

drops were maximum (37.32%, 38.37% and 39.23% respectively) under control experiment and minimum (25.32%, 26.20% and 28.31% respectively) in honeybee pollinated flowers. In open pollinated flowers of Golden Delicious, the fruit drops were 28.40%, 28.25% and 30.41% at Bhalogi, Baskhola and Dhamadhar respectively (Table 2). Similarly at Bhalogi, Baskhola and Dhamadhar in Red Gold, the fruit drops were maximum (36.40%, 38.40% and 37.70% respectively) under control experiment and minimum (24.40%, 25.46% and 27.88% respectively) in honeybee pollinated flowers. In open pollinated flowers of Red Gold, the fruit drops were 30.60%, 32.43% and 31.64% respectively. No significant difference ($P>0.01$) was observed in fruits drops of self-compatible varieties between open and honeybees pollinated flowers. In self-incompatible variety like Royal Delicious, the fruit drops in open pollinated flowers were 29.61%, 30.74% and 30.14% at Bhalogi, Baskhola and Dhamadhar respectively, whereas, in honeybees pollinated flowers the fruit drops were 25.37%, 25.53% and 27.80% respectively. In other self-incompatible variety of Red Delicious, the fruit drops in open pollinated flowers at Bhalogi, Baskhola and Dhamadhar were 29.30%, 29.04% and 30.71% respectively, whereas, in honeybees pollinated flowers of Red Delicious, the fruit drops were 24.62%, 26.54% and 27.70% respectively. The difference observed in the fruit drops of self-incompatible varieties between open and honeybees pollinated flowers was without any significant difference ($P>0.01$).

3.3 Quality improvement in the apple fruits due to insect pollination

Quality improvement in the apple fruit was observed in terms of increase in weight (gm), length and breadth (cm), volume (ml) and number of seeds per fruit. In apple orchard at Bhalogi, the mean weights of apple fruit in honeybee pollinated Golden Delicious, Red Gold, Royal Delicious and Red Delicious were 190.06 ± 1.22 gm, 150.00 ± 4.50 gm, 173.60 ± 4.20 gm and 170.60 ± 8.03 gm respectively. Whereas, at Baskhola the mean weights in honeybees pollinated Golden Delicious, Red Gold, Royal Delicious and Red Delicious were 179.22 ± 2.50 gm, 165.02 ± 2.30 gm, 213.00 ± 1.20 gm and 188.08 ± 4.20 gm respectively. At Dhamadhar, the mean weights of Golden Delicious, Red Gold, Royal Delicious and Red Delicious in honeybee pollinated fruits were 287.02 ± 6.01 gm, 203.00 ± 1.10 gm, 301.60 ± 1.30 gm and 290.20 ± 3.02 gm respectively (Table 3).

The mean lengths of Golden Delicious, Red Gold, Royal Delicious and Red Delicious under this set of experiment at Bhalogi were 7.32 ± 0.04 cm, 6.70 ± 0.50 cm, 6.97 ± 0.50 cm and 6.48 ± 0.11 cm respectively, while at Baskhola the mean lengths of Golden Delicious, Red Gold, Royal Delicious and Red Delicious were 6.80 ± 0.15 cm, 6.40 ± 0.06 cm, 7.00 ± 0.40 cm and 6.60 ± 0.24 cm respectively. The mean lengths of fruit in honeybees pollinated flowers of Golden Delicious, Red Gold, Royal Delicious and Red Delicious were 7.60 ± 0.08 cm, 6.80 ± 0.14 cm, 8.90 ± 0.29 cm and 8.92 ± 0.16 cm respectively at Dhamadhar (Table 3).

In apple orchard at Bhalogi, the mean breadths of Golden Delicious, Red Gold, Royal Delicious and Red Delicious in

honeybee pollinated flowers were 7.80 ± 0.21 cm, 7.30 ± 0.06 cm, 7.82 ± 0.30 cm and 7.40 ± 0.26 cm respectively. The mean breadths of Golden Delicious, Red Gold, Royal Delicious and Red Delicious in Honeybees pollinated flowers were 7.90 ± 0.10 cm, 7.05 ± 0.10 cm, 7.80 ± 0.22 cm and 7.14 ± 0.11 cm respectively at Baskhola, whereas, the mean breadths were 8.80 ± 0.10 cm, 7.90 ± 0.06 cm, 8.78 ± 0.04 cm, and 8.80 ± 0.07 cm, in Golden delicious, Red Gold, Royal Delicious and Red Delicious respectively at Dhamadhar. The mean volumes of Golden delicious, Red Gold, Royal delicious and Red Delicious were 170.20 ± 4.12 ml, 158.10 ± 6.80 ml, 160.50 ± 3.45 ml and 135.12 ± 6.10 ml respectively at Bhalogi, whereas, 140.00 ± 3.01 ml, 100.04 ± 2.30 ml, 240.02 ± 2.50 ml and 150.06 ± 5.20 ml respectively at Baskhola and 250.60 ± 2.30 ml, 201.20 ± 1.25 ml, 320.60 ± 1.28 ml and 270.02 ± 3.32 ml respectively at Dhamadhar (Table 3).

At Bhalogi, the mean number of seeds per fruit in honeybee pollinated flowers of Golden Delicious, Red Gold, Royal Delicious and Red Delicious were 9.00 ± 0.25 , 8.91 ± 2.50 , 7.00 ± 0.61 and 6.30 ± 0.92 respectively whereas, the mean number of seeds per fruit were 6.42 ± 0.25 , 6.20 ± 1.12 , 7.40 ± 0.52 and 6.00 ± 1.20 , respectively at Baskhola and these were 9.00 ± 0.32 , 8.60 ± 0.41 , 7.30 ± 0.70 and 7.20 ± 0.80 respectively at Dhamadhar (Table 3).

In self-incompatible varieties like Royal Delicious and Red Delicious there was not any fruit set in control experiment but in self-compatible varieties like Golden Delicious and Red Gold the quality of apple fruit was noticed. It was noticed that weight, length, breadth, volume and number of seeds per fruit in Golden Delicious and Red Gold at all the three orchards were significantly maximum ($P<0.01$) in fruits which developed from honeybees pollinated flowers and minimum in fruits under control experimental conditions, whereas, in Royal Delicious and Red Delicious the weight, length, breadth, volume and number of seeds per fruit were significantly more ($P<0.01$) in fruits from honeybees pollinated flowers than in fruits from open pollinated flowers.

In honeybee pollinated flowers the fruits were larger in size than fruits from open pollinated flowers which were in turn larger than the fruits from control experiment. Observations on fruit quality were made by some earlier workers (27, 19) who reported that honeybee pollination increased quality and quantity of apple fruits. The better pollinating efficiency of honeybees help in the fertilization of maximum number of ovules and thereby more number of seeds are formed in this way maximum amount of auxin (a growth hormone) is produced which results in better size of fruits. Fruits obtained by self pollination had a lower average weight, size and poor colour and contained a small number of seeds as compared to the fruits obtained from cross pollination (20, 15, 6). It was reported that greater number of seeds depended upon greater number of bees involved in cross pollination (4). There was positive relation between honeybee pollination and quality of apple crop (9, 26, 2). Fruit set in peach (*Prunus persica* L.) was maximum (6.5 fruit/branch) with placement of honeybee colonies at the closet distance of 20 m (5). Similar results on fruit quality and yield due to

honeybee pollination was also observed in different crops (22, 23).

4. Conclusion

Present study revealed that pollination by honeybees increased the fruit set and decreased the fruit drop in apple crop. Moreover quality of apple fruit (in terms of weight, length, breadth, volume and number of seed) was improved by honeybee pollination. We hope that our study will be useful for promoting awareness among people regarding the importance of honeybee pollination in horticulture and agriculture.

5. Conflict of Interest

The authors confirmed that this article content has no conflicts of interest.

6. Acknowledgment

The authors are thankful to the Chairman, Department of Biosciences, Himachal Pradesh University, Shimla for providing the necessary facilities and for encouragements. Thanks are also due to the University Grants Commission (UGC), New Delhi for providing the financial assistance in the form of UGC-JRF to Thakur Bhagat.

Table 1: Percentage of fruit set in three different experimental designs

Sr. No.	Apple Variety	Bhalogi (1400 m)			Baskhola (1580 m)			Dhamadhar (1810 m)		
		Honeybees pollinated flowers (H)	Open pollinated flowers (O)	No insect pollinator (Control) (C)	Honeybees pollinated flowers (H)	Open pollinated flowers (O)	No insect pollinator (Control) (C)	Honeybees pollinated flowers (H)	Open pollinated flowers (O)	No insect pollinator (Control) (C)
1.	Golden delicious	30.60	20.44	17.21	29.46	18.22	16.30	22.20	19.02	17.20
2.	Red Gold	23.20	17.04	15.31	22.34	16.52	15.51	21.62	19.42	16.65
3.	Royal Delicious	22.42	15.62	0	21.52	15.31	0	16.90	8.48	0
4.	Red Delicious	20.84	13.73	0	20.07	11.05	0	16.80	8.32	0

For honeybee pollination two colonies, one *Apis mellifera* and one *Apis cerana* with 6 frames each were placed inside the net.

Each percentage is an average of twelve observations.

S.E. = Standard error about the mean.

For fruit set: $H > O > C$ ($P < 0.01$).

Table 2: Percentage of fruit drop in three different experimental designs

Sr. No.	Apple Variety	Bhalogi (1400 m)			Baskhola (1580 m)			Dhamadhar (1810 m)		
		Honeybees pollinated flowers (H)	Open pollinated flowers (O)	No insect pollinator (Control) (C)	Honeybees pollinated flowers (H)	Open pollinated flowers (O)	No insect pollinator (Control) (C)	Honeybees pollinated flowers (H)	Open pollinated flowers (O)	No insect pollinator (Control) (C)
1.	Golden delicious	25.32	28.40	37.32	26.20	28.25	38.37	28.31	30.41	39.23
2.	Red Gold	24.20	30.60	36.40	25.46	32.43	38.40	27.88	31.64	37.70
3.	Royal Delicious	25.37	29.61	0	25.53	30.74	0	27.80	30.14	0
4.	Red Delicious	24.62	29.30	0	26.54	29.04	0	27.70	30.71	0

For honeybee pollination two colonies, one *Apis mellifera* and one *Apis cerana* with 6 frames each were placed inside the net.

Each percentage is an average of twelve observations.

S.E. = Standard error about the mean.

For fruit drop: $H < O < C$ ($P < 0.01$).

Table 3: Effect of insect pollinators on the quality of apple fruit in terms of weight (gm), length (cm), breadth (cm), volume (ml) and number of seeds per fruit

Apple Variety	Honeybees pollinated flowers (H)					Open pollinated flowers (O)					No insect pollinator (C) control					
	Weight W(H)	Length L(H)	Breadth B(H)	Volume V(H)	No. of Seeds SH	Weight W(O)	Length L(O)	Breadth B(O)	Volume V(O)	No. of Seeds SO	Weight W(C)	Length L(C)	Breadth B(C)	Volume V(C)	No. of Seeds SC	
Bhalogi (1400 m)																
1.	Golden delicious	190.06 ±1.22	7.32 ±0.04	7.80 ±0.21	170.20 ±4.12	9.00 ±0.25	152.00 ±2.18	6.30 ±0.08	7.02 ±0.04	158.60 ±3.30	7.50 ±0.29	90.00 ±2.40	6.04 ±0.04	6.80 ±0.05	70.60 ±5.08	6.40 ±0.29
2.	Red Gold	150.00 ±4.50	6.70 ±0.50	7.30 ±0.06	158.10 ±6.80	8.91 ±2.50	123.30 ±5.90	5.50 ±0.06	6.20 ±0.04	127.00 ±3.80	6.00 ±0.42	108.44 ±4.30	5.00 ±0.02	5.80 ±0.04	60.30 ±1.40	4.90 ±0.22
3.	Royal Delicious	173.60 ±4.20	6.97 ±0.50	7.82 ±0.30	160.50 ±3.45	7.00 ±0.61	161.21 ±4.01	6.08 ±0.22	7.20 ±0.30	140.23 ±3.45	5.40 ±0.22	No fruit set				
4.	Red Delicious	170.60 ±8.03	6.48 ±0.11	7.40 ±0.26	135.12 ±6.10	6.30 ±0.92	104.70 ±4.51	5.00 ±0.14	5.50 ±0.22	90.20 ±8.30	5.00 ±0.25	No fruit set				
Baskhola (1580 m)																
1.	Golden	179.22	6.80	7.90	140.00	6.42	152.30	6.20	6.40	160.00	7.48	120.60	5.42	5.90	70.00	5.82

	delicious	±2.50	±0.15	±0.10	±3.01	±0.25	±2.02	±0.03	±0.16	±4.50	±0.80	±0.51	±0.03	±0.09	±2.70	±0.20
2.	Red Gold	165.02 ±2.30	6.40 ±0.06	7.05 ±0.10	100.04 ±2.30	6.20 ±1.12	140.00 ±0.42	5.80 ±0.03	6.21 ±0.06	148.30 ±4.40	7.32 ±0.29	101.01 ±0.56	4.00 ±0.11	4.90 ±0.02	62.60 ±1.02	5.71 ±0.67
3.	Royal Delicious	213.00 ±1.20	7.00 ±0.40	7.80 ±0.22	240.02 ±2.50	7.40 ±0.52	180.06 ±3.52	6.40 ±0.42	7.47 ±0.22	188.40 ±3.97	7S.00 ±0.41	No fruit set				
4.	Red Delicious	188.08 ±4.20	6.60 ±0.24	7.14 ±0.11	150.06 ±5.20	6.00 ±1.20	154.22 ±9.90	6.50 ±0.12	6.29 ±0.28	160.32 ±2.25	6.72 ±0.30	No fruit set				
Dhamadhar (1810 m)																
1.	Golden delicious	287.02 ±6.01	7.60 ±0.08	8.80 ±0.10	250.60 ±2.30	9.00 ±0.32	242.62 ±1.14	7.00 ±0.04	7.91 ±0.02	240.00 ±4.54	7.80 ±0.23	225.02 ±4.12	7.20 ±0.10	7.11 ±0.42	215.30 ±3.00	7.30 ±0.80
2.	Red Gold	203.00 ±1.10	6.80 ±0.14	7.90 ±0.06	201.20 ±1.25	8.60 ±0.41	188.60 ±2.50	6.00 ±0.02	7.40 ±0.09	142.24 ±4.00	6.60 ±0.29	130.21 ±5.61	5.90 ±0.08	6.10 ±0.11	80.02 ±2.12	6.00 ±0.08
3.	Royal Delicious	301.60 ±1.30	8.90 ±0.29	8.78 ±0.04	320.60 ±1.28	7.30 ±0.70	260.70 ±3.40	7.63 ±0.10	8.17 ±0.18	250.20 ±1.30	7.00 ±0.40	No fruit set				
4.	Red Delicious	290.20 ±3.02	8.92 ±0.16	8.80 ±0.07	270.02 ±3.32	7.20 ±0.80	220.51 ±3.12	7.91 ±0.15	7.30 ±0.11	253.32 ±5.41	6.10 ±0.66	No fruit set				

For honeybee pollination two colonies, one *Apis mellifera* and one *Apis cerana* with 6 frames each were placed inside the net.

Each percentage is an average of twelve observations.
 S.E. = Standard error about the mean.

In all the orchards:

1W(H) > 1W(O) > 1W(C) : 1L(H) > 1L(O) > 1L(C) : 1B(H) > 1B(O) > 1B(C) : 1V(H) > 1V(O) > 1V(C) : 1S(H) > 1S(O) > 1S(C) (P<0.01)
 2W(H) > 2W(O) > 2W(C) : 2L(H) > 2L(O) > 2L(C) : 2B(H) > 2B(O) > 2B(C) : 2V(H) > 2V(O) > 2V(C) : 2S(H) > 2S(O) > 2S(C) (P<0.01)
 3W(H) > 3W(O) : 3L(H) > 3L(O) : 3B(H) > 3B(O) : 3V(H) > 3V(O) : 3S(H) > 3S(C) (P<0.01)
 4W(H) > 4W(O) : 4L(H) > 4L(O) : 4B(H) > 4B(O) : 4V(H) > 4V(O) : 4S(H) > 4S(C) (P<0.01)

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