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Comparative foraging behaviour of honey bees, *Apis cerana* f. and *Apis mellifera* l. (Hym: Apidae) on apple bloom

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Abstract

The experiment was carried out to determine the foraging behaviour of honey bees, *A. cerana* and *A. mellifera* in apple orchards located at three different locations viz: Srinagar (1870 m), Shopian (2010 m) and Saller (2440 m) of Kashmir valley. *A. cerana* foraged for a significantly longer time, reached its peak activity, visited more flowers per minute and took greater time for completing a single foraging trip on apple bloom than *A. mellifera*. However, *A. mellifera* carried significantly heavier pollen loads, a greater number of pollen grains and carried more unifloral pollen loads as compared to *A. cerana*. Moreover, the interspecific comparison between *A. cerana* and *A. mellifera* with regards to the top as well as side workers showed no significant differences. In addition, both *A. cerana* and *A. mellifera*, showed pronounced floral constancy. Present results suggested that altitudinal variations affect the timings of initiation and cessation of foraging activity, duration of foraging activity, duration of foraging trip and number of flowers visited per minute. However, it did not affect the peak hours of foraging, time spent per flower and weight of pollen loads carried by *A. cerana* and *A. mellifera*.

Keywords: Foraging Behavior, Honeybees, Apple, Altitudinal variation, Kashmir valley

1. Introduction

Pollination of apples is more complicated as compared to other fruits by the fact that five stigmas have to be pollinated separately ^[1], otherwise misshapen fruits ^[2]. Honeybees are among the most important pollinating insects found within orchards and modern agricultural systems ^[3-6]. In particular, artificial pollination results in deterioration of fruit quality, such as decrease of the fruit size and uneven fruit shape ^[7]. Today apple is one of the most widely grown and important fruit crops in temperate areas of the world ^[8-10]. China dominates global apple production ^[11]. Most immature fruit drops within a few weeks of flowering typically have fewer developing seeds than fruit that remains on the tree ^[12], as many mature fruits do not contain a full complement of seeds ^[13]. Foraging behavior is one of the important characteristics of any insect. In principle, promising pollinator species should show a preference for foraging on flowers of the target crop ^[14-16]. Foraging rate is one of the important factors to compare pollination efficiency of different bee species ^[17]. In India foraging behavior of honey bee species has been recorded by different workers on different crops ^[18-21]. Bees and beekeeping provide free ecosystem services in the form of crop pollination, thereby helping in conservation of forest and grassland ecosystems, therefore, it is becoming an important component of present day strategies for sustainable development and organic farming programmes ^[22].

2. Materials and methods

The study was carried out during the peak season of the flowering of apple in three different locations viz: Srinagar (1870 m), Shopian (2010 m) and Saller (2440 m) of Kashmir valley. One colony from each species (i.e. *A. cerana* and *A. mellifera*) were placed on the respective experimental plots starting from initial blooming to final sesasion and observations recorded on foraging activities, time spent by bees per flower and number of flowers visited by bees per minute using an electronic stopwatch. All the bee colonies had almost equal number of frames in brood chamber with similar strength and almost equal amount of brood. The experiment was started, when about 10-15% flowering had taken place; so that bees do not forage outside by attracting other floral resources. Data was recorded from 900 h to 1800 h at the time of opening of flowers.

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The observations were made for the different foraging parameter continuously for a period of 7 days. Effect of altitudinal variations on the foraging behaviour of *A. cerana* and *A. mellifera* was analyzed for different foraging traits. Various parameters studied were: commencement of foraging, cessation of foraging, duration of foraging activity, peak foraging hours, duration of a foraging trip, time spent per bee per flower, number of flowers visited per minute and number of honeybees visiting different heights of apple tree. Data was analyzed statistically by using Standard error about mean, coefficient of variation and t-test so as to test the significance of results.

3. Results

Studies on the foraging behaviour of honeybees i.e. *Apis cerana* and *A. mellifera* in terms of foraging time, flight activity patterns, foraging speed and rate, duration of the foraging trip, pollen carrying capacity etc., have been summarized in Table 1:

3.1 Foraging time

It was observed that the foraging time of *A. cerana* (0615, 0618 and 0630 hours respectively) was significantly higher than *A. mellifera* (0620, 0624 and 0640 hours respectively) in all the three apple orchards i.e. Srinagar, Shopian and Saller respectively. In the evening, *A. cerana* (1925, 1842 and 1835 hours respectively) ceased its flight activity later than *A. mellifera* (1856, 1818 and 1805 hours respectively) in all the above orchards. *A. cerana* commenced its foraging activity significantly ($P < 0.01$) earlier in the morning and ceased its flight activity significantly later in the evening than *A. mellifera*. Thus flight activity lasted for 13.10 ± 0.75 , 12.26 ± 0.04 and 12.11 ± 0.01 hours in *A. cerana* and 12.40 ± 0.01 , 12.00 ± 0.01 and 11.35 ± 0.01 hours in *A. mellifera* at Srinagar, Shopian and Saller orchard respectively. Above results thus suggest that *A. cerana* foraged significantly longer time on apple bloom at ($P < 0.01$) than *A. mellifera* (Fig. 1 and 2).

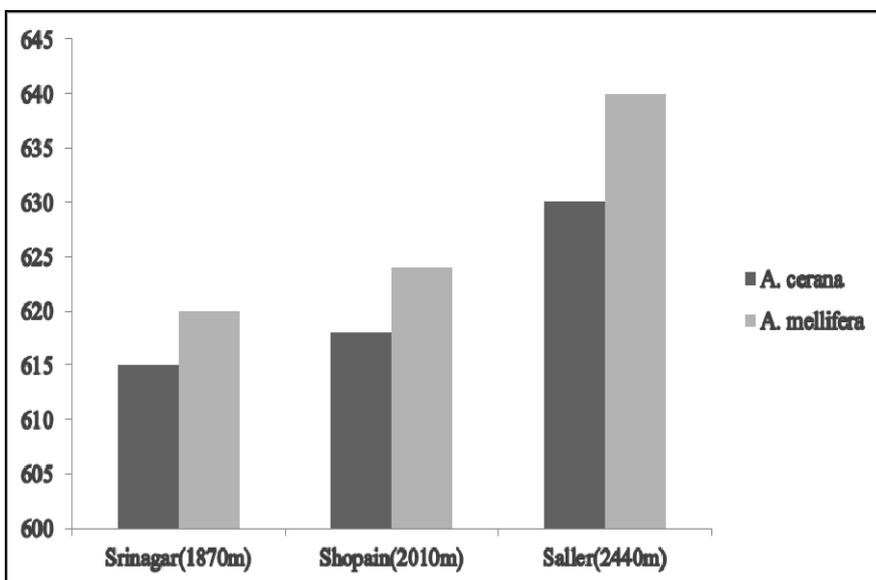


Fig 1: Initiation of foraging

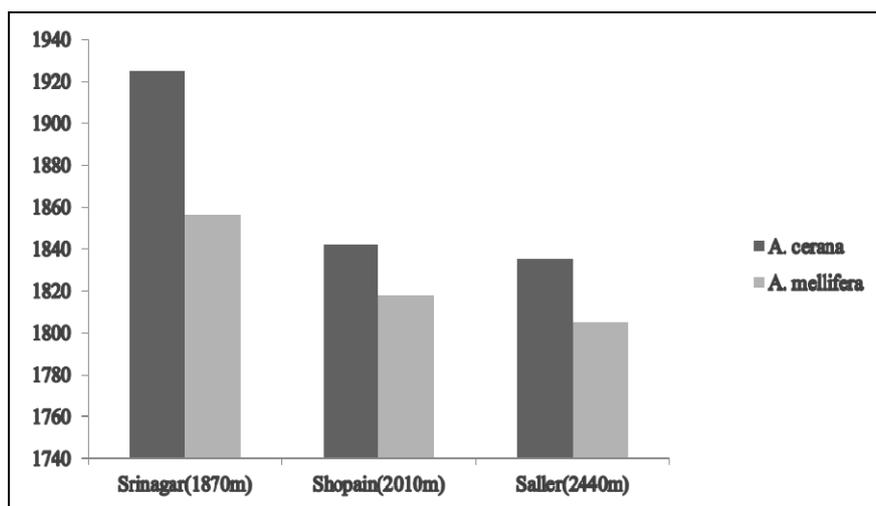


Fig 2: Cessation of foraging

3.2 Flight activity patterns

The foraging activity of both the bee species was monitored at regular hourly intervals in different apple orchards. In Srinagar, flight activity of *A. cerana* showed an increase from 0700 (4.23%) hours in morning to 1000 (10.15%) hours and

then it peaked from 1100 (13.54%) to 1300 (13.36%) hours. From 1400 (10.73%) hours to 1700 (2.73%) it showed a decrease in foraging activity. The peak of foraging activity time was achieved between 1100 (13.54%) to 1300 (13.36) hours. On the other hand, *A. mellifera*, showed an increase in

its foraging activity from 0700 (2.58%) to 1200 (11.91%) hours and then it peaked from 1300 (13.86) to 1600 (14.28%) hours and then decreased abruptly from 1600 (11.33%) to 1800 (1.07%) hours. In the apple orchard at Shopian, flight activity of *A. cerana* showed a continuous increase from 0700 (2.5%) to 0900 (10.58%) hours and then it peaked between 1000 (16.62%) to 1100 (16.82%) hours. Afterwards, it showed regular decrease from 1200 (12.57%) to 1400 (1.93%) hours. In the case of *A. mellifera*, flight activity increased continuously from 0700 (3.06%) hours up to 1100 (10.33%) hours, remained almost constant from 1200 (14.43%) to 1400 (14.46%) hours. From 1500 (10.63%) onwards, a regular decline was observed up to 1800 (2.29%) hours. At Saller, flight activity of *A. cerana* showed an

increase from 0700 (11.05%) to 1000 (14.40%) hours and then peak was achieved between 1100 (17.64%) to 1200 (18.10%) hours. From 1300 (14.47%) hours onwards, it decreased up to 1800 (6.52%) hours. In case of *A. mellifera*, foragers showed a regular increase from 0700 (4.83%) to 1100 (10.56%) hours and peaked from 1200 (13.08%) to 1400 (13.29%) hours. Then showed continuous decrease from 1400 (12.63%) to 1800 (3.46%) hours. Thus present results indicate that peak hours of foraging activity for *A. cerana* were between 1000 to 1300 hours, whereas, *A. mellifera* showed maximum foraging activity between 1200 to 1600 hours (Fig. 3 and 4). In addition, present results suggest that *A. cerana* reached its peak activity before *A. mellifera* in all the three apple orchards.

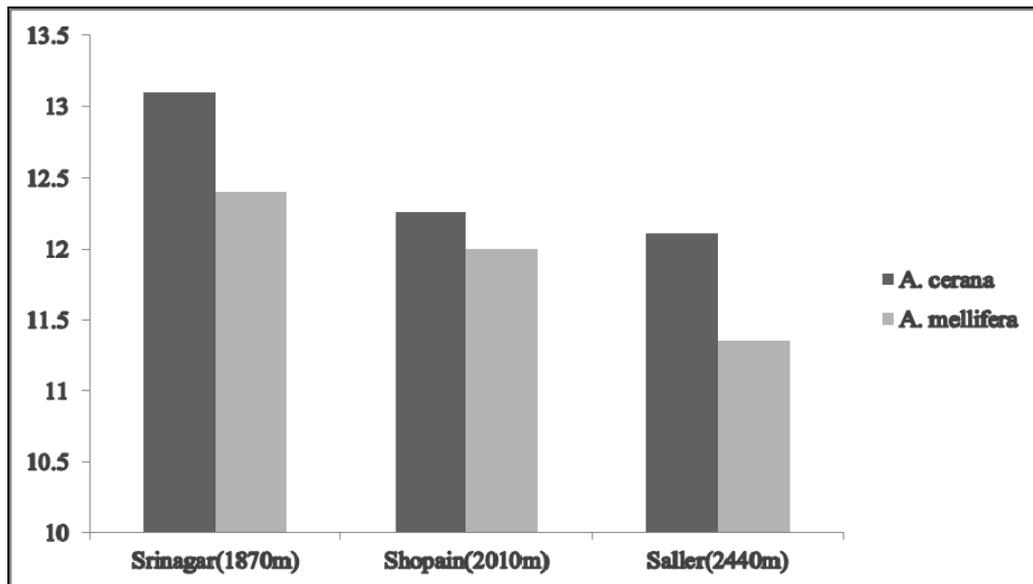


Fig 3: Duration of foraging activity (hours)

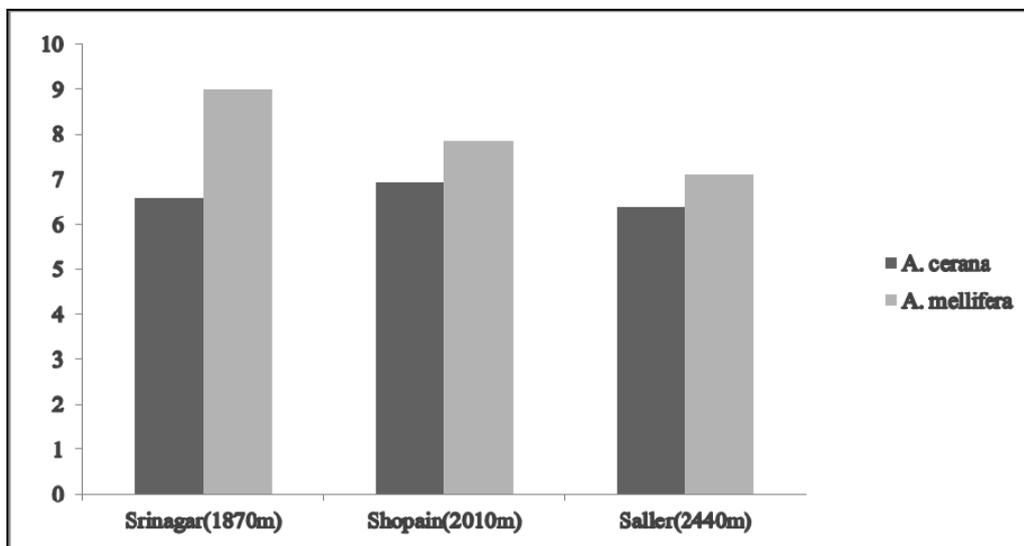


Fig 4: Time spent/bee/flower (Sec)

3.3 Foraging speed and rate

In the apple orchard at Srinagar, foraging data on time spent per flower and number of flowers visited per minutes revealed that at 0900 hours, *A. cerana* spent 6.24 ± 0.12 seconds per apple flower and visited 10.50 ± 0.18 flowers per minute. Whereas, *A. mellifera* spent 8.44 ± 0.38 second per flower and visited 9.40 ± 0.12 flowers per minute. Similarly at 1200 hours, time spent per flower and number of flowers visited per minute was 6.85 ± 0.11 seconds and 9.16 ± 0.25 flowers for *Apis*

cerana and 10.05 ± 0.13 seconds and 9.60 ± 0.14 flowers for *Apis mellifera* respectively. At 1500 hours, *A. cerana* spent 6.33 ± 0.14 seconds per apple flower and visited 10.66 ± 0.31 flowers per minute. Whereas, *A. mellifera* spent 7.49 ± 0.18 seconds and visited 9.77 ± 0.12 flowers per minute. Thus during all the three hours, *A. cerana* visited significantly ($P < 0.01$) more number of flowers and spent significantly ($P < 0.05$) less time per flower than *A. mellifera*. In Shopian, at 0900 hours, *A. cerana* spent 6.20 ± 0.17 seconds per flower and

visited 10.56 ± 0.13 flowers per minute, whereas, *A. mellifera* spent 7.87 ± 0.20 seconds per flower and visited 8.70 ± 0.16 flowers per minute. At 1200 hours, time spent per flower by *A. cerana* and *A. mellifera* was 8.17 ± 0.13 and 7.76 ± 0.16 seconds and visited 9.90 ± 0.14 and 8.52 ± 0.13 flowers per minute respectively. At 1500 hours, *A. cerana* spent on an average 6.43 ± 0.19 seconds per flower and visited 9.62 ± 0.14 flowers per minute, whereas, *A. mellifera* spent 7.87 ± 0.23 seconds and visited 7.92 ± 0.13 flowers per minute. Thus during all the three hours of the day, *A. cerana* visited significantly ($P < 0.05$) more flowers and spent significantly ($P < 0.01$) less time per flower than *A. mellifera*. In apple orchard at Saller, at 0900 hours, *A. cerana* spent 6.12 ± 0.20 seconds per flower and visited 8.67 ± 0.13 flowers per minute, whereas, *A. mellifera* spent 6.57 ± 0.16 seconds per minute and

visited 8.16 ± 0.14 flowers per minute. Similarly, at 1200 hours, the time spent and number of flowers visited for *A. cerana* was 6.40 ± 0.13 second and 8.82 ± 0.13 flowers and for *A. mellifera* it was 7.31 ± 0.16 seconds and 7.76 ± 0.16 flowers per minute respectively. At 1500 hours, *A. cerana* spent on an average 6.65 ± 0.21 seconds per flower and visited 9.10 ± 0.13 flowers per minute, whereas, *A. mellifera* spent 7.49 ± 0.13 seconds and visited 6.50 ± 0.15 flowers per minute. Present results suggest that *A. cerana* spent significantly ($P < 0.01$) less time per flower and visited significantly ($P < 0.01$) more flowers per minute than *A. mellifera* (Fig. 5 and 6). The present study indicates that *A. cerana* is much more efficient pollinator for the temperate region than *A. mellifera*. There have been earlier reports on the time spent by *A. mellifera* on apple flowers.

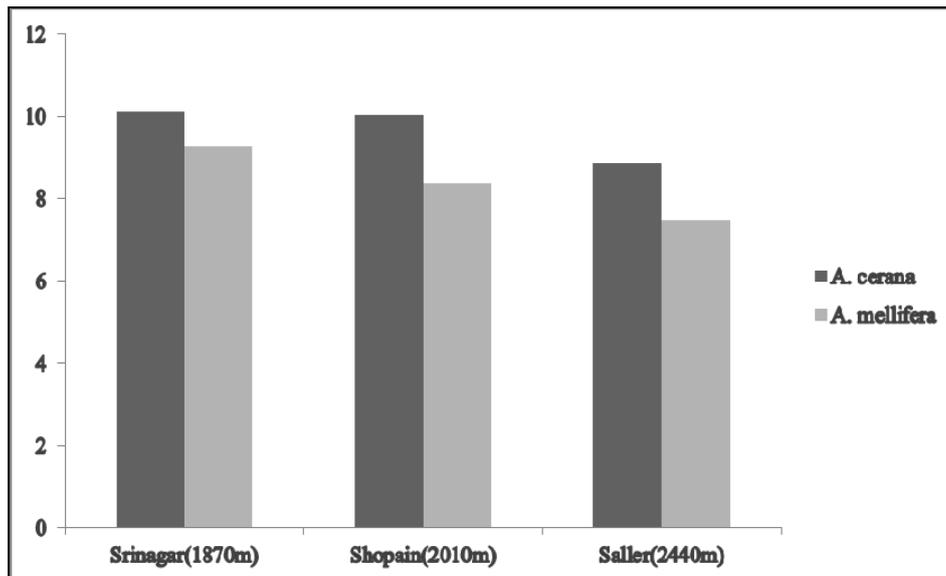


Fig 5: Number of flowers (visited /bee /minute)

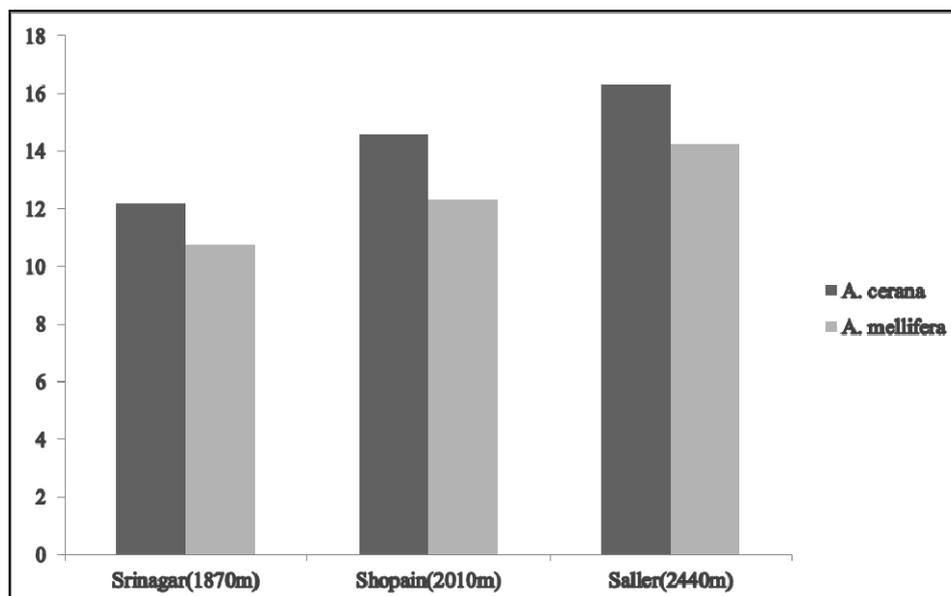


Fig 6: Duration of a foraging trip (Minute)

3.4 Duration of foraging trip

Foraging data on apple bloom showed that *A. cerana* spent on an average 12.20 ± 1.10 , 14.60 ± 0.78 and 16.30 ± 1.13 minutes for a single foraging trip, whereas, this duration was 10.77 ± 0.77 , 12.33 ± 0.80 and 14.23 ± 0.62 minutes for *A. mellifera*, at Srinagar, Shopian and Saller orchards

respectively. These results showed significant ($P < 0.05$) differences between *A. cerana* and *A. mellifera* regarding this parameter in all the three apple orchards (Fig. 7). Thus *A. cerana* took significantly ($P < 0.05$) greater time for completing a single foraging trip as compared to *A. mellifera*.

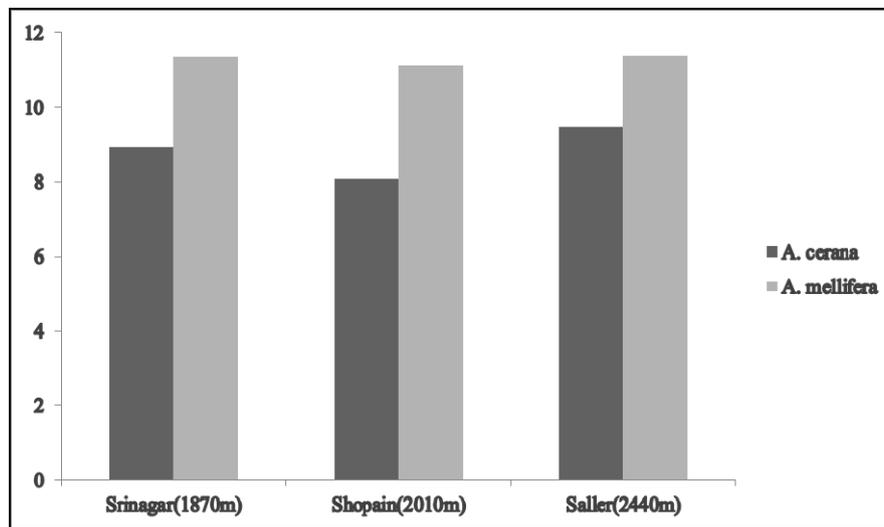


Fig 7: Weight of pollen load (mg)

3.5 Pollen carrying capacity

Pollen carrying capacity was calculated in terms of pollen load carried by a worker bee of *A. cerana* and *A. mellifera* at 0900, 1200 and 1500 hours of the day in a particular orchard. In Srinagar orchard, at 0900 hours, mean weight of pollen pellet carried by *A. cerana* was 8.42 ± 0.61 mg, whereas, it was 11.26 ± 0.47 mg for *A. mellifera*. At 1200 hours, *A. cerana* and *A. mellifera* carried pollen pellets weighing 9.27 ± 0.31 and 11.46 ± 0.31 mg respectively. At 1500 hours, average pollen load carried by a forager of *A. cerana* was 9.02 ± 0.34 mg, whereas, it was 11.39 ± 0.43 mg for *A. mellifera*. Thus *A. mellifera* carried significantly ($P < 0.01$) heavier pollen loads than *A. cerana* during different hours of the day. In Shopian orchard, at 0900 hours, pollen load carried by *A. cerana* was 9.37 ± 0.52 mg, whereas, it was 11.27 ± 0.49 mg for *A. mellifera*. At 1200 hours, the mean weight of pollen loads carried by *A. cerana* and *A. mellifera* was 9.09 ± 0.46 and 11.21 ± 0.30 mg respectively. At 1500 hours, *A. cerana* carried

on average pollen weighing 8.79 ± 0.28 mg, whereas, this weighed 10.89 ± 0.27 mg for *A. mellifera*. These results showed that *A. mellifera* carried significantly ($P < 0.01$) heavier pollen loads than *A. cerana* during different hours of the day. In Saller orchard, mean weight of pollen pellets carried by *A. cerana* at 0900 hours was 9.96 ± 0.73 mg, whereas, it was 11.58 ± 0.98 mg for *A. mellifera*. At 1200 hours, *A. cerana* and *A. mellifera* carried pollen pellets weighing 9.56 ± 0.66 and 11.09 ± 0.75 mg respectively. At 1500 hours, average pollen load carried by a forager of *A. cerana* was 8.88 ± 0.55 mg whereas it was 10.44 ± 0.85 mg for *A. mellifera*. Thus weight of pollen loads carried per bee differ significantly ($P < 0.01$) between *A. cerana* and *A. mellifera* at different hours of the day (Fig. 8). Above results suggest that in case of apple, *A. mellifera* carried significantly ($P < 0.01$) heavier pollen loads than *A. cerana* in all the three experimental orchards.

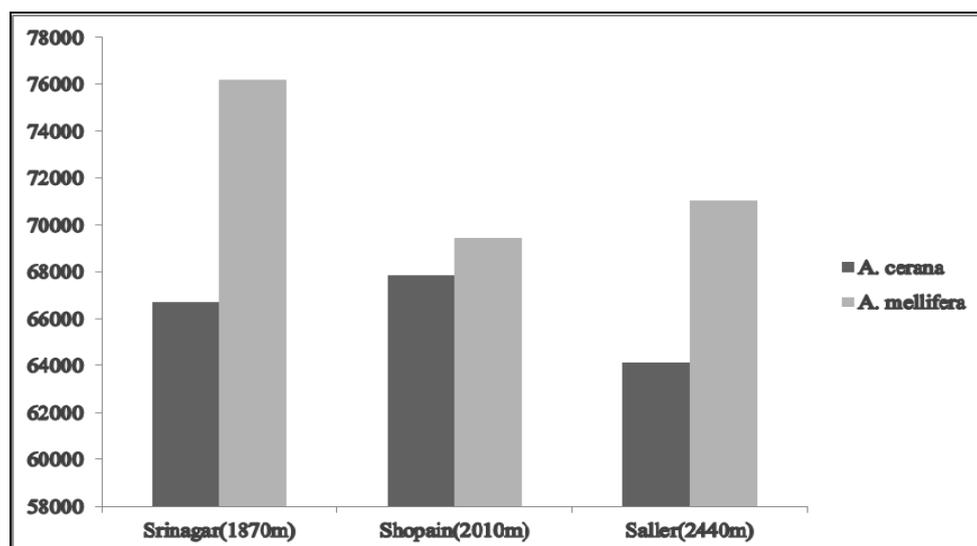


Fig 8: Number of grains per pollen load

3.6 Number of pollen grains in pollen load

In apple orchard at Srinagar, the number of pollen grains carried by *A. cerana* and *A. mellifera* pollen foragers at 0900 hours was 67287 ± 104.20 and 76532 ± 110.42 respectively. Similarly, at 1200 hours, *A. cerana* carried 68377 ± 102.69 pollen grains, whereas, *A. mellifera* picked up 72462 ± 103.34 pollen grains. At 1500 hours, *A. cerana* and *A. mellifera*

carried 64505 ± 104.33 and 79515 ± 111.36 pollen grains respectively. In Shopian orchard, at 0900 hours, the number of pollen grains carried by *A. cerana* and *A. mellifera* were 69463 ± 85.51 and 70402 ± 88.89 respectively. At 1200 hour and 1500 hours, *A. cerana* had 68489 ± 84.15 and 65537 ± 72.22 and *A. mellifera* had 69482 ± 91.12 and 68500 ± 83.28 pollen grains respectively (Table 1). In apple

orchard at Saller, the number of pollen grains carried at 0900, 1200 and 1500 hours by *A. cerana* were 67479 ± 79.12 , 66555 ± 89.55 and 64320 ± 89.54 pollen grains whereas; *A. mellifera* carried 71682 ± 98.05 , 70181 ± 102.91 and 71356 ± 96.12 pollen grains respectively. Thus *A. mellifera*

carried significantly ($P < 0.01$) more pollen grains than *A. cerana* in all the experimental orchards (Fig. 9). Above results suggested that *A. mellifera* carried significantly ($P < 0.01$) greater number of pollen grains than *A. cerana*.

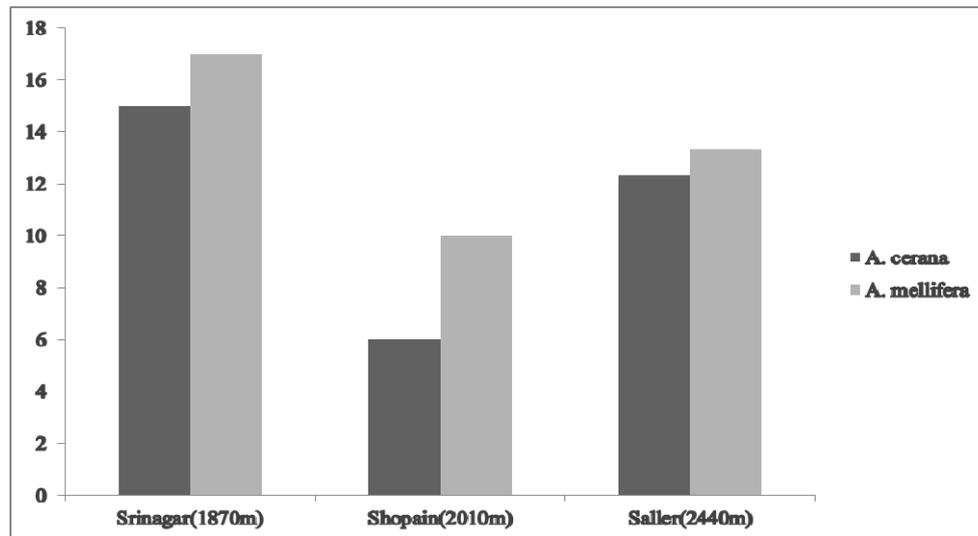


Fig 9: Percentage of multi floral (MF) loads

3.7 Floral constancy

The floral constancy of honey bees was worked out by analyzing pollen loads of *A. cerana* and *A. mellifera* on apple bloom at different hours of the day. In apple orchard at Srinagar, at 0900 hours, *A. cerana* carried 86% pollen grains from apple and 14% from other floral resources present around the orchard, whereas, *A. mellifera* carried 82% pollen grains from apple and 18% from other pollen resources. At 1200 hours, *A. cerana* and *A. mellifera* carried 88% and 84% apple pollen and 12% and 16% pollen grains from other plants resources respectively. Similarly at 1500 hours, *A. cerana* had 81% apple pollen and 19% pollen from other floral resources and these percentages were 83% and 17% respectively for *A. mellifera*. In apple orchard at Shopian, at 0900 hours, *A. cerana* carried 95% pollen grains from apple and 5% from other floral resources present around the orchard, whereas, *A. mellifera* carried 90% pollen from apple and 10% from other pollen resources. At 1200 hours, *A. cerana* and *A. mellifera* carried 94% and 89% apple pollen

and 6% and 11% pollen grains from other floral resources respectively. Similarly, at 1500 hours, *A. cerana* returned to hive with 93% apple pollen and 7% pollen from other floral resources and these percentages were 91% and 9% respectively for *A. mellifera*. In Saller orchard, at 0900 hours, *A. cerana* carried 88% pollen grains from apple and 12% from other floral resources present around the orchard, whereas, in case of *A. mellifera*, pollen foragers returned to hive with 87% apple pollen and 13% pollens from other honey plants. At 1200 hours, both *A. cerana* and *A. mellifera* carried 89% apple pollen and 11% from other floral resources in equal percentage. Similarly, at 1500 hours, *A. cerana* foragers returned to hive with 86% apple pollen and 14% pollen from other honey plants, whereas, these percentages were 84% and 16% respectively for *A. mellifera* (Fig.10 and 11). Thus both *A. cerana* and *A. mellifera* carried significantly ($P < 0.01$) more unifloral pollen loads than multifloral pollen loads from apple crop, thereby showing pronounced floral constancy.

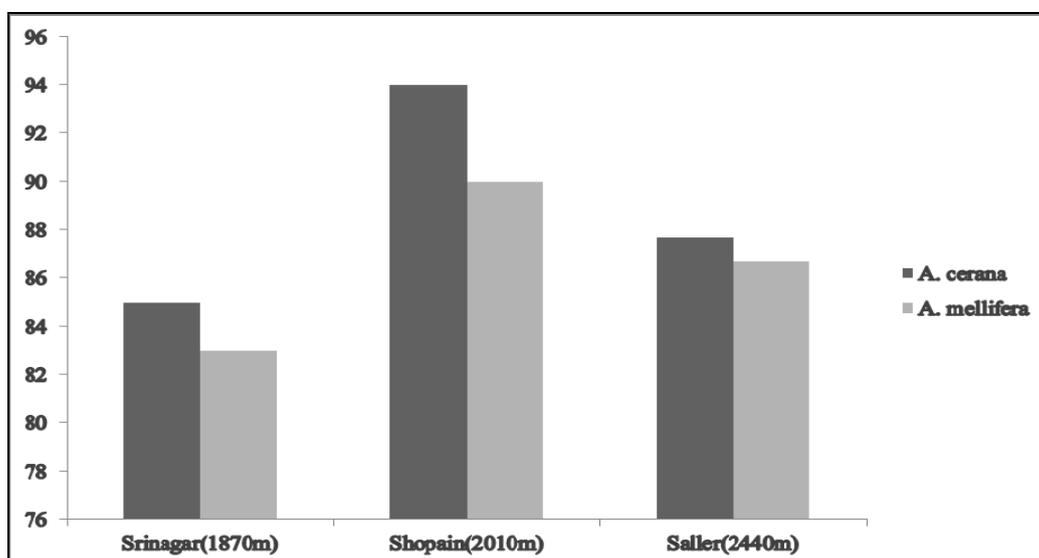


Fig 10: Percentage of uni floral (UF) loads

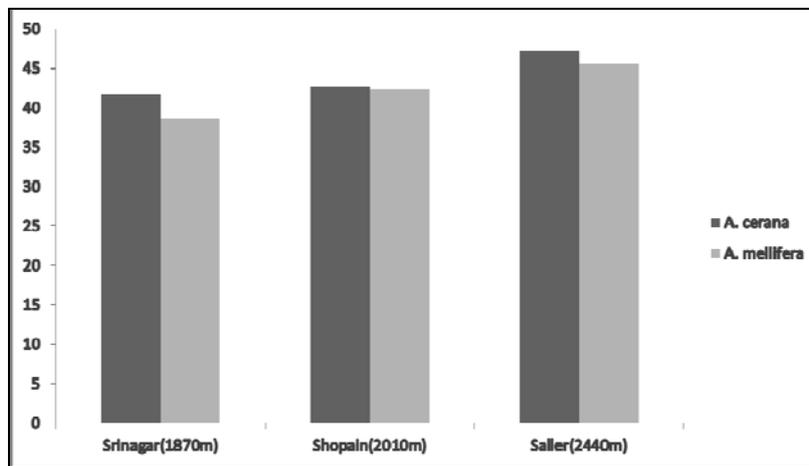


Fig 11: Percentage of top workers (TW)

3.8 Top versus side workers

There were fluctuations in the percentage of top and side worker bees of *A. cerana* and *A. mellifera* on apple bloom. Top workers of both *A. cerana*, 41.67, 42.67 and 47.33% and *A. mellifera*, 38.67, 42.33 and 45.67% differ from side workers of these species with 58.33, 57.33 and 52.67% for *A. cerana* and 61.33, 57.67 and 54.33% for *A. mellifera* respectively at all the three orchards. The average hourly ratio of top workers to side workers was 1:1.39, 1:1.34 and 1:1.11 for *A. cerana* at 0900, 1200 and 1500 hours of the day, whereas, the ratio of top workers and side worker for *A. mellifera* was 1:1.58, 1:1.36 and 1:1.18 respectively (Fig.12 and 13). Interspecific comparison between *A. cerana* and *A. mellifera* with regards to the top as well as side workers showed no significant ($P>0.05$) differences.

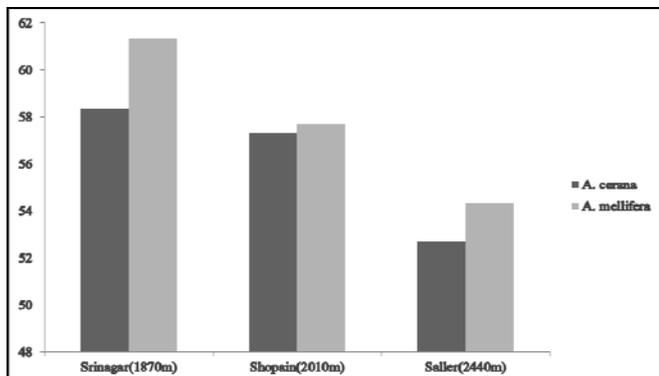


Fig 12: Percentage of side workers (SW)

4. Effect of altitudinal variations on the foraging behaviour of honeybees

Effect of altitudinal variations on different foraging traits like initiation of foraging, cessation of foraging, duration of foraging activity, peak foraging hours, duration of foraging trip, time spent per bee per flower, number of flowers visited per minute, weight of pollen load, number of grains per pollen load, percentage of unifloral and multifloral pollen loads and number of honeybees at different heights of tree revealed following results:

Statistical analysis of foraging data on *A. cerana* and *A. mellifera* at three different altitudes i.e. Srinagar (1870 m), Shopian (2010 m) and Saller (2440 m) revealed that altitudinal variations affect the timing of initiation and cessation of foraging activity of both *A. cerana* and *A. mellifera*. For example, *A. cerana* commenced its activity at 0615 hours at Srinagar, whereas, at Saller the timing of

commencement was delayed (0630 hours). Similarly, in *A. mellifera*, foraging commenced at 0620 hours, at Srinagar but it started later at Saller (0640 hours) orchards. The timing of cessation of foraging activity was also delayed at higher than lower elevations in the case of both *A. cerana* and *A. mellifera*. For example, foraging activity of *A. cerana* ceased at 1925 hours in Srinagar and 1835 hours in Saller. Similarly, in the case of *A. mellifera*, foraging activity ceased earlier at Saller (1805 hours) than Srinagar (1856 hours). Present studies therefore suggest that altitudinal variations also affect the duration of foraging activity of honeybees. Altitudinal variations did not considerably affect the peak hours of foraging activity i.e. peak hours of foraging activity of *A. cerana* were at 1100 to 1300 hours, 1000 to 1100 hours and 1100 to 1200 hours at Srinagar, Saller and Shopian orchards respectively. Similarly, in *A. mellifera*, foraging activity was between 1300 to 1600 hours at Srinagar, and 1200 to 1400 hours at both at Shopian and Saller. Thus, peak hours of activity of *A. cerana* and *A. mellifera* were almost in the same range in all the three altitudes. Foraging data on duration of foraging trip of *A. cerana* and *A. mellifera* showed that this parameter was affected by altitudinal variations because at Srinagar (12.20 minutes), duration of foraging trip of *A. cerana* was significantly less ($P<0.01$) than that of the highest elevation i.e. Saller (16.33 minutes). Similarly, *A. mellifera* took significantly ($P<0.01$) more time to complete a foraging trip at Saller (14.23 minutes) than Srinagar (10.77 minutes). Data on foraging rate and speed showed that *A. cerana* visited significantly ($P<0.05$, 0.01) more number of flowers per minute at Srinagar (10.11) than Saller (8.86). Similarly, number of flowers visited by *A. mellifera* were significantly more ($P<0.01$) at Srinagar (9.26) than Saller (7.47). Moreover, no significant differences were observed with regards to time spent per flower by *A. cerana* and *A. mellifera* at different altitudes. Thus, the altitudinal variation affect number of flowers visited per minute by *A. cerana* and *A. mellifera*, but not the time spent per flower. Foraging data showed no significant differences in weight of pollen loads and number of grains per pollen load carried by *A. cerana* and *A. mellifera* at all the three altitudes. Further, both the species of honeybees i.e. *A. cerana* and *A. mellifera* preferred unifloral than multi floral pollen loads at all the three elevations. *A. cerana* and *A. mellifera* preferred to forage on middle than top and lower heights of apple trees at all the altitudes. Present results suggest that altitudinal variations affect the timing of initiation and cessation of foraging activity, duration of foraging activity, duration of foraging trips and number of flowers visited per minute. However, it

did not affect the peak hours of foraging, time spent per flower and weight of pollen loads carried by *A. cerana* and *A. mellifera*. Both the species of honeybees preferred uni floral pollen loads and tried to forage maximum on the middle heights of apple tree.

5. Discussion

In the present study, it was observed that in Kashmir valley *Apis cerana* initiates foraging early in the morning (0615±1.19) and ceases late in the afternoon (1925±0.55) as compared to *A. mellifera* (0620±1.10) and (1856±1.20) respectively. Similar observations were studied on the initiation and cessation of *A. cerana* and *A. mellifera* foraging on apple [23]. The present findings were also in proximity with the views of [24-26], where they made similar observations on initiation, cessation and duration of the honeybee (*A. cerana*) foraging activity on *Brassica juncea*. The finding is also in agreement with the observation that *A. cerana* started foraging earlier and showed higher foraging efficiency compared to *A. mellifera* [27, 28]. In the present study, it was observed that foraging activity of *A. cerana* is more (13.10±0.75) compared to *A. mellifera* (12.40±0.01), whereas peak foraging activity for *A. cerana* was recorded at 1100-1200 and *A. mellifera* at 1200-1400. The peak foraging activity for *A. cerana* at 09.00 to 11.30 am between temperature of 15.5 °C to 21 °C and 11.00 to 13.30 pm for *A. mellifera* when the temperature was 21 °C to 25 °C was recorded on apple bloom [19]. The same observations have also been reported by many workers [17, 29, 30]. Similar results were also observed regarding the peak foraging activity and rate for *A. cerana* and *A. mellifera* on apple [23, 31]. Foraging data on apple bloom showed that *A. cerana* spent 6.57±0.12 seconds per apple flower and visited 10.11±0.27 flowers per minute. Whereas, *A. mellifera* spent 8.99±0.23 second per flower and visited 9.26±0.13 flowers per minute. *A. cerana* spent on an average 12.20±1.10, 14.60±0.78 and 16.30±1.13 minutes for a single foraging trip, whereas, this duration was 10.77±0.77, 12.33±0.80 and

14.23±0.62 minutes for *A. mellifera*, at Srinagar, Shopian and Saller orchards respectively. Thus *A. cerana* took significantly ($P<0.05$) greater time for completing a single foraging trip as compared to *A. mellifera* [19]. The time spent by any bee on any flower depends on many factors including the size of flower and nectar present in the flower. *A. mellifera* visits 3.33 flowers of an apple per minute and was also reported that apple blooms were more attractive to *A. cerana* than to *A. mellifera* [19, 32]. In the present study, it was observed that *A. cerana* and *A. mellifera* carries 9.47±0.65 and 11.40 ± 0.86 mg of pollen load respectively, at Saller which is the highest in both the species, whereas 11.19 ± 0.11 mg of pollen load was recorded in *A. mellifera* [31]. It has reported this as 15.50 mg in plum [33] and weight as 11.20 mg in *Brassica juncea* [21]. The behavior of an efficient apple pollinator should be such that the insect contacts the stigma of the flower in many of its visits and carries enough germinable pollen grains of compatible cultivars on its body. In apple orchards of Kashmir valley, *A. cerana* and *A. mellifera* carried significantly more unifloral than multifloral pollen loads from apple crop, thereby showing pronounced floral constancy. Both the species carried about 80-95% of unifloral pollen and 5-20% of multifloral pollen loads. Interspecific comparison between *A. cerana* and *A. mellifera* with regards to the top as well as side workers showed no significant differences. Similar results were also observed [23, 31]. Present results suggest that altitudinal variation affect the timings of initiation and cessation of foraging, duration of foraging activity, duration of foraging trip and number of flowers visited per minute. However, it did not affect the peak hours of foraging, time spent per flower and weight of pollen loads carried by *A. cerana* and *A. mellifera*. Both the species of honeybees preferred unifloral pollen loads and tried to forage maximum on the middle heights of apple tree (Table 1). Similar results were observed by various workers regarding the various parameters discussed [23, 34].

Table 1: Comparative Foraging Behaviour of *A. cerana* and *A. mellifera* on Apple bloom

Parameters	Srinagar (1870m)		Shopian (2010m)		Saller (2440m)	
	<i>A. cerana</i> Mean ± S.E.	<i>A. mellifera</i> Mean ± S.E.	<i>A. cerana</i> Mean ± S.E.	<i>A. mellifera</i> Mean ± S.E.	<i>A. cerana</i> Mean ± S.E.	<i>A. mellifera</i> Mean ± S.E.
Initiation of foraging (am)	0615 ± 1.19	0620 ± 1.10	0618 ± 1.04	0624 ± 0.84	0630 ± 0.95	0640 ± 1.08
Cessation of foraging (pm)	1925 ± 0.55	1856 ± 1.20	1842 ± 1.25	1818 ± 1.12	1835 ± 0.80	1805 ± 0.75
Duration of foraging activity (hours)	13.10 ± 0.75	12.40 ± 0.01	12.26 ± 0.04	12.00 ± 0.01	12.11 ± 0.01	11.35 ± 0.01
Peak foraging hours (time of day)	1100 – 1300	1300 – 1600	1000 – 1100	1200 – 1400	1100 – 1200	1200 – 1400
Time spent/bee/flower (Sec)	6.57 ± 0.12	8.99 ± 0.23	6.93 ± 0.16	7.84 ± 0.20	6.39 ± 0.18	7.12 ± 0.15
No. of flowers (visited /bee /minute)	10.11 ± 0.27	9.26 ± 0.13	10.03 ± 0.14	8.38 ± 0.14	8.86 ± 0.13	7.47 ± 0.15
Duration of a foraging trip (Minute)	12.20 ± 1.10	10.77 ± 0.77	14.60 ± 0.78	12.33 ± 0.80	16.30 ± 1.13	14.23 ± 0.62
Weight of pollen load (mg)	8.93 ± 0.42	11.37 ± 0.43	8.08 ± 0.42	11.12 ± 0.35	9.47 ± 0.65	11.40 ± 0.86
Number of grains per pollen load	66723 ± 103.74	76170 ± 108.37	67830 ± 80.63	69461 ± 87.76	64118 ± 86.07	71073 ± 99.03
Percentage of multi floral loads (MF)	15.00	17.00	6.00	10.00	12.33	13.33
Percentage of uni floral loads (UF)	85.00	83.00	94.00	90.00	87.67	86.67
Percentage of top workers (TW)	41.67	38.67	42.67	42.33	47.33	45.67
Percentage of side workers (SW)	58.33	61.33	57.33	57.67	52.67	54.33

For Initiation: Srinagar>Shopian>Saller for *A. cerana* and *A. mellifera*

For cessations: Srinagar>Shopian>Saller for *A. cerana* and *A. mellifera*

Duration of foraging activity: Srinagar>Shopian>Saller ($P<0.01$)

Peak foraging hours: Srinagar>Saller>Shopian

Time spent/bee/flower: Srinagar>Shopian>Saller for *A. mellifera* ($P<0.01$)

No. of flowers visited/minute: Srinagar>Shopian>Saller for *A. cerana* and *A. mellifera* ($P<0.05$)

Duration of foraging trip: Saller>Shopian>Srinagar for *A. cerana* and *A. mellifera* ($P<0.05$)

Weight of pollen load: Saller>Srinagar>Shopian for *A. cerana* ($P<0.01$)

No. of grains per pollen load: Srinagar>Saller>Shopian for *A. mellifera* ($P<0.01$).

Percentage of uni floral (UF) and multi floral (MF) loads: UF>MF for *A. cerana* and *A. mellifera* ($P<0.01$)

Top workers and side workers: SW>TW for both *A. cerana* and *A. mellifera*.

6. Conclusion

Honeybees have long been recognized as important pollinators of apple crop because of their potential for long working hours, presence of pollen baskets, floral fidelity, micromanipulation of flowers, maintainability of high population and adaptability to different climatic conditions. From the study, it is clear that the apple bloom are preferable to both of the bee species, *A. cerana* and *A. mellifera*. The apple flowers are self-incompatible and required cross-pollination by insect pollinators. Although, both of the bee species showed a slight deviations in their foraging activities. Hence this study concluded that both the bee species, *A. cerana* and *A. mellifera*, due to their longer duration of foraging activity, superior pollinating efficiency effects on the quality and yield increment under different treatments including its variation with altitude in Kashmir valley.

7. References

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