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Quantitative and qualitative assessment studies in apple and functional role played by honey bee colonies installed with pollen dispenser

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Abstract

Understanding the importance of effective pollination methods is essential for maximizing apple production, as it directly affects the quantity and quality of the harvest. In this study, we aim to evaluate the impact of managing pollination using *Apis mellifera* colonies installed with pollen dispenser on fruit set in commercial apple orchards. In the experiment conducted at Mashobra (> 33% pollinizer proportion) and Kullu (< 10% pollinizer proportion) areas of Himachal Pradesh, significantly higher fruit set was recorded, during the year 2020 (74.01, 47.92%) and 2019 (56.60, 48.70%), respectively in apple orchards installed with honey bee colonies and pollen dispenser compared to treatments (orchards without pollen dispenser and without honey bee colonies). To check the field applicability, effect on yield and people's response the technique was shared with the beekeepers and orchardists of the state during camps and training. This study concludes that pollen dispenser cannot replace the role of honeybees in pollination but certainly adds up to their efficiency combating the fruit set deficit caused by low pollinizer proportion.

Keywords: Pollinizer, *Apis mellifera*, colonies, yield, fruit set, fruit weight

Introduction

Apple (*Malus domestica* Borkh) belongs to Rosaceae family and is grown in sub-temperate states, Himachal Pradesh, where the world's finest and choicest varieties of temperate fruits, including apples are grown (Chadha and Awasthi 2005) [3]. Here, the area under apple cultivation has expanded from 3,025 hectares in 1960-61 to 1,12,500 hectares in 2017-18, which constitutes more than 50 percent of the total area under fruit cultivation. More than 90 percent of the produce goes to the domestic market, contributing to approximately 40% of state economy. However, the profits from apple cultivation, which alone constitutes 89 percent of the total fruit economy, is not as fruitful as it used to be a decade ago. The fruit production has declined to 4.06 lakh tonnes in 2018-19 (till December 2018) against 5.65 lakh tonne in 2017-18 (Economic survey of Himachal Pradesh 2018-19). Pollination is one of the key factors influencing fruit yield, fruit size, and fruit quality in apples. Unfortunately, apple is also one of the crops to suffer from reduced crop and pollination success due to. To improve the pollination process, there are several important factors and efforts to consider, such as variety selection and pollination methods. Honey bees are the main insects involved in apple pollination. They are considered the best apple pollinators because they have a wide floral diet, are strong pollinators, and exhibit nectar and pollen-seeking behavior. For efficient pollination, honey bees can be moved when approximately 5 percent of apple trees are in full bloom and have a high concentration of flower nectar and pollen. One such efforts involves installing pollen dispenser or pollen inserts with honey bee colonies for enhancing cross-pollination. Pollen dispensers are the compact wooden structures placed (Lotter 1960) [13] at the colony entrance, constructed such that foragers walk on the hand-collected pollen (Townsend *et al.* 1958; Griggs and Iwakiri 1960; Lotter 1960) [20, 8, 13].

The regularly replenished pollens get stuck onto the body of foragers exiting from the colony and while visiting flowers for nectar and pollen, they enhance their pollination efficiency in crops (Karmo 1958; Jaycox and Owen 1965; Mayer and Johansen 1989) ^[11, 10, 14].

The use of pollen dispensers in old and unplanned apple plantations hold the potential of overcoming the impending fruit set. Although the pollen dispensers are being investigated for last 70 years and have displayed credible benefits, very little effort were made in the direction of assessing their impact on enhancing the apple production. Wide gap in the demand versus supply of colonies as well as the proportion of pollinizers in orchards especially old one are major limitations contributing to loss. To overcome these hurdles keeping in view these aspects and the importance of pollinators and pollination, in the year 2017, "Managed Pollination" was proposed as the necessary components under the World Bank-funded project (HP-HDP) in Himachal Pradesh. Under this project, the foremost attempt was made to advocate the use of pollen dispensers to improve pollination in the state, the apple bowl of India. These were standardized, evaluated, and then distributed among the selected beekeepers and the orchardists of the state to test the ground usefulness of pollen dispensers accounting for their effect on fruit set and qualitative parameters at different levels of pollinizer proportion. The present investigation was also carried to check the field applicability of these modified dispensers and their effect on productivity enhancement in apple crops of medium and commercial farmers.

Materials and Methods

The pollen dispenser is a structure made of wood that is attached to the hive entrance. It is so constructed that outgoing foragers, especially worker honey bees, walk through the pollen spread at its base. As a result, they carry the pollen on their legs and pollinate the apple blooms while visiting the flowers for nectar and pollen.

The flowers for the pollen dispenser were obtained at closed balloon stage from the Red Gold apple pollinizer. The anthers of 100 flowers were removed with a wire mesh. Anthers were collected and stored for dehiscence beneath muslin fabric in labelled petri dishes inside an incubator at 24 °C or overnight at room temperature under low temperature Led bulbs to cause pollen from the anthers burst open.

During the experiment, pollen dispensers measuring 37.5 cm in length, 4.9 cm in width with a 20 cm base and a front strip height of 2 cm here built and installed at the hive entrance of the *A. mellifera* colonies conditioned for apple bloom.

Effectiveness of pollen dispenser

Experimental trials conducted in apple orchards (Variety Scarlet Spur) in 2018 and 2019 at two locations: in a private orchard at Naggur, Kullu with less than 10 percent pollinizer proportion and at Regional Horticultural Research Station, Mashobra, Shimla with more than 33 percent pollinizer proportion. Three distinct orchard systems with replications were established at each site, and the mean was determined. Two *A. mellifera* colonies (8-10 frames strong; brood in 4-5 frames) were maintained 200 metres apart in two systems. One of the orchards (PD) had pollen dispenser installed at the hive entrance, whereas the other orchards (WPD) had no pollen dispenser at all. For the experiment, the apple orchards without colony (WC) served as the control.

Fruit set: Pollen replenishment was carried out once a day for

five days in orchards including honey bee colonies and pollen dispensers. 2 g of dehisced pollen was combined with powdered dried anther husk in a ratio of 1:1 at 0900 and 1100 hours. In all three orchards, fruit set was measured on a spur basis in sites where the percentage of pollinizer was 10% and 33%. For the purpose of ensuring data consistency, trees were marked at 25, 50, 75 and 100 m intervals from the colony placement in PD and WPD orchards, as well as at the same distances in WC orchards. The spurs (100-150) at balloon stage were counted three weeks following the petal fall in order to measure the percentage of fruit set.

Fruit quality parameters: In order to examine the impact of pollen dispensers on fruit quality attributes, 10 randomly chosen fruits were gathered from each treatment. Using digital vernier callipers, fruit size was measured in millimeters (mm) and represented as a length and width. Fruit weight was recorded with the help of top pan balance and the average value was expressed in grams per fruit. Fruit volume was determined by the water displacement method. The average value was expressed in milli liter (ml). Total Soluble Solid (TSS) content expressed as Degree Brix (°B) in the randomly selected fruits was determined by Erma hand refractometer. Seed Number/fruit were counted by cutting the fruit cross-sectionally. Firmness of fruit expressed in kilogram per square centimeter (kg/cm²), was determined by pressure tester (Magness- Taylor pressure tester). The data were analyzed statistically using the Randomized Block Design (RBD) factorial and t-test after proper transformation wherever needed (Gomez and Gomez 1986) ^[6].

Success in the field at commercial level

In the year 2019, beekeepers along with orchardists were given the field demonstration in apple orchards with bee hives and shown how to install and utilize pollen dispensers to improve pollination effectiveness, particularly in areas with low pollinizer proportions. An experiment was done to determine the efficiency of pollen dispensers in commercial apple orchards. Pollen dispensers were created and given to the state's beekeepers and orchardists during camps out of which seven orchardists were selected with apple plantation of about 200-250 trees between 10-15 years of bearing age. Fruit production data from 2019 (with pollen dispensers) and 2018 (without pollen dispensers) were compared, and the percentage increase in fruit output was determined to measure field adaptability, yield impact, and public response.

Results

Effectiveness of pollen dispenser

Fruit set: The experimental trial to evaluate the pollen dispenser under field condition was laid out at Mashobra, Shimla (at more than 33 percent pollinizer proportion), data presented in Table 1 and Naggur Block, Kullu (at less than 10 percent pollinizer proportion), data presented in Table 2. The rainfall and temperature variations recorded at the site selected for fruit set in apple plantations during March-April 2018-19 is presented in figure 1.

During 2018, the data on fruit set (on spur basis) at Mashobra, Shimla (Table 1) with pollinizer proportion of 33 percent (irrespective of distance), indicated a significantly higher fruit set of 74.01 percent in the orchards installed with pollen dispenser (PD) as compared to the 54.27 percent fruit set in the orchard without pollen dispenser (WPD) which was more than 44.81 percent fruit set in orchards without colonies (WC). The fruit set at different distances (irrespective of system) from the

placement of bee colonies with pollen dispenser was higher up to 75m (83.57%) par to 81.12 percent at 50 m in PD-orchard. The trend of fruit set in the orchards having colony without pollen dispenser was highest (56.84 percent) at 50 m and 50.90 percent at 75 m in orchards without colonies.

During 2019, the overall fruit set in the orchards (Table 1) was recorded comparatively less than the fruit set of previous year. Fruit set in orchards having colonies with pollen dispenser (PD) was recorded to be more (56.60%) than 48.23 percent in orchards without pollen dispensers (WPD) and 39.90 percent in orchards without colonies (WC). The fruit set recorded at different distances (irrespective of system) followed the decreasing pattern with 67.32 percent at 25m and 60.43 percent at 50m and 54.63 percent and 44.01 percent at 75m and 100m, respectively in orchards with pollen dispenser. In orchards without pollen dispenser, the highest fruit set, 67.32 percent was recorded at 25m. The lowest fruit set of 44.01 and 38.01 percent, were obtained at 100 m in PD and WPD orchard, respectively.

In orchards that had a lower than 10 percent of the pollinizer's share at Naggar Block, Kullu during 2018, the data on the effect of the pollen dispenser on the apple fruiting process were

different than in Mashobra orchards (>33% of the pollinizer's share). The analysis of the data in Table 2 demonstrated that the fruit set percentage was higher in PD-orchard than in WPD-orchard and 15.42 percent in WC-orchard. The fruit set recorded in PD-orchard (irrespective of system) was highest, 56.79 percent at 25m following decreasing format with distance. Similar observations were made in WPD-orchards that had the greatest fruit composition of 34.17 percent at 25m, and 18.87 percent at 100m. In orchards that lacked colonies, 21.54 percent of the fruiting occurred in the highest percentage. The percentage of fruit that was set at different distances was higher in 25m (66.80%) in PD-orchard than it was in 45.93 percent in WPD-orchard, which was then followed by a decrease towards larger distances.

In 2019, (Table 2), the PD-orchard had the largest fruit set (48.70%) compared to the WPD-orchard (34.34%) and WC-orchards (17.84%). Fruit set at different distances was higher at 25m (66.80%) in PD-orchard and 45.93 percent in WPD-orchard, followed by a decreasing tendency as distance increased.

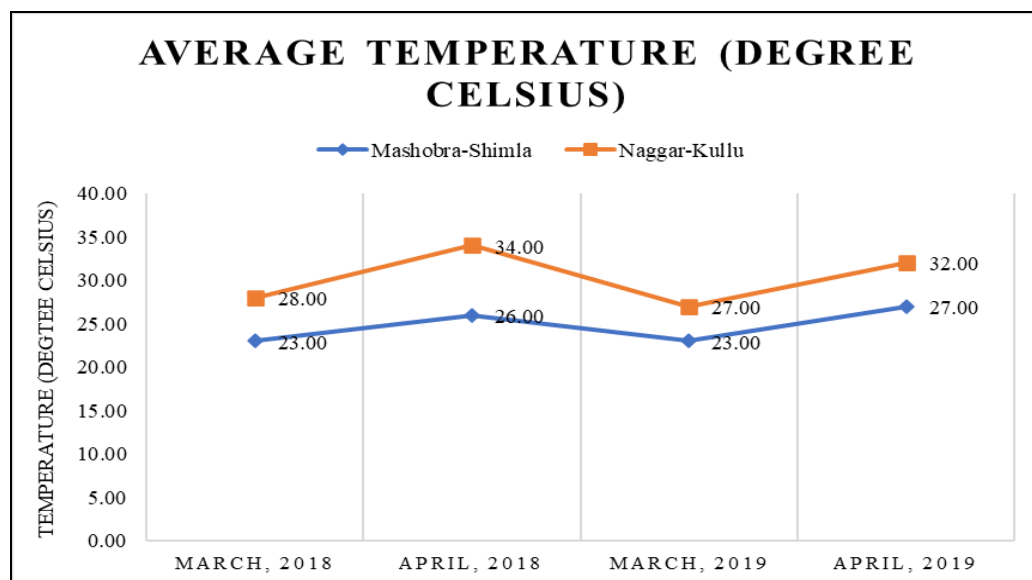
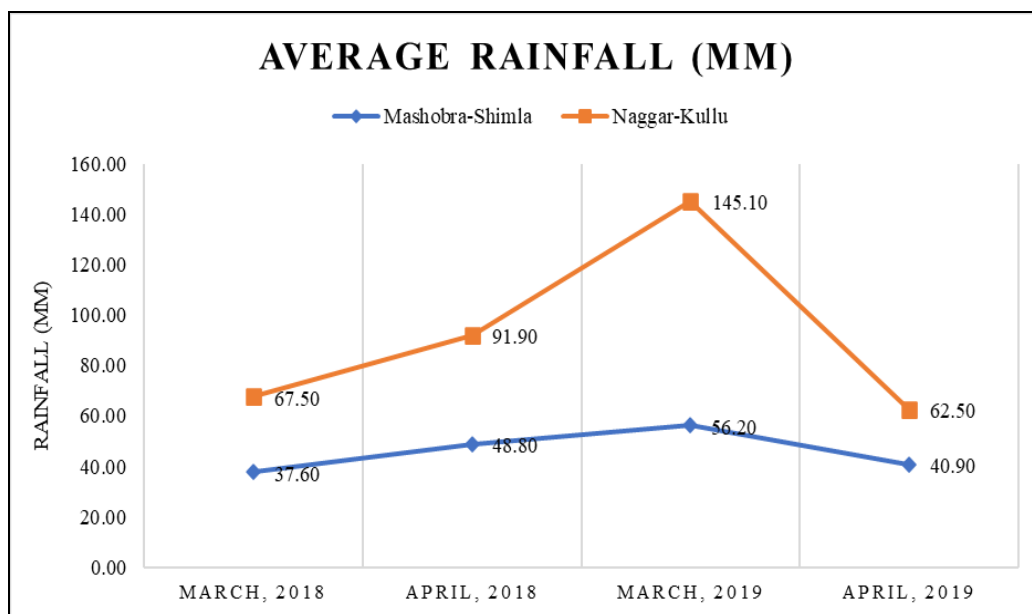


Fig 1: Rainfall and temperature (March-April 2018-19) recorded during bloom and fruit set period in apple plantations at Mashobra-Shimla and Naggar- Kullu

Fruit quality parameters

To assess the effect of pollen dispenser on fruit quality parameters, data on fruit length (Table 3) showed that fruits from PD-orchard were longer, 63.39 mm in 2019 and 65.26 mm in 2018, while those from WPD-orchard were 58.17 mm in 2018 and 49.62 mm in 2019; the smallest fruits were obtained in orchards without colonies, 42.66 mm in 2018 and 35.21 mm in 2019. Fruit breadth was likewise found to be greater in PD-orchards (58.63 mm) than in WPD-orchards (49.21 mm) and WC-orchards (41.29 mm), but broader fruits were recorded in WPD-orchards (56.20 mm). Pollen dispenser had a considerable favourable influence on apple fruit weight under field conditions in 2018 (125.2 g) and 2019 (121.82 g) in PD-orchard. Similar was the pattern with fruit volume and TSS. The quantity of seeds recorded in the fruit was non-significant for the year 2018, while recorded to be more (5.75) in PD-orchard in 2019. The harvested fruits from PD-orchard were more solid over the years than other systems. The visual inspection of the fruits collected lacked prominent lobes and the fruits collected from both

orchards were found to have flattened protuberances.

Percent fruit set was recorded higher for the year 2018 (74.01, 54.27 and 44.81%) and 2019 (56.60, 48.23 and 39.90%) in apple orchards having honey bee colony with pollen dispenser, without pollen dispenser and orchards without colonies, respectively, at 33 percent pollinizer proportion in Mashobra, Shimla compared to orchards at Naggar, Kullu (< 10% pollinizer proportion) where lower fruit set was recorded in all the three orchard systems.

As per the observations of Table 3, bee colonies with pollen dispenser had positive effect on the fruit quality parameter. The difference in fruit quality in orchard with and without pollen dispenser again imprints that in case of lower pollinizer proportion or less pollen production during a particular year use of pollen dispenser can compensate the fruit quality that decides the crop market value. The fruits in orchard without colonies were of lower grade with respect to all the quality attributes which suggest the significance of honeybees as pollinators.

Table 1: Effect of Pollen dispenser at more than 33 percent pollinizer proportion in apple fruit set at Mashobra, Shimla during 2018-19

Systems	2018					2019				
	25m	50 m	75m	100m	Mean	25m	50 m	75m	100m	Mean
PD	72.50	81.12	83.57	58.87	74.01	67.32	60.43	54.63	44.01	56.60
WPD	64.93	56.84	52.57	42.73	54.27	53.60	51.37	49.93	38.01	48.23
WC	41.81	50.43	50.90	36.10	44.81	36.76	38.20	39.78	44.87	39.90
Mean	59.75	62.80	62.34	45.90		52.56	50.00	48.12	42.29	
CD _(0.05) Systems = 4.85, Distance = 5.60; System x Distance =9.70						Systems = 4.24, Distance = 4.90; System x Distance =8.49				

(PD: Bee colony with Pollen Dispenser; WPD: Bee colony without Pollen Dispenser; WC: Without colonies)

Table 2: Effect of Pollen dispenser at less than 10 percent pollinizer proportion in apple fruit set at Naggar, Kullu during 2018-19

Systems	2018					2019				
	25m	50 m	75m	100m	Mean	25m	50 m	75m	100m	Mean
PD	56.79	51.13	44.10	39.67	47.92	66.80	53.60	42.18	32.22	48.70
WPD	34.17	30.07	18.48	18.87	25.39	45.93	40.89	27.10	23.45	34.34
WC	15.97	13.64	21.54	10.53	15.42	10.70	18.13	28.33	14.20	17.84
Mean	35.64	31.61	28.04	23.02		41.14	37.54	32.54	23.29	
CD _(0.05) Systems = 3.51, Distance = 4.04; System x Distance =7.01						Systems = 5.48, Distance = 6.33; System x Distance =10.96				

(PD: Bee colony with Pollen Dispenser; WPD: Bee colony without Pollen Dispenser; WC: Without colonies)

Table 3: Effect of Pollen dispenser at 10% pollinizer proportion on fruit quality of apple fruit at Naggar, Kullu during 2018-19

Systems	Fruit length (mm)	Fruit breadth (mm)	Fruit weight (g)	Fruit volume (ml)	TSS (⁰ B)	Seed No.	Firmness (Kg/cm ²)	
2018	PD	63.39	58.63	125.21	164.03	9.81	5.53	9.37
	WPD	58.17	49.21	117.93	159.75	9.18	5.48	8.73
	WC	42.66	41.29	99.28	153.72	8.22	5.22	7.66
	CD _(0.05)	6.67	7.87	5.02	7.86	0.40	NA	0.46
2019	PD	65.26	50.10	121.82	163.42	10.31	5.75	8.93
	WPD	49.62	56.20	108.66	145.86	9.20	5.19	8.78
	WC	35.21	43.23	98.73	124.11	7.99	5.00	6.90
	CD _(0.05)	6.88	5.17	5.41	6.26	0.65	0.36	0.99

(PD: Bee colony with Pollen Dispenser; WPD: Bee colony without Pollen Dispenser; WC: Without colonies)

Implications of pollinizer and pollen dispenser for orchardists

During the flowering in apple, out of six orchardists, three used honeybee colonies with pollen dispenser and three did not opt for pollen dispenser. The details provided in Table 4, describes the findings; out of the orchardists Mr. Sanjeev Sharma recorded the highest increase in fruit yield. He used 3 colonies with pollen dispenser in his orchard of 246 trees at 32 percent pollinizer proportion fetching him up to 176.52 percent higher yield at an average of 32.27 Kg fruits/trees in 2020 as compared to 11.67 Kg fruits/tree in 2019. Mr. Jayant Attreta with 2 colonies and pollen dispenser in his orchard of 235 trees with 30 percent

pollinizer proportion recorded 175 percent increase in fruit yield at an average of 27.50 Kg/trees in 2020 as compared to 10 Kg/tree in 2019. Whereas, with pollen dispenser and 2 Apis mellifera colonies, Mr. Suraj Chauhan at 28 percent pollinizer proportion in the orchard (210 trees) recorded 166.71 percent increase in fruit yield. Mr. Bhopinder Sharma without pollen dispenser at 30 percent pollinizer proportion in his orchard (250 trees) with 3 colonies recorded about 40 percent increase in fruit yield. It was also noted that with the use of a higher number of honey bee colonies the average fruit yield showed a considerable increase (Gupta *et al.* (1993) ^[9] as observed by Mr. Deepak Singha in his orchard (254 trees) who without pollen dispenser

and 4 colonies at 15 percent pollinizer proportion recorded 12.82 percent increase in fruit yield. Mr. Vivek Bharanta in his orchard (220 trees) at 28 percent pollinizer proportion with 2 honeybee colonies and without pollen dispenser recorded lowest increase (12.53%) at an average of 22 Kg/trees in 2020 as compared to 19.55 Kg/tree in 2019.

Graphical representation in the figure 2 compares the effect of

pollen dispenser on fruit yield in the conditions of different level of pollinizer proportion. In orchards where pollen dispenser was used increase in fruit yield puts a clear stamp on the synergistic effect of pollen dispenser on fruit yield if used at the recommended level of pollinizer proportion (Bist and Sharma, 1986; Mishra *et al.*, 1976)^[2, 15] along with honey bee colonies in the orchard.

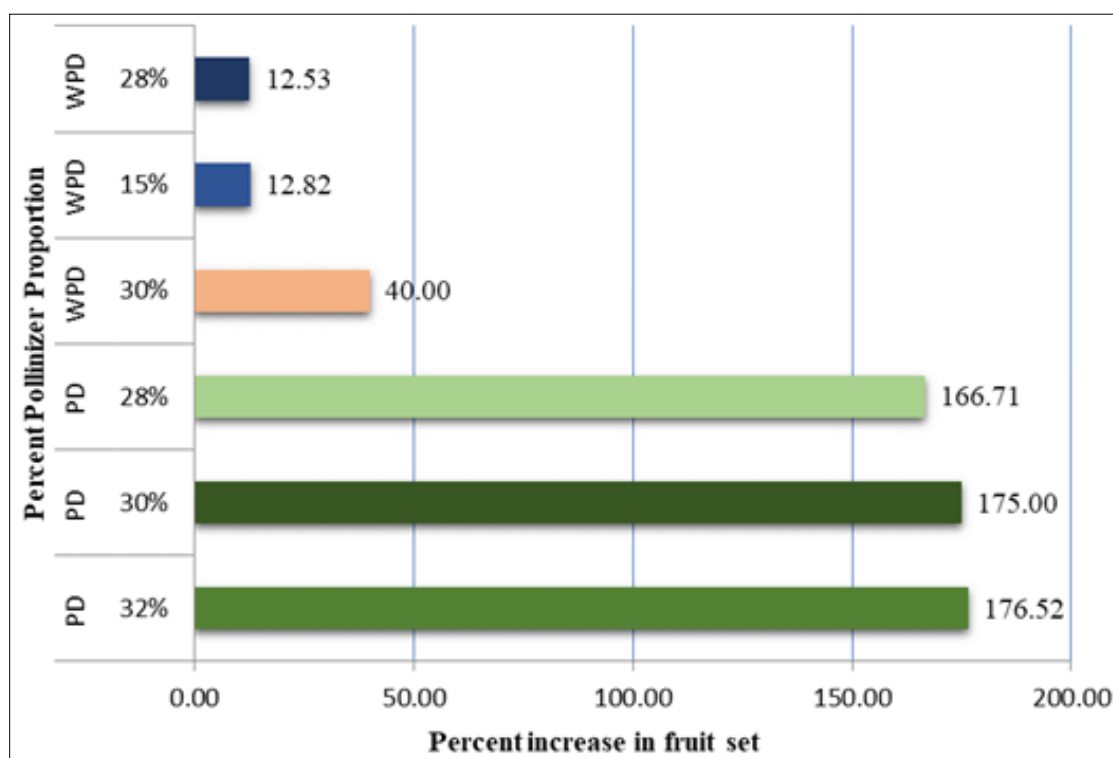


Fig 2: Percent increase in fruit yield (2019-20) with pollen dispenser (PD) and without pollen dispenser (WPD)

Table 4: Percent increase in fruit yield in different pollination trials of apple orchardists

S. No.	Growers Name	Varieties	Location And Altitude m abs	(Altitude; Latitude; Longitude)	Percent pollinizer proportion	No. of colonies	Pollen dispenser (PD- with pollen dispenser; WPD- without pollen dispenser)	Fruit yield Kg/tree 2019	Fruit yield Kg/tree 2020	Percent increase
1	Sanjeev Sharma	Royal Delicious	Matiana- Shimla 2472 m	31°12'32"N 77°24'01"E	32	3	PD	11.67	32.27	176.52
2	Jayant Attreta	Red Chief, Scarlett II	Rohru- Shimla 1651 m	31°12'31"N 77°45'04"E	30	2	PD	10.00	27.50	175.00
3	Suraj Chauhan	Red Chief, Orgeon Spur,	Rohru- Shimla 1597 m	31°12'18"N 77°45'04"E	28	2	PD	15.71	41.90	166.71
4	Bhopinder Sharma	Red Chief, Orgeon Spur, Scarlett II	Rohru- Shimla 1542 m	31°12'10"N 77°45'56"E	30	3	WPD	26.40	36.96	40.00
5	Deepak Singha	Royal Delicious, Red Richard	Kotgarh- Shimla 1945 m	31°18'44"N 77°28'29"E	15	4	WPD	39.00	44.00	12.82
6	Vivek Bharanta	Red Chief, Orgeon Spur, Scarlett II	Rohru- Shimla 1726 m	31°12'46"N 77°45'12"E	28	2	WPD	19.55	22.00	12.53

Discussions

Variation in fruit set during the year 2018 and 2019 primarily directed at the observation that year-to-year variations in fruit set as reported by Sharma *et al.* (2004)^[19] attributed to several biological and physical factors. The discrepancy in fruit set observed in these systems was significant in apple tree having low pollinizer proportion during 2018 and 2019 in Naggar, Kullu. This emphasizes the necessity of a required percentage of pollinizers that could have negative effect on setting of fruits, even if the colonies provided are sufficient. Sharma *et al.* (2004)^[19] in their research documented an increase in the number of

fruit set per plant and yield of fruit harvested from plants that were placed with bee colonies that were more proficient than plants that were placed with insufficient pollinizer.

Additionally, in the evaluation of the number of *A. mellifera* colonies necessary per hectare to achieve optimal pollination, the pattern followed at different distances in the orchards of Mashobra and Kullu, showed that the fruit set was highest closer to the bee colonies as reported by Rana *et al.* (1995)^[16] and Sharma and Gupta (2001)^[17], which imply on an average two strong colonies to be sufficient enough for pollinating about 1 ha area of apple plantation.

The pattern of fruit set seen in various systems indicates that pollen dispensers have an additive impact on improving the performance of honeybees in pollination. These findings are consistent with those of Karmo and Vickery (1958)^[11] and Townsend *et al.* (1958)^[20], who achieved a greater percentage of fruit set on Bartlett pear trees using modified Karmo-Vickery inserts. Karmo (1958)^[11] investigated the efficacy of pollen dispensers and discovered 25 percent greater fruit set and less deformed fruits. Lotter (1960)^[13] also claimed a 50 percent increase in production in a commercial experiment of pollen dispensers in apple orchards. These data are likewise consistent from that of Legge and Williams (1974)^[12], who reported an initial fruit set of 10.5 percent near to hive equipped with pollen dispenser which decreased to 3 percent at 100m distance. They also reported greater fruit set in a commercial trial in apple orchard particularly around the beehive with pollen dispenser. In relation to the fruit parameters, the present findings are in line with Dulta and Verma (1987)^[4] who observed that in the Golden Delicious, Royal Delicious and Red Delicious cultivars of apples, there was an increase in weight, length, breadth, volume and number of seeds in fruits which developed from honey bee-pollinated flowers. In conformity with these, many workers reported significantly positive effects on fruit quality parameters as in case of fruit size by Gourley and Howlett (1955)^[7] and Sharma and Thakur (2003)^[18] that compared quality of fruits from different modes of pollination and reported that the maximum number of seeds was found in fruits obtained from bee pollination.

Conclusion

The experiment demonstrates the importance of pollinizers in conjunction with honeybee colonies. Furthermore, the amalgamation of honey bee colonies and pollen inserts elucidates their quantitative benefits for pollination in apple crop production settings, implying that pollen dispensers can certainly add up to the honey bees' efficiency and mitigate the disadvantages caused by insufficient pollinizer proportion to a certain extent. Henceforth, pollen dispenser can play significant role at times when the flowering period in reproductive and pollinizer varieties does not coincide and during the times of low pollen production caused by difficult weather conditions. However, the study also acknowledges the impact of environmental factors, such as regional weather conditions, on pollinator efficacy, emphasizing the need to consider external influences on pollination processes. With changing environmental conditions and the need for greater efficiency and sustainability, it has become evident that for an orchard to thrive and produce consistent yields of high-quality fruit, a good pollination system is essential. These findings obtained in coordination with state beekeepers and orchardist, should be widely accepted and have the potential to persuade more orchardists and beekeepers to adopt this technology, which could certainly lead to the most anticipated positive changes in the field of managed as well as sustainable pollination and shall revolutionize the way honeybees are used.

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Ethics approval: The manuscript has not been submitted to any other journal for consideration. The submitted work is original and has not been published elsewhere in any form or language. No data, text, theories by others are presented here.

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