2010 and 2011)**

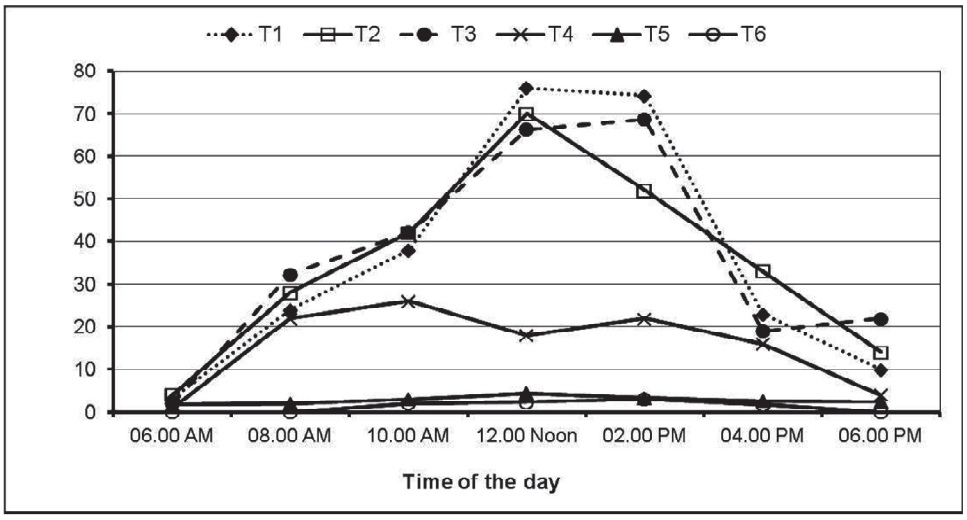


**Fig. 2. Visits of other bees and non-bee pollinating insects on litchi flowering panicles (numbers/panicle/hour) (Mean of 2010 and 2011)**

**Fig. 3. *Apis mellifera* foraging on litchi flowers (L), and nylon net cage having *A. mellifera* bee hive for pollination under control conditions (R)**

the respective stages of bloom overlap between panicles and trees, but rarely overlap within individual panicles. Chaturvedi (1965) reported that the flowers and its different phases were dependent on the age of tree, panicle and environmental conditions.

The data indicated that fruit set increased gradually with increased number of visits/panicle/hour in close vicinity to bee colonies, while there was a decrease in the number of honey bee visits per panicle and less increase in fruit set when the colony placement was at the furthest distance. The result of monitoring of the effect of overcrowding and excessive number of honey bee visits on pollination/fruit set in different treatments during particular periods of the day showed that the visits were maximum (number/panicle/hour) during the blossom period on the trees which were nearest to the bee colonies. The maximum fruit set, 2.41% and 1.68% in 2010 and 2011, respectively was recorded in the trees which were nearest to the *A. mellifera* bee colonies (apiculture shed), while the lowest fruit set, 0.86% and 1.03% in 2010 and 2011, respectively was recorded in the trees which were at the distant location having no honey bee colonies in the vicinity ($T_4$) (Table 1 and 2). Similarly, mass of fruits/panicle and fruit yield were highest in treatment ($T_1$) during both the years. There was considerable variability in the number of female flowers per panicle in the treatments and the higher the number of female flowers per panicle the higher were the yield which is in conformity of earlier report of Menzel and Simpson (1992). Fruit set in litchi is climate dependent and profoundly affected by temperature and humidity. It varies greatly within panicles (McConchie and Batten, 1991), with ranges up to 30-40% of the total flowers produced (Galan Sauco, 1989). Reproductive failure is common and not always explained. In some years, certain panicles bear few, or only male flowers and, as a result, little or no fruit is set, but this does not always happen. Winter/spring temperature extremes affecting bloom penology and adverse weather conditions limiting bee flight during bloom have been identified as other causes of low fruit set (Batten, 1986). Moreover, abscission of fruitlets resulting after pollination and fruitset may lead to increased yields due to bigger fruit size (Stern *et al.* 1993; Degani *et al.* 1995).

The maximum fruit mass (20.66 g) was recorded in treatment ($T_5$), where trees were under caged conditions for pollination exclusively by *A. mellifera* bees. The maximum enhancement of fruit yield (160.82%) compared to open pollination without honey bee hives ($T_4$) was recorded in treatment ($T_1$) having trees nearest (25 m) to *A. mellifera* bee colonies. The maximum pulp to seed ratio was also recorded in treatment ($T_1$) (Table 3) Pulp to seed ration was maximum (4.14)was maximum in treatment ($T_1$) and minimum in ($T_4$) while the TSS value was in reverse order i.e. maximum (20.8) in ($T_4$) and minimum in ($T_1$).

These studies clearly showed litchi as a cross pollinated crop and proper management of insect

**Table 1. Effect of planned pollination by *Apis mellifera* on fruit yield of litchi during 2010**

| Treatment | Total no. of flowers/ panicle | Fruit set (%)* | Mass of fruits/ panicle (g) | Fruit yield (kg/tree) | Fruit yield (t/ha) |
|---|---|---|---|---|---|
| $T_1$ | 926.8 | 2.41 (22) | 432.8[a] | 51.94[a] | 7.48[a] |
| $T_2$ | 981.2 | 1.87 (18) | 350.0[b] | 38.15[b] | 5.49[b] |
| $T_3$ | 792.4 | 1.96 (16) | 305.0[b] | 32.63[c] | 4.70[c] |
| $T_4$ | 879.6 | 0.86 (08) | 140.0[c] | 15.54[d] | 2.24[d] |
| $T_5$ | 1021.6 | 1.13 (15) | 297.4[b] | 35.88[bc] | 5.12[bc] |
| $T_6$ | 831.2 | 0.01 (01) | 0.2 | 1.00 | 0.01 |
| **CD (P = 0.05)** | - | - | 58.83 | 5.19 | 0.74 |
| **SE (m) ±** | - | - | 6.40 | 1.32 | 0.33 |

*Value in parenthesis is no. of fruits per panicle. Means followed by same alphabets in a column do not differ significantly

**Table 2. Effect of planned pollination by *Apis mellifera* on number of flowers, types of flowers, sex ratio and fruit yield of litchi during 2011**

| Treatment | Total no. of flowers/ panicle | Fruit set (%)* | Mass of fruits/ panicle (g) | Fruit yield (kg/tree) | Fruit yield (t/ha) |
|---|---|---|---|---|---|
| $T_1$ | 1337.8 | 1.68 (23) | 442.2[a] | 63.80[a] | 9.18[a] |
| $T_2$ | 1230.4 | 1.38 (17) | 334.0[b] | 48.14[b] | 6.93[b] |
| $T_3$ | 1190.8 | 1.41 (17) | 338.0b | 50.20[b] | 7.23[b] |
| $T_4$ | 993.4 | 1.03 (10) | 204.0[d] | 28.76[d] | 4.14[d] |
| $T_5$ | 1084.4 | 1.23 (14) | 276.0[c] | 38.92[c] | 5.60[c] |
| $T_6$ | 1001.8 | 0.01 (01) | 0.2 | 1.00 | 0.01 |
| **CD (P = 0.05)** | - | - | 31.41 | 6.11 | 0.88 |
| **SE (m) ±** | - | - | 4.09 | 1.04 | 0.11 |

*Value in parenthesis is no. of fruits per panicle. Means followed by same alphabets in a column do not differ significantly

**Table 3. Effect of planned pollination by *Apis mellifera* on fruit yield and quality characteristics under different treatments.**

| Treatment | Fruit yield (t/ha) | Yield increase (%) over ($T_4$)* | Fruit quality characteristics | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Fruit mass(g) | Pulp mass(g) | Seed mass(g) | Peel mass(g) | Pulp: Seed ratio | TSS (° Brix) |
| $T_1$ | 8.33[a] | 160.82 | 20.02[bc] | 12.88[a] | 3.11[b] | 4.03[ab] | 4.14:1 | 20.1 |
| $T_2$ | 6.21[b] | 94.36 | 20.17[ab] | 12.16[bc] | 3.82[a] | 4.19[a] | 3.18:1 | 20.2 |
| $T_3$ | 5.97b | 86.83 | 19.95[bc] | 12.42[b] | 3.78a | 3.75[c] | 3.29:1 | 20.2 |
| $T_4$ | 3.19d | 0.00 | 19.60[c] | 11.93[c] | 3.79[a] | 3.88[bc] | 3.15:1 | 20.8 |
| $T_5$ | 5.36[c] | 67.71 | 20.66[a] | 12.83[a] | 3.88[a] | 3.95[abc] | 3.31:1 | 20.4 |
| $T_6$ | 0.01 | - | 0.01 | - | - | - | | - |
| **CD (P=0.05)** | 0.48 | - | 0.53 | 0.29 | 0.17 | 0.21 | - | NS |
| **SE (m) ±** | 0.21 | - | 0.09 | 0.12 | 0.07 | 0.09 | - | - |

*Open pollination without honey bee hives; Data presented in table is mean of two years, 2010 and 2011; Means followed by same alphabets in a column do not differ significantly

pollinators in abundance for pollen transfer prerequisite for fruit set and enhanced yield and quality. The study conclusively proved that considerable increase in fruit yield and quality can be achieved by integration of Italian honey bee in planned way and timely establishment of colonies in sufficient numbers in litchi orchards since this bee species proved to be the dominant and efficient forager. In spite of the specific recommendations about the number of colonies per unit of litchi trees, the continuous presence of enough honey bee foragers is more important and therefore serves as a practical recommendation for assuring adequate pollination and fruit set. Additionally, economic benefits and surplus production of litchi honey and other bee products could also be advantageous. During the period of litchi bloom in litchi production areas, honey bees do not move further to find other pollen source, which was confirmed by Butcher (1957). Chaturvedi (1965) and Das and Choudhury (1958) mentioned honey bees as floral visitors and since there is only a partial overlapping of female and male flowers within a single litchi cultivar, optimal overlap of floral stages ensures maximum yield potential. Self-pollination can occur, however, litchi flowers are generally recognized as self-sterile and

require insects, usually honey bees, to transport pollen from anthers to stigmas for fruit set (King *et al.* 1989, Stern and Gazit, 1996). Pandey and Yadava (1970) reported that only 0.03 to 0.10% of caged flowers to exclude insects, set fruit, whereas 0.7 to 11.2% of flowers exposed to insect pollination set fruit. Butcher (1957) also reported that no fruit set on a tree caged to exclude insect pollination.

The extent of cross pollination leading to enhanced fruit set, fruit yield and quality was obtained mainly by the presence of honey bees in close proximity of the food source. Considerable increases in fruit yield and quality was obtained exclusively by honey bee pollination. The Italian honey bee in India has the added advantage of higher honey production apart from its role as a pollinator. Regulated pollination under caged conditions, using Italian honey bees gave the best quality, mono-floral honey which also had a better market value. This study provides the basis for continued improvement regarding specific pollination service estimates.

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