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FORAGING BEHAVIOUR OF THE HIMALAYAN HONEYBEE (*Apis cerana* F.) ON FLOWERS OF *Fagopyrum esculentum* M. AND ITS IMPACT ON GRAIN QUALITY AND YIELD

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ABSTRACT

This paper presents the findings of two studies - one conducted on foraging behaviour of Himalayan honeybee (*Apis cerana* F.) on flowering buckwheat (*Fagopyrum esculentum* Moench) in November 2001 to 2002 and another on its impact on the grain quality and yield increment of this crop conducted during 2000-2002 under different pollination treatments at Kirtipur, Kathmandu valley. *Apis cerana* bees started their foraging activities early in the morning (06.14 ± 0.004) and ceased late in the evening (17.28 ± 0.011). Total duration of foraging activity was 10:00 h and the average duration of foraging trip was 4.5 ± 0.14 min. Two peaks of foraging activities were observed between 08.30 to 10.30 (Peak I) and 11.30 to 13.30 O' clock (Peak II). The peak I period was the main foraging period and peak II was the second foraging period, both were very useful from the pollination point of view. After this, *Apis cerana* activity slowly diminished to a stand still at 17.30 pm. The time spent by *Apis cerana* on the buckwheat inflorescence at different hours of the day 09.00, 12.00, 15.00 O' clock showed longest (24 ± 3 min) in the morning and it decreased as the afternoon approached. This study revealed that *Apis cerana* bee pollination increased grain set in terms of the total number of grains per plant (169.76 ± 4.10), grain weight (33.03 ± 0.26 g) and grain yield (4.40 ± 0.12 g). It also increased the value of fertility (16.08 ± 0.21) and harvest index (35.32 ± 0.35) when compared with Control pollination/excluding all the insects (CP) and Open pollination (OP) treatment. This is mainly due to greater number of pollinators in the Bee pollination (BP) treatment, their longer duration of foraging and also due to superior pollinating efficiency of *Apis cerana* bees.

Key words: *Apis cerana,* F. beekeeping, buckwheat, fertility, foraging, harvest index, pollination, Kathmandu valley.

INTRODUCTION

Nepal is one of the least developed countries where food deficit and protein malnutrition have been acute problems. These problems are confronting the poor people where traditional crop production system does not look likely to solve them. Buckwheat belongs to such an ideal staple food crop species which has rich nutritional value especially in iron, protein and amino acids. In Nepal, this crop is grown on marginal lands with conventional technologies in a wide altitudinal range of 345 to 4,500 m above sea level.

Due to longer blooming periods and copious nectar content (0.2-0.4 mg/flower/day), buckwheat crop plays a very significant role in bee-farming when honey production from other flowering plants ceases (Lovell 1977, Partap 1997). The honey bearing property of buckwheat (10 to15 kg/colony/season) makes this crop more valuable (Bangyu *et al.* 1996) if extra household income could be generated from honey production by keeping the hive bees from the same parcel of land where buckwheat is growing.

According to Bhandari and Sah (2001) and Mulicha (2001), cultivation of buckwheat is declining. It is to be backed by the scientific research for its improvement to reach to the rural farmers and to contribute for the well being of the rural people. The average yield of buckwheat in Nepal is only 600 to 800 kg per ha (Rajbhandari and Hatley 1994) which is two to five times lower than USSR, Canada and Japan. The yield level of common buckwheat in the USSR is being as high as 2500 to 3000 kg per ha (Yakimenko 1982). This indicates that both the production and productivity of this crop needs to be elevated to keep pace with the growing demands of the population residing in the mountains and rural areas. The factors responsible for poor yield are lack of sufficient pollinators, strong wind during flowering, shattering of grains and other unknown factors.

Studies in the developed countries carried out by Moeller and Koval (1973) and Nye and Anderson (1974) have shown that honeybee pollination increased fruit set by 10 to 25 percent and fruit yield by 18 to 100 percent depending upon the cultivar. Many researchers have described pollination requirements of crops (Mc Gregor 1976, Free 1993, Partap and Verma 1993, Verma and Partap 1994, 1995, Sihag 2000, Mary and Weaver 2001 and Klein *et al.* 2006). In this paper, studies on foraging behaviour of *Apis cerana* F. on the flowering common buckwheat (*Fagopyrum esculentum* Moench) and their effects on the grain quality and yield increment by analyzing fertility rate and yield formation under different treatments for pollination were carried out.

MATERIALS AND METHODS

Foraging behaviour of hive bees (*Apis cerana* F.) on buckwheat (*Fagopyrum esculentum* Moench) crop was studied during the flowering season of the crop in 2001 and 2002 and their effects on grain quality and yield increment were carried out during the year 2000-2002 at the farmland in the premises of RECAST, Kirtipur, Kathmandu, Nepal.

Observations on floral biology included the number of flowers per plant, size of flowers and their total blooming period. Observations on the foraging behaviour of the hive bees were made on the daily time of initiation and cessation of foraging, total duration of foraging activity, peak foraging hours, time spent on the inflorescence and lastly the number of inflorescence visited per minute by marked bees taken at 9.00 h, 12.00 h and 15.00 h. The weights of pollen load carried by an individual bee were also noted.

For pollination studies, experiment was laid out on Randomized Complete Block Design with three replications in each treatment. There were altogether three treatments: Control pollination (CP); Open pollination (OP) and Bee pollination (BP) plots. Each treatment plot of 5m×5m was shown with crop geometry of 25cm×5cm. Before anthesis, the Control pollination (CP), and Bee pollination (BP) plots were caged. One *Apis cerana* colony (strength of five frames) was kept inside each Bee pollination (BP) treatment plot following Kraii (1954). The Open pollination (OP) treatment was grown open to permit the pollinating insects visit the flowers of buckwheat plants.

In order to determine the effect of bee pollination on the crop yield, fifty plants were randomly selected in each treatment and replication and their biometric measurements were recorded. Measured such biometric parameters include: total number of inflorescence per plant, total number of flowers per terminal inflorescence per plant, total number of grains per terminal inflorescence per plant, total number of grains per plant, test weight of 1000 grains, grains yield per plant and total dry matter (TDM) per plant. Fertility per plant and Harvest Index (HI) were calculated as following Rajbhandari and Hatley (1996) method:

$$\text{Fertility} = \frac{\text{total number of grains per terminal inflorescence}}{\text{total number of flowers per terminal inflorescence}} \times 100$$

$$\text{HI} = \frac{\text{grain yield per plant}}{\text{TDM}} \times 100$$

When flowering was over, the *Apis cerana* bee colonies were removed from Bee pollination (BP) treatment plots. Statistical analysis was performed on the selected traits applying SPSS (version SPSS 12.0) and excel software programme.

RESULTS

Flowering started from 25 to 30 days after planting of crops in the Kathmandu conditions. Buckwheat flowers were observed to be borne in raceme at the ends of branches or on short pedicel arising from the leaf axils. Each flower consisted of five perianths, a three parted styles with knobbed stigmas, one single superior ovary and eight stamens arranged in two whorls. The inner three stamens closely surrounded the style which protrudes outward and the remaining five located in the outer whorl protrude inwards.

Each plant in a population showed two types of flowers. They were pin type (having long style and short stamen) and thrum type (long stamen and short style) of flowers. There were eight small nectaries which alternate with the filaments of the stamens. The flowers looked light green, white, pink or red in colour and had a pleasant fragrance and were highly attracted to insect pollinators especially the bees.

The flowering pattern showed first flower bloom on the stem and then it was followed on the branches. Flowering started from the bottom towards the top and from inside to outside of the branches. The diameter of flower was observed to be 5.94 ± 0.36 mm. Each flower remained open and receptive for a day only. The total flowering period of this crop was observed to be around 30 days.

Apis cerana started their foraging activities early in the morning at 06.14 ± 0.004 h and ceased late in the evening at 17.28 ± 0.011 h. The total duration of foraging activity was 10:00 h and the average duration of foraging trip 4.5 ± 0.146 min (Table 1). Two peaks of foraging activities were observed from 08.30 to 10.30 (Peak I) and 11.30 to 13.30 O' clock (Peak II) when the temperature of experimental field ranged between 20°C to 21°C. (Fig. 1). The peak I period was the main foraging period and the peak II was the second foraging period. After this the activity slowly diminished to a stand still at 17.30 O' clock. The time spent by *Apis cerana* bees on the buckwheat inflorescence at different hours of the day 09.00, 12.00, 15.00 O' clock was longest (24 ± 3 min) in the morning period; and it decreased as the afternoon approached. A pollen collector on an average collected 4.78 ± 0.58 mg of pollen load (Fig. 1 and Table 1).

The quantitative and qualitative effects of *Apis cerana*. on buckwheat yield components showed in the CP treatment, decreased yield and large percentage of wrinkled grains set 5.32 ± 0.39. The fertility (2.49 ± 0.18%) and harvest index (10.39 ± 0.52%) were also found low in the CP treatment. Bee pollination showed significantly enhanced number of grains (33.70 ± 0.56) per inflorescence and total number of grains per plant (169.76 ± 4.10). The values of harvest index and fertility were also found higher in comparison with OP and CP treatments. Average increase in percentage when compared between BP and CP on the parameters: weight of grains, fertility and harvest index were found to be 37.45%, 545.78% and 239.94%. Similarly average increase in percentage when compared between BP and OP treatments on the parameters: weight of grains, fertility and harvest index were found to be 9.59%, 17.89% and 12.13%, respectively (Table 2).

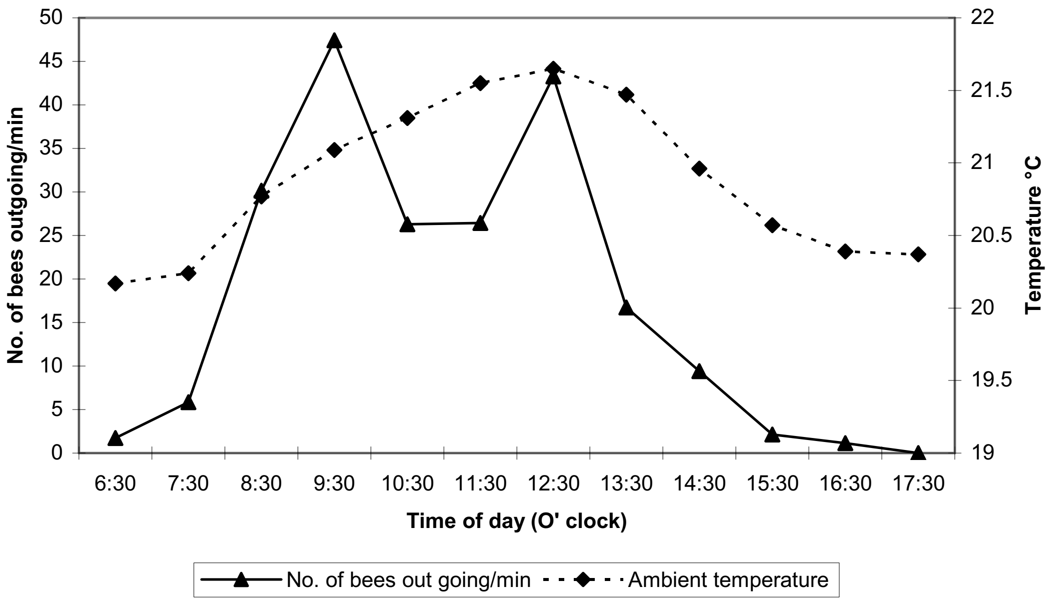


Fig. 1. Foraging behaviour of *A. cerana* on buckwheat flower, Kirtipur (mean values of the years 2001-2002).

Table 1. Foraging behaviour of *Apis cerana* on flowering buckwheat (mean values of the years 2001-2002).

Parameters	Measurement
A. Initiation of foraging (Time of day)	06.14 ± 0.004 (am)
B. Cessation of foraging (Time of day)	17.28 ± 0.011 (pm)
C. Average duration of foraging activity	9.48 ± 0.15
D. Peak foraging hours (Time of day)	i) 08.30 (am) to 11.30 (am)
	ii) 11.30 (am) to 14.30 (pm)
E. Average duration of foraging trip	4.5 ± 0.146* min
F. Time spent on inflorescence	
09.00 O' clock (2.46 h after sunrise)	24 ± 3 min
12.00 O' clock (5.46 h after sunrise)	20 ± 3 min
15.00 O' clock (8.46 h after sunrise)	16 ± 3 min
G. Weight Pollen load	4.78 ± 0.58 mg

* The scale is in minute and second. Each value is a mean ± standard error. A, B, C, D = mean of 7-days observation, E and G = mean of 20 observations, F = mean of 50 observations.

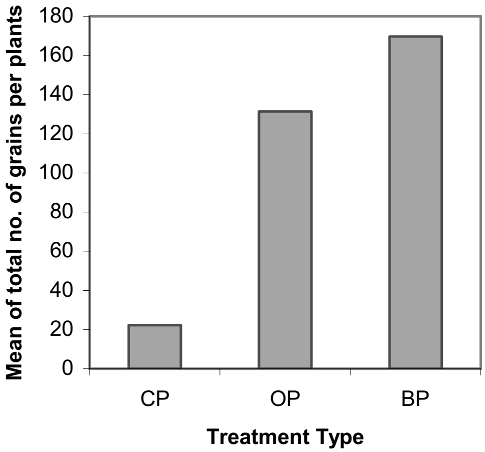
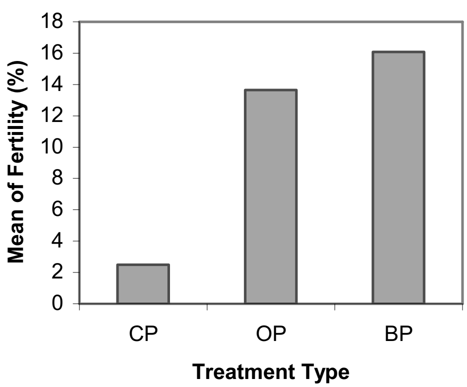


Fig. 2 A



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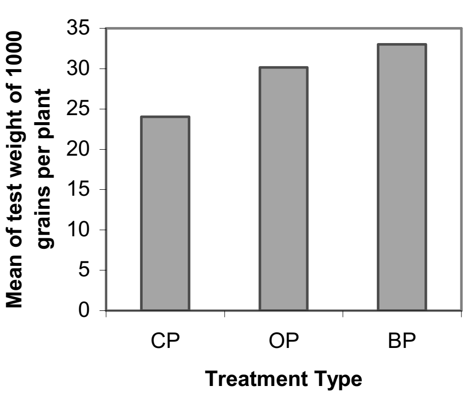

Fig. 2 C

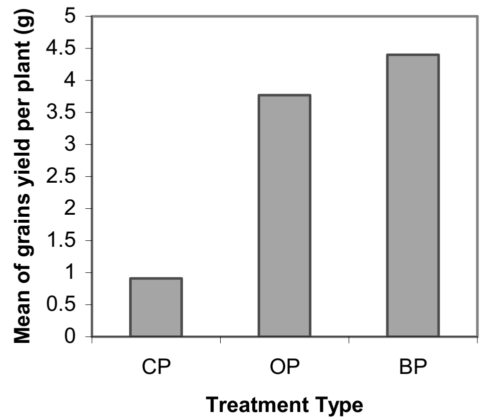

Fig. 2 D

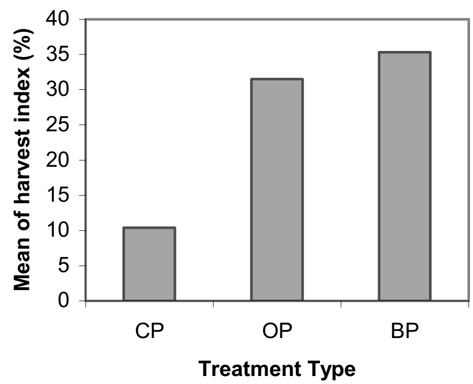

Fig. 2 E

Fig. 2. Overall Response of the Treatment (CP, OP, BP) to different traits of common buckwheat (average of three years 2000-2002).

The nature of graph among CP, OP and BP treatments, plotted separately on the selected traits of the common buckwheat have also elucidated that the number of grains per plant, test weight and grains yield per plant, fertility and harvest index showed highest in the BP treatment (Fig. 2).

Table 2. Effects of *Apis cerana* pollination on buckwheat yield components (mean values of the years 2000–2002).

Parameters	Control pollination (CP)	Open pollination (OP)	Bee pollination (BP)	Average Increase (%)		
				BP c.t. CP	BP c.t. OP	OP c.t. CP
Total no. of grains per terminal Inflorescence	5.32±0.39	27.41±0.58	33.70±0.56	533.46	22.95	415.23
Total no. of grains per plant	22.26±1.83	131.36±3.34	169.76±4.10	662.62	29.23	490.12
Fertility (%)	2.49±0.18	13.64±0.27	16.08±0.21	545.78	17.89	447.79
Test weight of 1000 grains (g)	24.03±0.49	30.14±0.23	33.03±0.26	37.45	9.59	25.43
Grains yield per plant (g)	0.91±0.11	3.77±0.10	4.40±0.12	383.52	16.71	314.29
H.I . (%)	10.39±0.52	31.50±0.34	35.32±0.35	239.94	12.13	203.18

values are mean ± s.e.; c.t. = compared to

All the mean differences are significant at 0.05 level.

DISCUSSION

In the present study, it was observed that in Kirtipur, Kathmandu valley *Apis cerana* initiates foraging early in the morning and ceases late in the afternoon. The total foraging duration was 10 hours per day and the average duration of foraging trip was found to be 4.5 ± 0.146 min (Table 1). The present findings were in proximity with the views of Singh *et al.* (2000), Verma and Partap (1994) and Joshi (2000) where they made similar observations on initiation, cessation and duration of honeybee (*Apis cerana*) foraging activity on *Brassica juncea*.

The observations recorded on the foraging rates of the pollinators which were few in the early morning (06.30 to 07.30 am) and late in the evening (14.30 to 16.30 pm) and also the two peaks of foraging activity in between 08.30 to 10.30 (Peak I) and 11.30 to 13.30 O' clock (Peak II) tune with the findings of Verma and Dulta (1986). They recorded peak foraging activity for *Apis cerana* at 09.00 to 11.30 O' clock between temperature of 15.5°C to 21°C and 11.00 to 13.30 O' clock for *Apis mellifera* when the temperature was 21°C to 25°C on apple flowers.

The peak foraging hours of the visit coincide with the number of blooming flowers. The peak hours of activity of honeybees are of great interest from the pollination point of view, because by keeping bees in the agricultural blooming crops, the total period of peak foraging activity can be increased for timely pollinating the blooming flowers and for intense honey harvest.

The time spent by bees for foraging on the flowers depends on the amount of nectar and pollen present in the flower. It also varies with the type of flower and the stage of its development with climatic conditions. In the present study it was noticed that the time spent on the flowers by *Apis cerana* was more during early hours than in the afternoon (Table 1). This accord with Kopel'kievski (1953) who also described that insect pollinators are mostly abundant on the buckwheat flowers between 09.00 to 12.00 am. This is because nectar flow is copious in the buckwheat crop especially in the morning period, there after the nectar concentration gradually diminishes (Solov'ev 1960).

During the study it was also noticed that bees did not visit the buckwheat flowers in the first two-three days of flowering but soon after the mass initiation of flowering, the bees became busy in foraging in the buckwheat flowers which correlates with the views of Free (1993).

The results on grain yield and its components show that the method of pollination and succeeding fertilization, rather than the number of flowers alone control seed/grain or fruit development. The results agree with Williams (1978) who stated that inadequate pollination probably limits yield. More or less self-sterile crops, regardless of fertilizers, irrigation or cultural practices, may not give even a fraction of their potential yields unless agronomists provide adequate number of pollinating bees (Deodikar and Suryanarayana 1972, 1977).

The effects of *Apis cerana* on pollination showed significant difference among the tested traits of common buckwheat such as total number of grains per plant, fertility percentage, test weight of 1000 grains, grain yield per plant and harvest index among BP, OP and CP treatments.

Regarding the quantitative and qualitative effects of *Apis cerana* on buckwheat crop, the results showed that little grain set in CP treatment may be due to wind movement inside the cage showing that wind also plays some role in the dispersal of buckwheat pollens. This is also supported by Marshall (1969). Beside this, the value of fertility and harvest index were also found low in the CP treatment. Bee pollination showed significantly enhanced grain set and the total number of grains per plant (Table 2). The values of harvest index and fertility were also observed to be higher in comparison with OP and CP treatments. This may be due to the superior pollinating efficiency of honeybees (*Apis cerana*) visiting the flowering buckwheat crops in the BP treatment. In the OP treatment due to wind movement and due to the visit of some insect pollinators in buckwheat, fewer flowers were pollinated as compared to BP treatment. This resulted in lower grain set and grain yield in the OP treatment than with BP treatment. The fertility and harvest index of OP treatment were also lower than with BP treatment.

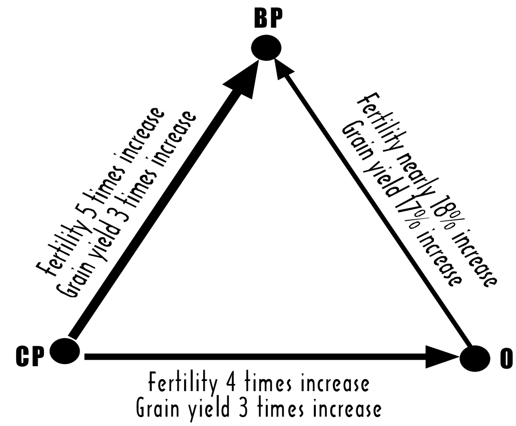

Fig. 3. Diagram showing interaction among three treatments Bee pollination (BP), Open pollination (OP), Control pollination (CP) of the experiment.

Fertility percentage was found higher both in BP and OP treatments as compared to CP treatment (Table 2). Here it was observed that fertility percentage increased five times and grain yield per plant increased by three times in BP as compared to CP treatment (Fig. 3). Similarly fertility percentage was four times higher and grain yield up to three times higher in OP than in the CP treatment. Likewise fertility percentage was found to be increased nearly up to 18 percent and grain yield per plant was up to 17 percent higher in BP than in OP treatment (Fig. 3).

Estimation of simple correlation coefficients among various pairs attributing to grain yield revealed significant positive correlations among various pairs (Table 3 a,b,c). Estimation of correlation coefficient among fertility percentage with various yield attributing traits revealed significant (P=0.01) positive correlation with grain yield per plant in all treatments (Table 3 a,b,c). Fertility percentage had significant (P=0.01) positive correlation with total number of grains per terminal inflorescence (r = 0.683), total number of grains per plant (r = 0.179), and harvest index (r = 0.274) in the treatment with BP (Table 3a). Similar significant positive correlation of fertility was obtained with these traits in other treatments as well (Table 3b and c). These findings corroborate with the reported results of Rajbhandari (2006).

Table 3. Correlation coefficients among various pairs of parameters used in this study (no. of observations = 450).

Table 3a. Treatment: Bee pollination (BP).

Parameters*	2	3	4	5	6	7
1	.521(**)	.009	-.223(**)	.218(**)	.225(**)	.090
2		.191(**)	.683(**)	.187(**)	.405(**)	.306(**)
3			.179(**)	.226(**)	.642(**)	.447(**)
4				.019	.258 (**)	.274(**)
5					.462(**)	.408(**)
6						.575(**)

Table 3b. Treatment: Open pollination (OP).

Parameters	2	3	4	5	6	7
1	.258(**)	.128(**)	-.410(**)	.020(**)	0.69(**)	0.77(**)
2		.316(**)	.682(**)	.238(**)	.315(**)	.336(**)
3			.288(**)	.214(**)	.915(**)	.572
4				.189(**)	.320(**)	.302
5					.401(**)	.336(**)
6						.635(**)

Table 3c. Treatment: Control pollination (CP).

Parameters	2	3	4	5	6	7
1	.205(**)	.087	.059	.074	-.010	.102(*)
2		.728(**)	.963(**)	.230(**)	.375(**)	.723(**)
3			.718(**)	.185(**)	.486(**)	.753(**)
4				.224(**)	.383(**)	.710(**)
5					.099(*)	.294(**)
6						.599(**)

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Parameters:

1. Total number of flowers per terminal Inflorescence
2. Total no. of grains per terminal Inflorescence
3. Total no. of grains per plant
4. Fertility (%)
5. Test weight of 1000 grains (g)
6. Grains yield per plant (g)
7. Harvest Index (HI) (%)

CONCLUSION

Honeybee pollination increased grain weight, fertility and also harvest index, thus producing bigger, bold and well filled grains of superior quality. Less grain set in the CP treatment means that buckwheat flowers are self-incompatible and required cross-pollination by insect pollinators. Hence this study concluded that higher number of grains per plant, higher fertility percentage and total grain yield indicate effective bee pollination in realizing the yield potential of the common buckwheat crop. The yield may reach five times higher than the national average yield of buckwheat in Nepal.

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