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Effect of bee pollination, *Apis mellifera* L. on yield and quality parameters of Bael (*Aegle marmelos* Correa)

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Abstract
The present experiment was conducted to mensurate the pollination effect of *Apis mellifera* L. on yield attributing characters i.e. fruits per panicle, its weight and TSS percentage of cultivar "Narendra Bael 9" at Main Experiment Station, Horticulture and Apiculture laboratory, Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.), India during 2014. Bael is mostly cross pollinated fruit crop and pollination is carried out by various insect visitors. The 'NB 9' cultivars were laden with floral buds panicle^{-1} within 7-10 days 0f emergence of new leaves and reached to its full bloom during the moths of May- June, when days were long and temperature was so high. From the four treatments, i.e. pollination by honeybee only, natural pollination with augmentation of honey bees, natural pollination and control (no pollination), maximum average number of fruit panicle^{-1}, average fruit weight and average TSS percentage were 27.3, 2.05 kg and 41.3% in natural pollination with augmentation of honey bees while minimum 1.3, 1.8 kg and 35.7% were observed in control. Similarly an increase of 2000.00%, 8.46% and 15.68% over control and 47.56%, 6.22% and 5.08% over natural pollination was observed in average number of fruit panicle^{-1}, average fruit weight and average TSS percentage under the treatment natural pollination with augmentation of honey bees.

Keywords: Pollination, *Apis mellifera*, Bael fruit panicle^{-1}, fruit weight, TSS percentage

1. Introduction
Pollination is defined as the transfer of pollens from the male portion of a flower to the female portion which is essential for the process of fertilization and production of fruits and/or seeds [1]. About 90% pollination is carried out by insects, 85% of which comprises the honeybees [2].The nature and extent of pollination can vary between crops, ranging from increasing the quality and quantity of fruits or seeds and increase genetic diversity within crop species [3].
Inadequate pollination can result not only in reduced yield but also in delayed yield and a high percentage of inferior fruits [4]. The insects of family Apidae are the most reliable agents for pollination. Among members of Apidae family, honey bees are particularly important pollinators as they are capable of carrying pollens with which they feed their immature stages, and in the process, the plants visited by them are benefited [5]. Bees are active when flowers are most receptive. Collection of pollens by bees usually ends before noon but nectar collection continuous into late afternoon. Bees visit the fruit producing flowers more often than the male blossoms and stay on them longer [6].
Bael is mostly cross pollinated fruit crop and pollination is carried out by various insect pollinators like honeybees, hover fly, yellow wasp, carpenter bee, weevil, black ants, butterflies etc.[7] Emergence of new leaves commenced during the 2nd and 4th week of May and continued till July. The transfer of pollen requires some agents and animal pollinators such as honeybee, *Apis mellifera* L. play an important role for carrying out the pollination process [3]. The present study was planned to determine the effect of pollinators including honeybee (*Apis mellifera* L.) on yield and quality parameter of bael.

2. Materials and Methods
The present study was carried out under saline sodic soil condition and experimental site is located at Main Experimental Station, Department of Horticulture, Narendra Deva University of Agriculture and Technology, Faizabad (U.P.) [26.47^0 N latitude, 82.12^0 E longitude and altitude of 113 metres from mean sea level] during 2014. A randomized block design (RBD) with four treatments and six replications was applied. Six different bael plants were selected

for pollination by honeybees only. These plants were caged with mosquito net (5m×5m×5m). A four framed nucleus hives with *Apis mellifera* L. bee colony were placed in each cage. The plants were caged in such a way that no other insects may enter the cage except honeybees already present inside the cage. For natural pollination with augmentation of honey bees, six bael plants randomly selected and allowed for visiting of all pollinators along with honey bees.

The number of bee colonies for pollination was according to general recommendation i.e. 01 bee colony per acre [8]. Five inflorescence branches on each plant, of six randomly selected plants were selected and bagged in 25×4 cm muslin cloth bag to prevent from pollinators [9]. A group of five panicles in each treatment were tagged, which are represented as sampling unit. The average number of fruits per inflorescence, average fruit weight and total soluble solid (TSS) percentage were determined by counting total number of fruits in sampling unit divided by five, total fruit weight divided by total number of fruits and total TSS percentage in sampling unit divided by five.

2.1. Statistical Analysis

All the data pertaining to quality (T.S.S. and Fruit weight) and quantity (Number of Fruit set) were subjected to statistical analysis by using factorial RBD [10].

3. Results and Discussions

The pollination effect of *Apis mellifera* L. on average number of bael fruit setting per panicle is summarized in Table 1. Significant differences (C.D. at 5%) were observed among the treatments in terms of average number of fruits per panicle. The maximum average fruit setting was found 27.3 in natural pollination with augmentation of bee colony followed by pollination by honey bees only i.e. 25.1, which were 2000.0% and 1830.76% increase over control respectively. Similarly an increase of 47.56% in number of bael fruits per panicle over natural pollination was observed in natural pollination with augmentation of honey bees. The findings regarding percentage increase of average number of bael fruit per panicle over control in a result of pollination by honey bees only; this was studied by some other scientist in apple where percentage of fruit number was 1451.65%, which was 138.44% increase of fruit set over natural pollination [3]. The result of percentage increase in number of bael fruit panicle^{-1} in natural pollination over control was 1323.07%, which was in accordance with the result of fruit set percentage of pummelo, *Citrus maxima* i.e. 196.75% increase of fruit set over cage without bees (No pollination)[11]. The findings about natural pollination with augmentation of honeybees for fruit set in peach (*Prunus persica* L.) was maximum (6.5 fruit/branch) with placement of honeybee colonies at the closest distance of 20 meter [12].

Pollination effect of honey bees (*Apis mellifera* L.) on quality parameters like average fruit weight (in kg) and TSS % were indicated in Table 2 and 3 respectively, which reflect significant differences among treatments. The average fruit weight was found 1.99 kg and 1.93 kg in pollination by honey bees only and natural pollination respectively, which were relatively less than natural pollination with augmentation of honey bees i.e. 2.05 kg, that is increased by 6.22% over natural pollination. Same finding was recorded in apple cultivar, where highest fruit weight was observed, i.e. 166.19 gram with natural pollination with augmentation of honey bees, which was 28.22%, 112.13% and 42.53% increased of fruit weight in pollination by honeybees only, natural pollination with augmentation of honeybees and natural pollination over control, respectively [3]. Similarly an increase of 48.83% in fruit weight over natural pollination along with augmentation of honeybees was observed in apple variety "Braeburn" [13]. The TSS% was observed highest in case of natural pollination with augmentation of honey bees i.e. 41.3 which was 15.68% and 5.08% increase over control and natural pollination, respectively. Similar finding was recorded with the significant improvement on fruit characteristics, i.e. fruit weight, volume, length, diameter and T.S.S. of Anna and Dorsett Golden apple cultivars, as a result of increased honey bee visits/flower [14].

Table 1: Pollination effect of *Apis mellifera* L. on average number of bael fruit setting

Treatments	Number of fruits	Percentage increase over control	Percentage increase over natural pollination
Pollination by Honey bees only	25.1	1830.76	
Natural pollination + Augmentation of honey bees	27.3	2000.00	47.56
Natural pollination	18.5	1323.07	
Control (no pollination)	1.3		

Table 2: Pollination effect of *Apis mellifera* L. on average fruit weight (in kg)

Treatments	Weight of fruit (in kg)	Percentage increase over control	Percentage increase over natural pollination
Pollination by Honey bees only	1.99	5.29	
Natural pollination + Augmentation of honey bees	2.05	8.46	6.22
Natural pollination	1.93	2.11	
Control (no pollination)	1.89		

Table 3: Pollination effect of *Apis mellifera* L. on fruit TSS %

Treatments	TSS % of fruit	Percentage increase over control	Percentage increase over natural pollination
Pollination by Honey bees only	40.2	12.60	
Natural pollination + Augmentation of honey bees	41.3	15.68	5.08
Natural pollination	39.3	10.08	
Control (no pollination)	35.7		

4. Conclusion

To sum up, importance of honeybees as pollinators has been increasing day by day. It has been observed with this study that honeybees, *Apis mellifera* L. had a significant effect on productivity and quality of bael fruit, which was increased with the use of honeybees as pollinators. The use of honeybees for pollination in fruit cultivation will provide an increase in cultivating more and higher quality products in our country. When the role and importance of honeybees in pollination and its effective role in quality and quantity increase in the products are thoroughly understood, then it will have great developmental effect on agricultural structure. Moreover, the encouragement of producers to use of bee colonies in fruit production areas will contribute to fruit cultivation and bee keeping in our country.

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