GSJ: Volume 6, Issue 11, November 2018, Online: ISSN 2320-9186

www.globalscientificjournal.com

# ASSESSMENT OF POLLINATION DEFICIT IN BUCKWHEAT (FAGOPYRUM ESCULENTUM MOENCH) AND ITS IMPACT ON PRODUCTION IN DIFFERENT AGROECOSYSTEMS OF CHITWAN, NEPAL

S.P. Rijal, R.B. Thapa, M.D. Sharma, S.K. Sah, Y.D. GC
Corresponding Author: sprijalb@gmail.com

*1= Ph.D.Scholar, Institute of Agriculture and Animal Science, Tribhuvan University.Kathmandu, Nepal*
*2=Professor, Institute of Agriculture and Animal Science, Tribhuvan University, Kathmandu, Nepal*
*3= Professor, Agriculture and Forestry University, Chitwan, Rampur, Nepal*
*4= Professor, Agriculture and Forestry University, Chitwan, Rampur, Nepal*
*5=Secretary, Ministry of Agriculture and Livestock Development, Singha Darbar Kathmandu.*

Key words:

Bees; buckwheat; Intensive agriculture; Semi-natural; Open pollination; bee pollination, Agroecosystems



## ABSTRACT

Buckwheat pollination is crucial for increasing its yield, ensuring food security and improving livelihoods. To quantify the response of honeybee on buckwheat seed pollination and yield, an experiment was conducted at three agro-ecological sites (Semi-natural, organic and intensive agriculture sites of Megauli, Fulbari and Jutpani Village Development Committees (VDCs), respectively) of Chitwan district during the winter season of 2012/13 and 20013/14. The experimental design Randomized complete block design (RCBD) with four treatments (i. open pollination; ii. plants caged with honeybees (Apis melifera L); iii. hand pollination iv. plant without pollinators) replicated four times. Plant height (cm), branch number, and blossoms, seed number per plant, 1000 grains wt (g)., and seed yield/sq.m. were measured. Pollinators' abundance and diversity were also observed. The impact of pollinators on each agro-systems resulted in significantly increased yields attributes compared to restricted pollination. Plants not pollinated by bees resulted in taller, higher branch numbers, and lower seed yield. There was different levels of pollinators in semi-natural, organic and intensive agriculture sites, however deficit in pollination noticed in intensive agriculture field resulted lower yield.

The dominant pollinators were Hymenopterans, followed by Dipterans, Coleopteran, and Lepidopterans insects, respectively. The major honeybees were Apis melifera L., Apis cerana F., Apis dorsata F. and Apis florea F. Syrphid flies, Syurphus sp., Eristalis sp. and cabbage butterfly, Pieris rapae L. the dominant Dipteran and Lepidopteran pollinators. Hence, integrating pollinator diversity and managed pollination to sustain production through biodiversity-based ecosystem services. The experimental results showed that there was significantly higher plant height in pollination restricted plots (control) and branch number were the greatest in the control treatment compared to pollinated plots. Pollination increased grains per plants increased 1000 grain weight when compared with control plot. Thus, the quality and quantity of buckwheat production get improved with bee pollination especially in open and bee enclosed treatments suggesting increased use of managed honeybees and conservation of wild bees and other pollinators.

GSJ: Volume 6, Issue 11, November 2018
ISSN 2320-9186


## Introduction

The common buckwheat ((*Fagopyrum esculentum* Moench.), *Fagopyrum esculentum*; family: Polygonaceae) popularly known as "Pseudo-cereal, is the most economically important buckwheat species for world food production.This belongs to such an ideal staple food crop species, which has rich nutritional value [1] [2] high quality, easily digestible protein, having a balanced amino acid composition [3] cholesterol free and perfectly fits our modern low calorie, high nutrition diets [4][5]. Many small landholders across Asia grow common buckwheat, however, China, Russia, and Japan are currently the world's top producers of buckwheat [6]. In Nepal, it is one of an important underexploited crops of Nepal majorly grown with conventional technologies in mid-hills (345 to 4,500 m above msl) occupying 10,339 ha of land area, with the production of 10,021 t/ha and productivity of 0.97 t/ha [7]. Major constraint to buckwheat production worldwide is (around 15-30%)) low production [8] [9] [1].

Buckwheat flowers 35 to 35 days after planting of crops in the Chitwan conditions. Each plant in a population showed two types of flowers i.e. pin type (having long style and short stamen) and thrum type (long stamen and short style) of flowers were observed to be borne in raceme at the ends of branches or on short pedicel arising from the leaf axils [10][11]. Buckwheat fields have approximately equal numbers of pin and thrum flowers [10] a pleasant fragrance and were highly attracted to insect pollinators especially the bees [12]. 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. Each flower remained open and receptive for a day only [10]. 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 [13] [14]. Buckwheat flowers highly attractive to bees in the first sunshine and most of the pollination activities occur. It is said that a single visit of buckwheat flower by a bee increases plant productivity by 25-30% [15]. Cultivation of buckwheat along with beekeeping may produce 50 to 100 kg of honey per hectare, due to its extended flowering period for more than 30 days [16]. Three to four insect visits are enough to pollinate one blossom of buckwheat while bee visiting more than 5 times the productivity of plant decreases [17]. Many factors, such as the floral physiology and morphology, pollinator characteristics, as well as effects of weather influence the success of pollination

The honey bearing property of buckwheat (10 to15 kg/colony/season) makes this crop more valuable [18], if extra household income could be generated from honey production. Buckwheat produced 21.7- 41.4% higher seed yield when intensively visited by pollinators compared with the seed yield obtained in isolated areas [19]. Honeybee pollination increased fruit set by 10 to 25 percent and fruit yield by 18 to 100 percent depending upon the cultivar [20]. [21]showed that there was significantly lower plant height (49.71 cm at peak flowering ) and branch number (2.72) in *Apis cerana* F. pollinated plot followed by *Apis mellifera* L. pollinated plots (50.33 cm at peak flowering , branch number 2.89) compared to open pollination, hand pollination and control plot. However, genetic quality of buckwheat is best with pollen deliveries of at least 10 grains, thus need frequent visit of bees and other small pollinators [17]. Numerous insect groups, including Hymenoptera, Diptera, Coleoptera, and Lepidoptera, visit common buckwheat flowers, however Hymenoptera especially honeybees are the major pollinators [22]. There has been considerable research on the role that field margins play, especially when managed for conservation, in providing foraging and nesting sites for insect pollinators within intensively managed agricultural landscapes [23] [24]. Insect pollinators are responsible for the pollination of the many wild plants and thus play a vital role in the maintenance of terrestrial ecosystems [25]. Landscape factors might hive expected to affect pollinator behavior, consequently affect on production, however the farmers' knowledge and perception regarding the effect of pollination has not well understood. Hence, this study was conducted to know the effects of diverse pollinator species on yield attributes of common buckwheat at three agro-ecological sites i.e. semi-natural (Megauli), organic (Fulbary) and intensive agriculture (Jutpani) sites of Chitwan district during the winter season of 2012/13 and 20013/14.

## Materials and Methods

The research was conducted in three sites, i.e. very close to natural habitat (Meghauli VDC), organic farming site (Fulbari VDC), intensive agriculture practiced site (Jutpani VDC) of Chitwan district for two years (2012-13 and 2013-2014).The experiment in RCBD wirh Factor A: Agro-ecosystem (semi natural, organic, intensive agriculture), Factor B: Pollination (open, hand pollination, bee supplementation with *Apis melifera* L *and* without pollination). Each treatment was replicated four times in each agro-ecosystem. Two framed broods *A. mellifera* L. were evaluated in bee supplemented treatment

GSJ: Volume 6, Issue 11, November 2018
ISSN 2320-9186



plots), In case of hand pollination, each treatment was evaluated in 1 m² area. Land preparation was done by conventional tillage and harrowing. FYM were incorporated with the rate of 10 ton/ha and NPK of 30:20:10 kg/ha. Seeds were sown on 3rd week of November with crop geometry of 15 cm×10 cm and seed rate of 60 kg/ha. Plants were harvested when grains at lower nodes turned brown and were allowed to dry for easy threshing. Experimental plots (12 plots) were caged with mosquito nylon net of 5×3m2 size and 4 plots with same net of size 1×1 m2. The plots assigned for control and bee supplementation with *Apis mellifera* L. were caged with net of 5×3 m2 and for hand pollination plot, caging was done in 1×1 m2 area. The *A. mellifera* hive with 2 frame bees were kept within the cage. Within this area, 1×1 m2 was taken as experimental unit for data recording. Caging was done at 5-10% flowering up to 90% flowering. Bee colonies were fed with 1:1 sugar syrup once in a week throughout the entire pollination .For assessing the diversity and intensity of pollinators in the near and far from natural habitat, a big plots of 25m x 50m was selected in nearby of farmers' fields (followed the [26] Insect visitation rates were observed and recorded at 10%, peak and 10% remaining to flower by counting the number of flower visits per $m^2$ for five minutes. Only insects that visited flowers flowers were captured or counted; thus, insects visiting other portions of the plant were excluded. The observations were made at 10-11 AM under sunny weather conditions with temperature above 17°C. Measured such biometric parameters inclues plant height, total number of brances per plant, inflorescences per plant, test weight of 1000 grains, grains yield per sq m. Collected data were analyzed using the ANOVA procedure in MSTATC program.

## Results and Discussion

### Plant height

There was significance difference on the plant height of buckwheat in pollination treatments compared to ocontrol (Table 1).

**Table 1. Effect of honeybee pollination on plant height (cm) at different stages of buckwheat (DAS) at different locations of Chitwan, Nepal in 2012/13 and 2013/14.**

| Agro-ecosystems | Treatment | Plant height (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10% F | | Ave | Difference with control (%) | Peak flowering | | Ave | Difference with control (%) | 10% Remaining | | Ave | Difference with control (%) |
| | | 2013/14 | 2014/15 | | | 2013/14 | 2014/15 | | | 2013/14 | 2014/15 | | |
| Semi-natural | Open | 39.2b | 43.2ab | 41.2 | 17.70 | 52.1ab | 52.9c | 52.5 | 6.3 | 63.9c | 62.1b | 63 | 39.0 |
| | Bee supplementation | 44.8a | 46.9b | 45.9 | 8.00 | 50.3b | 57.0b | 53.7 | 5.1 | 61.3c | 68.4ab | 64.9 | 13.9 |
| | Hand pollination | 47.8a | 51.3a | 49.5 | 0.57 | 58.8a | 63.2a | 61 | -2.2 | 69.6b | 73.5a | 71.6 | 5.0 |
| | No pollination (control) | 51.97a | 47.7a | 49.9 | | 55.5a | 62.0a | 58.8 | | 76.3a | 74.4a | 75.4 | |
| Organic | Open | 43.3ab | 44.4a | 43.9 | 8.55 | 53.7b | 54.0ab | 53.6 | 9.2 | 63.9b | 65.4b | 64.7 | 37.9 |
| | Bee supplementation | 45a | 41.9a | 43.5 | 13.62 | 54.7b | 53b | 53.9 | 8.9 | 66.8b | 63.1b | 64.9 | 12.3 |
| | Hand pollination | 46.6a | 47.0a | 46.8 | 6.96 | 56.5ab | 55.8a | 56.2 | 6.6 | 68.2b | 66.6ab | 67.4 | 9.0 |
| | No pollination | 50.3a | 50.3a | 50.3 | | 64.9a | 60.7a | 62.8 | | 74.9a | 73.2a | 74.1 | |
| Intensive Ag | Open | 35.6c | 42.7b | 39.2 | 5.54 | 48.5b | 52.3b | 50.4 | 10.8 | 58.5b | 64.3b | 61.4 | 37.6 |
| | Bee supplementation | 45.7b | 39.2b | 42.5 | 12.83 | 56.5ab | 50.4b | 53.5 | 7.7 | 67.1a | 60.1b | 63.6 | 13.7 |
| | Hand pollination | 48.9a | 49.1a | 49 | -0.62 | 60.5a | 53.7b | 57.1 | 4.1 | 70.9a | 64.8b | 67.9 | 7.9 |
| | No pollination | 48.3a | 49.1a | 48.7 | | 59.4a | 62.9a | 61.2 | | 72.9a | 74.5a | 73.7 | 39.0 |
| | Significance (<0.05) | | | | | | | | | | | | |
| | Location | Ns | | | | Ns | | | | ns | | | |
| | Treatment | * | | | | * | | | | * | | | |
| | LSD value | 5.424 | | | | 5.424 | | | | 5.501 | | | |
| | CV% | 7.97 | | | | 6.76% | | | | 5.73 | | | |

The plant height of buckwheat was non significance among locations, howover it is significant among treatments. The significant difference on the plant height of due to the effect of insect pollination on buckwheat. The plant height was shorter in open, hand pollinated, bee pollinated treatments compared to control. Non significant results in eco-types was mainly due to the well distribution of pollinators in all locations.

GSJ: Volume 6, Issue 11, November 2018
ISSN 2320-9186



**Number of branches**

The number of branches per plant was also found lower than non pollinated plants. During peak flowering, the open pollination, honeybee pollination were found lowering by 33.3 and 31.3 percent compared to no pollination (control), and In case of hand pollination, there was somewhat higer ( 2.1 %) numbers of plant compared to control in semi-natural site.In organic site there was 37.5, 35.4, 0.0 percent in open, bee pollination and hand pollinated plots respectively. Similarly, in intensive agriculture site, the treatments (open, bee and hand plollinated) plots followed trend as mentioned above, i.e lowering the number of branches by 21.6, 16.0, and 8.0 percent. During 10% remaining to flowering, differene in branches/plant in open pollination, bee pollination and hand pollination were lowered by 34.1, 32.5, +10.6 in semi-natural; 32.3, 40.0, 1.5 in organic and 18.8, 24.8, 12.8 in intensive agriculute, respectably.

**Table 2. Effect of honeybee pollination on number of branches per plant at different stages of buckwheat (DAS) at different locations of Chitwan, Nepal in 2012/13 and 2013/14**

| Agro-ecosystems | Treatment | Number of branch/plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10% Flowering | | | | Peak flowering | | | | 10% Remaining of flowering | | | |
| | | 2012/13 | 2013/14 | Ave | Difference to respective control (%) | 2012/13 | 2013/14 | Ave | Difference to respective control | 2012/13 | 2013/14 | Ave | Difference to respective control |
| Semi-natural | Open | 2.5a | 2.9a | 2.7 | 3.6 | 3.8c | 4.3b | 4 | 33.3 | 4.8b | 4.3b | 4.05 | 34.1 |
| | Bee supplementation | 2a | 2a | 2.0 | 28.6 | 4b | 4.3b | 4.1 | 31.3 | 4.3ab | 4.1b | 4.15 | 32.5 |
| | Hand pollination | 2.3a | 1.8a | 2.0 | 28.6 | 5.5a | 6.8a | 6.1 | -2.1 | 6.8ab | 6.8b | 6.8 | -10.6 |
| | No pollination (control) | 2.8a | 2.8a | 2.8 | | 6.5a | 5.5a | 6.0 | | 5.8a | 6.5a | 6.15 | |
| Organic | Open | 2.8a | 2.3a | 2.6 | 3.7 | 4b | 3.5b | 3.8 | 37.5 | 4.5b | 4.3b | 4.4 | 32.3 |
| | Bee supplementation | 3.3a | 2.8a | 3.0 | -11.1 | 3.8b | 4b | 3.9 | 35.4 | 3.8b | 4b | 3.9 | 40.0 |
| | Hand pollination | 2.3b | 2.3a | 2.3 | 16.7 | 5.8a | 6.3a | 6.0 | 0.0 | 5.8b | 6.9b | 6.4 | 1.5 |
| | No pollination (control) | 2.5b | 3a | 2.7 | | 6.3a | 5.8a | 6.0 | | 6.5a | 6.6a | 6.5 | |
| Intensive Ag | Open | 2.8a | 2.5a | 2.7 | 0.0 | 4.8a | 5.0b | 4.9 | 21.6 | 4.8b | 6.0b | 5.4 | 18.8 |
| | Bee supplementation | 2a | 2a | 2.0 | 25.9 | 4.8a | 5.8a | 5.3 | 16.0 | 4.8b | 5.3ab | 5 | 24.8 |
| | Hand pollination | 1.8a | 2.5a | 2.2 | 18.5 | 5a | 6.5a | 5.8 | 8.0 | 5b | 6.5ab | 5.8 | 12.8 |
| | No pollination (control) | 2.8b | 2.5a | 2.7 | | 5.8a | 5.5a | 6.3 | | 6.8a | 6.5a | 6.65 | |
| | Significance (<0.05) | | | | | | | | | | | | |
| | Location | Ns | | | | Ns | | | | Ns | | | |
| | Treatment | Ns | | | | * | | | | * | | | |
| | LSD value | 1.034 | | | | 1.662 | | | | 2.351 | | | |
| | CV% | 30.46% | | | | 21.59% | | | | 22.97% | | | |

The number of branches at different times of flowering indicated non-difference among agro-ecosystems, i.e lowering of number of branches, howover, it was significantly differnces in number of branches among treatments. At 10% flowering, it was not significant but significant in peak and 10% remaining to flower.

GSJ: Volume 6, Issue 11, November 2018
ISSN 2320-9186


**Number of blossoms**

Number of blossoms per plant in pollinated plots were higher irrespective to treatments compared to control It was highly significant among the treatments (P≤ 0.01). The highest number of blossoms per plant of buckwheat was observed honeybee pollinated plots and open pollinated plots compared to control. Locationwise, the results was not significant (Table 3).

**Table 3. Effect of honeybee pollination on number of blossoms per plant of buckwheat at location, Chitwan, Nepal, 2012/13-2013/14**

| Location | Treatment | No.of blossoms at 10% flowering | | Ave | Differnce to respective control | No.of blossoms at 50% flowering | | Ave | Difference to respective control | No.of blossoms 10% remaining of flowering | | Ave | Differnce to respective control |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2012/13 | 2013/14 | | | 2012/13 | 2013/14 | | | 2012/13 | 2013/14 | | |
| Semi-natural | Open | 12.3a | 12ab | 12.2 | 27.9 | 17.3a | 16.5ab | 16.9 | 21,2 | 9.8a | 10.8a | 10.3 | 10.4 |
| | Bee supplementation | 12a | 13.5a | 12.8 | 34.2 | 16a | 18a | 17 | 22.3 | 9.5a | 11.3a | 10.4 | 9.6 |
| | Hand pollination | 12.3a | 11bc | 11.6 | 12.4 | 17.3a | 13.8bc | 15.5 | 11.5 | 11.3a | 12.3a | 11.8 | 2.6 |
| | No pollination (control) | 9.8a | 9.3c | 9.5 | | 14.8a | 13c | 13.9 | | 12.5a | 10.5a | 11.5 | |
| Organic | Open | 11.3a | 13.3a | 12.3 | 12.4 | 15.5a | 16.8a | 16.1 | 15.8 | 10a | 11.5a | 10.8 | 4.7 |
| | Bee supplementation | 11.3a | 12.8ab | 12 | 10.1 | 16a | 16.8a | 16.4 | 18 | 10.5a | 11.8a | 11.1 | 9.4 |
| | Hand pollination | 11.3a | 11.8ab | 11.5 | 5.5 | 18a | 15ab | 16.5 | 18.7 | 11.8a | 10a | 10.9 | 2.3 |
| | No pollination (control) | 11.3a | 10.5b | 10.9 | | 15a | 12.8b | 13.9 | | 10.8a | 10.5a | 10.6 | |
| Intensive Ag | Open | 11ab | 12.5ab | 11.8 | 14.6 | 15.5b | 17.5a | 16.5 | 7.75 | 10.5a | 8.5a | 9.5 | 22.1 |
| | Bee supplementation | 13.3a | 14.8a | 14 | 36.6 | 19.3a | 17.3a | 18.5 | 12.9 | 13.3a | 11.5a | 12.4 | 10.2 |
| | Hand pollination | 13a | 11.3b | 12.1 | 18 | 16b | 15.5ab | 15.8 | 7.75 | 10.5a | 10.5a | 10.5 | 13.4 |
| | No pollination (control) | 10.3b | 10.3b | 10.3 | | 13b | 12.8b | 12.9 | | 12.8a | 11.5a | 12.1 | |
| Significanace ( ≤ 0.5) Location Treatment | | ** Ns | | | | ns ** | | | | ns ns | | | |
| LSD | | 2.351 | | | | 2.926 | | | | 2.853 | | | |
| CV | | 7.14 | | | | 6.07 | | | | 8.33 | | | |

GSJ: Volume 6, Issue 11, November 2018
ISSN 2320-9186



**Yield attributes**

Seed per plant in open, bee and hand pollinated plots were result of 298.6, 310, 273.3 percent higher seeds per plants than control in seminatural site; 285.2, 378 .6, 240 percent higher in organic; and 353.8, 463.1, 313.8 percent higher in intensie agriculture site .While considering 1000 grains weight, it was higher weight by 53.1, 59.6, 53.1 in open, bee and hand pollinated treatment under seminatural site, 41.9, 41.6, 38.5 in organic site and 42.2, 46.4, 24.4 in intensive agriculture site respectively.. The yield was also increased in pollination treatments irrespective to sites. i.e. open pollination (229.7%) , honeybee pollination (219.8%) and hand pollination (198.9%) in semi natural sites; open pollination (329.9%) , honeybee pollination (347 %) and hand pollination (316.2 %) in organic site; open pollination (244.5%) , honeybee pollination (253.9 %) and hand pollination (231.3 %) in intensive agriculture practiced site (Table 4).

**Table 4. Effect of honeybee pollination on number of seed per plant, 1000 grain weight and grain yield of buckwheat at different locations of Chitwan, Nepal, 2012/13-2013/14**

| Agro-ecosystems | Treatment | Seeds/ plant | | Ave | Difference to respective control (%) | 1000 grain wt. (g) | | Ave | Difference to respective control (%) | Seed Yield (g/m2) | | Ave | Difference to respective control (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2012/13 | 2013/14 | | | 2012/13 | 2013/14 | | | 2012/13 | 2013/14 | | |
| Semi-natural | Open | 29.6b | 26.9b | 28.3 | 298.6 | 23.6b | 26a | 24.8 | 53.1 | 93.2a | 88.9a | 91.0 | 229.7 |
| | Bee supplementation | 34.6a | 37.9a | 36.2 | 310 | 26.1a | 25.4a | 25.7 | 59.6 | 91.9a | 84.8a | 88.3 | 219.8 |
| | Hand pollination | 26.1c | 27.1b | 26.6 | 273.3 | 24.1b | 25.3a | 24.7 | 53.1 | 81.8a | 83.2a | 82.5 | 198.9 |
| | No pollination (control) | 7.6d | 6.7c | 7.1 | | 17.6c | 15.2b | 16.1 | | 29.3b | 25.9b | 27.6 | |
| Organic | Open | 30.3b | 27.6b | 28.9 | 285.2 | 25.9a | 23.6a | 24.7 | 41.9 | 92.0a | 83.5a | 87.7 | 329.9 |
| | Bee supplementation | 37.1a | 34.7a | 35.9 | 378.6 | 25.1a | 24.1a | 24.6 | 41.6 | 94.9a | 87.5a | 91.2 | 347 |
| | Hand pollination | 25.4c | 25.7c | 25.6 | 240 | 25.1a | 23.8a | 24.4 | 38.5 | 84.7a | 85.2a | 84.9 | 316.2 |
| | No pollination (control) | 7.1d | 8d | 7.5 | | 18b | 16.9b | 17.4 | | 20.3b | 20.5b | 20.4 | |
| Intensive Ag | Open | 29.5b | 29.7b | 29.6 | 353.8 | 23.2a | 24.2a | 23.7 | 42.2 | 88.8a | 87.7a | 88.2 | 244.5 |
| | Bee supplementation | 37.9a | 35.3a | 36.6 | 463.1 | 24.9a | 24.5a | 24.7 | 46.4 | 94.6a | 86.6a | 90.6 | 253.9 |
| | Hand pollination | 27c | 26.8c | 26.9 | 313.8 | 24.6a | 24.2a | 24.5 | 24.4 | 92a | 77.6a | 84.8 | 231.3 |
| | No pollination (control) | 6.8d | 6.3d | 6.5 | | 17.5b | 15.8b | 16.7 | | 31.5b | 19.6b | 25.5 | |
| | Significance (<0.05) | | | | | | | | | | | | |
| | Location | Ns | | | | Ns | | | | | Ns | | |
| | Treatment | * | | | | * | | | | | * | | |
| | LSD value | 3.831 | | | | 2.225 | | | | | 13.6 | | |
| | CV% | 10.99% | | | | 6.91% | | | | | 11.51% | | |

Table 4 shows that pollination was very important for increasing the seed number, test weight and grain in each agro-ecological sites. More than five times increase in yield attributes was due to the pollinators visits. Honeybee enclosed plots showed the greatest in seed per plant, test weight and grain yield in seminatural and organic sites in comaparion to intensive agriculture practiced site.

GSJ: Volume 6, Issue 11, November 2018
ISSN 2320-9186



## Population dynamic of pollinators in different distances from natural habitat

**Table 5. Availability of Hymenopteron pollinators (orderwise) in different time of flowering found in buckwheat field in different distances from natural habitat visually observed (No/m2/ 5sec) in Chitwan, Nepal, 2012/13 and 2013/14.**

| Treatments | Hymenoptera | | | | | |
|---|---|---|---|---|---|---|
| | 2012/13 | | | 2013/14 | | |
| | 10% F | Peak F | 10% R | 10% F | Peak F | 10% R |
| < 500 m from natural ecosytems | 108.7$^{b}$ | 174.5$^{a}$ | 114.3$^{a}$ | 129.8$^{a}$ | 125.83$^{a}$ | 118.7$^{a}$ |
| 1000m | 125.8$^{a}$ | 181.3$^{a}$ | 128.8$^{a}$ | 115.7$_{a}$ | 123.33$^{a}$ | 117.8$^{a}$ |
| 2000m | 118.8$^{a}$ | 169.5$^{a}$ | 112.7$^{a}$ | 114.7$^{a}$ | 112.67a | 111.5$^{a}$ |
| 3000m | 96.0$^{c}$ | 133.7$^{b}$ | 107.7$^{b}$ | 92.67$^{b}$ | 88.17$^{b}$ | 109.8$^{a}$ |
| Significance (0.05) | ** | ** | ** | ** | ** | ** |
| LSD | 17.88 | 27.27 | 19.85 | 17.88 | 27.27 | 19.85 |
| CV% | 13.16 | 14.93 | 13.89 | 13.16 | 14.93 | 13.89 |

Table 5 shows the significant difference among treatments.The Hymenopteron pollinators were found more number in during peak period and was found decreaing in 10% remaining to flowering. Hymenopteran population was found decreased when the locations goes away from natural habitat. In China, the probable country of origin for buckwheat [27], native non-*Apis* bees and syrphid flies accounted for over 50% of insect visits [28]. Honey bees have been shown to be an effective pollinator of buckwheat because they collect both pin and thrum pollen on a single trip, promoting contact with stigmas [17].

**Table 6. Availability of Diperan pollinators (orderwise) in different time of flowering found in buckwheat field in different distances from natural habitat visually observed (No/m2/ 5sec) in Chitwan, Nepal, 2012/13 and 2013/14.**

| Treatments | Diptera | | | | | |
|---|---|---|---|---|---|---|
| | 2012/13 | | | 2013/14 | | |
| | 10% F | Peak F | 10% R | 10% F | Peak F | 10%R |
| < 500 m from natural ecosytems | 47.0$^{a}$ | 64.7$^{a}$ | 49.3$^{a}$ | 47.2$^{a}$ | 44.8$^{a}$ | 25.8$^{a}$ |
| 1000m | 54.3$^{a}$ | 45.0$^{b}$ | 29.5$^{b}$ | 29.2$^{b}$ | 32.3$^{b}$ | 23.3$^{a}$ |
| 2000m | 36.5$^{b}$ | 32.3$^{c}$ | 26.3$^{b}$ | 34.8$^{a}$ | 35.2$^{b}$ | 27.7$^{a}$ |
| 3000m | 31.5$^{b}$ | 24$^{d}$ | 17.5$^{c}$ | 25.3$^{b}$ | 22.0$^{c}$ | 12.2$^{b}$ |
| Significance (0.05) | ** | ** | ** | ** | ** | ** |
| LSD | 9.136 | 11.75 | 9.036 | 9.136 | 11.75 | 9.036 |
| CV% | 20.27 | 26.46 | 28.16 | 20.27 | 26.46 | 28.16 |

Table 6 shows far the place from natural habitat, there was significant decrease in Dipteran population among the treatments.The visits of the insect in the flower of buckwheat was observed less in 10% flowering and 10% remaining to flower compared to peak flowering. Generally, the decreasd bee population if the distance goes 3000m far from natural agro-ecosytems. In overall, numerous syrphid flies and other Dipterrous insects was observed visiting buckwheat flowers. The result findings was found Similat to this finding of [29] that Syrphidae are efficient pollinators of many plants and can act as important predators in agricultural settings. Various flowering plant species have been shown to attract and sustain populations of aphidophagous in agricultural settings [30] [31]. Other, non-syrphid Diptera have been shown to be highly abundant and diverse within agricultural ecosystems and provide pollination services in these ecosystems [30] [32]**.** Table 7 shows the significant difference among treatments that the Coleopteran pollinators found more during peak flowering and got decreaing in 10% remaining to flower. Coleopteran found decreasing when the locations goes away from natural habitat.

**Table 7. Availability of Coleopteran pollinators (orderwise) in different time of flowering found in buckwheat field in different distances from natural habitat visually observed (No/m2/ 5sec) in Chitwan**, Nepal, 2012/13 and 2013/14.

| Treatments | Coleoptera | | | | | |
|---|---|---|---|---|---|---|
| | 2012/13 | | | 2013/14 | | |
| | 10% F | Peak F | 10% R | 10% F | Peak F | 10% R |
| < 500 m from natural ecosytems | 25.0[a] | 27.7[a] | 17.5[a] | 27.5[a] | 30.7[a] | 35.7[a] |
| 1000m | 25.8 [a] | 14.3 [b] | 14.3[a] | 21.5[a] | 20.3[b] | 20.3[b] |
| 2000m | 20.7 [ab] | 13.3[b] | 13.3[a] | 16.8[b] | 14.0[c] | 14.0[bc] |
| 3000m | 13.3[b] | 11.2[b] | 10.0[b] | 15.8[b] | 12.3[c] | 12.3[c] |
| Significance (0.05) | ** | ** | ** | ** | ** | ** |
| LSD | 8.285 | 5.954 | 7.489 | 8.285 | 5.954 | 7.489 |
| CV% | 33.76 | 24.53 | 37.96 | 33.76 | 24.53 | 37.96 |

**Table 8. Availability of Lepidopteron pollinators (orderwise) in different time of flowering found in buckwheat field in different distances from natural habitat visually observed (No/m2/ 5sec) in Chitwan, Nepal, 2012/13 and 2013/14.**

| Treatments | Lepidoptera | | | | | |
|---|---|---|---|---|---|---|
| | 2012/13 | | | 2013/14 | | |
| | 10% F | Peak F | 10% R | 10% F | Peak F | 10% R |
| < 500 m from natural ecosytems | 6.7[a] | 13.7[a] | 13.7[a] | 10.8[a] | 12.8[a] | 12.8[a] |
| 1000m | 5.5[ab] | 7.50[b] | 7.5[b] | 7.2[b] | 6.8[b] | 6.8[b] |
| 2000m | 3.5[b] | 7.3[bc] | 7.3[bc] | 5.8[b] | 8.8[bc] | 8.8[ab] |
| 3000m | 4.2[bc] | 5.7[c] | 5.7[c] | 4.5[b] | 6.7[c] | 6.7[c] |
| Significance (0.05) | ** | ** | ** | ** | ** | ** |
| LSD | 2.703 | 3.946 | 3.946 | 2.703 | 3.946 | 3.946 |
| CV% | 38.07 | 38.61 | 23.34 | 38.07 | 38.61 | 23.34 |

Lepidioperan population was significantly difference in popultaion when the field of visit goes far from natural habitat ( Table 8) .The visits was observed less in 10% flowering and 10% remaining to flower compared to peak flowering .This is due to greater availability of flowers during peak flowering. Generally, the decreasd bee population if the distance goes more than 500m from natural agroecosytems.

**Table 9. Effect of pollinators in the average production of rapeseed near to and far from natural habitat Megauli, Chitwan, Nepal, 2012/13 and 2013/14.**

| Treatments | Average grain yield ( kg/ha) | |
|---|---|---|
| | 2012/13 | 2013/14 |
| < 500 m from natural ecosytems | 812.4[a] | 758.2[a] |
| 1000m | 758.2[ab] | 608.5[b] |
| 2000m | 706.9[bc] | 395.0[c] |
| 3000m | 605.0[c] | 394.6[c] |
| Significance (0.05) | ** | ** |
| LSD | 87.26 | 87.26 |
| CV% | 10.8 | 10.8 |

The visits of pollinators found significantly effect on the production of rapeseed. If the place near to the natural habitat the higher was the production whereas the production was decreased when the field far from natural habitat.

## Discussion

The effect of bees and other insects on pollination showed significant difference in plant height, number of branch and yield attributes (seed per plant, 1000 grain weight and grain yield) of buckwheat compared to not pollination in all locations of study. Plant height found significantly higher in control. Branch number was also lower in most of the cases. This finding is in line with the result of [19] that the plant height of buckwheat with open pollination was 19.6% and bee pollination was 16.8% shorter, respectively than control plot. [21] showed that there was significantly lower plant height (49.71 cm at peak flowering) and branch number (2.72) in *Apis cerana* F. pollinated plot followed by *Apis mellifera* L. pollinated plots (50.33 cm at peak flowering , branch number 2.89) compared to open pollination, hand pollination and control plot. Buckwheat produced 21.7- 41.4% higher seed yield when intensively visited by pollinators compared with the seed yield obtained in isolated areas [33]. Honeybee pollination increased fruit set by 10 to 25 percent and fruit yield by 18 to 100 percent depending upon the cultivar [20]. Hand pollination produced seed set comparable to the open cages increases up to 43% [34].

In this experiment, the yield of buckwheat was not consistent with honeybee pollintion verified by a research done in Newyork that bee could not deliver pollen to reach pollen load over a short time [34]. The higher significant difference on the grain yield of buckwheat in pollinated treatments with control might be due to poor pollination on control plot. Some seed set in control treatments due to wind pollination as mentioned by [35] stated that seed set due to airborne pollen is the same (l %) as in pollen-free air [36]. [37] demonstrated that the highest 1000 grain weight was in caged condition with honeybee (25±0.8 gm) than open and control pollination plots is comparable to the findings. In this research, insignificant results obtained among locations might be due to predominance of natural pollinators in thes study sites. Hence, it is necessary to study the minimum bee population for satisfactory pollination which can be estimated by determining the relationship between bee activity and seed set. The increased yield near to natural habitat could justify since [38] [39] [40] and [41] showed within intensively managed agricultural landscapes, natural or semi-natural components provide important nesting and foraging sites for insect pollinators and proximity to such habitats has been found to increase pollinator species richness, crop visitation rates and pollination success. The grain yield related to abundance of pollinator near to forest might be due to the sufficient visits of pollinators there. [42] obtained buckwheat grain yield of 1,700 kg/ha at near to bee hive and only 500 kg/ha at away from the hive. [43] obtained 1,470 kg/ha grains adjacent to bee hive, but only 840 kg/ha away from the hive. [19] found that the increament in harvest index by 12.13% in bee pollination over control. This study shows the importance of considering the effects of landscape context on pollinator abundance that semi-natural habitats are factors that have enhanced bee populations and the pollination services bees provide in coffee [44], buckwheat [11], sweet cherry [45]and almond [46] production. Distance goes from forest did effect negatively on grain yield of buckwheat in this researh concurrence wirh the findings of [11] and [39] that they concluded distance to remnant vegetation is often negatively correlated with crop yields, as pollinator diversity and pollination services decline with greater isolation from natural or semi-natural habitats. However, [11] did highlights the requirement of multiple scale analysis for detecting these effects on the assemblage of local pollinators near to seminatural areas.

Good yield received in intensive agriculture practiced site reflects the species richness comparable to the findings of [47] that honeybee abundance on sweet cherry blossom showed a positive trend in relation to intensive fruit cultivation within 250 m and increased significantly with increasing intensive fruit cultivation within 1000 m.This finding confirms a positive relation between honeybee abundance by intensive agriculture [47]. However, there is no relation [48] and negative relations between honeybee abundance and intensive agriculture have also been detected [49][45] and wild pollination service to apple, strawberry, oil seed rape, buckwheat, field bean, pumpkin and sweet cherry decreases with increasing intensive agri- culture in the surrounding landscape [50] [47] [51] [52]. In this experiment the yield of buckwheat was not found consistent with honeybee pollination and hand pollination verified by a research done in Newyork that bee could not deliver pollen to reach pollen load over a short time [34] and also the genetic quality of buckwheat which benefits from pollen competition (for which simultaneous delivery of> 10 pollen grains is needed) [17].

Buckwheat field visited by a diverse kinds of insects dominantly wild and domesticated honeybees and flies, which are similar to a study done in buckwheat by [37] in Chitwan. He noticed the Rock bee, Little bee, European bee, Native bee, Hymenopteran wasps, Syrphid fly, Tabanid fly, March fly, Rice skipper, Legume pod borer, , Lady bird beetle, and Muscid fly.

In flies the dominant pollinator were Syrphid flies (*Eristalis cerealis*) as mentioned the predominant pollinators [53]. Buckwheat is visited by a diverse fauna, including Hymenoptera: honey bees (*Apis mellifera* L.), bumble bees, solitary bees and wasps; Diptera: Syrphidae and others; and Lepidoptera, and other orders [54] [55] [56] [57] Increased yield in semi natural, organic and intensive agriculture sites might be diverisy in the pollinators there. Because, four to five pollinator visits were necessary for good production in buckwheat [53] [17].

## Conclusions

The impact of pollinators on each system has resulting significantly increased yields compared to restricted pollination. There is relatively lower yield in intensive agriculture field, compared to seminatural and organic sites. There was significance difference on the plant height of buckwheat in pollination treatments compared to ocontrol. **T**he buckwheat plants freely visited by insects-pollinators during 10% remaining to flowering it was shorter by 16.4, 13.9, and 5.0 in semi-natural, 12.7, 12.3, 9.0 in orgaic and 16.7, 13.7 and 7.9 in intensive agriculute respectively than the plants isolated from pollinators. Insufficiently pollinated buckwheat during 10% remaining to flowering, differene in branches/plant in open pollination, bee pollination and hand pollination were lowered by 34.1, 32.5, +10.6 in semi-natural; 32.3, 40.0, 1.5 in organic and 18.8, 24.8, 12.8 in intensive agriculute compared to control. Seed per plant in open, bee and hand pollinated plots increased by 240- 463%. While considering 1000 grains weight, it was higher by 24.4- 59.6%. The yield was also increased in pollination treatments irrespective to sites ranges from 219.8 - 347 % compared to control (restricted pollination). Honeybees constituted the largest number insect visitors to the flowers during the time that pollen was available. Other insects included flower visiting were flies, *Syrphus spp. F.; houseflies, Musca domestica,* L.; beetle ladybird beetles, *Cocinella and few butterflies.* Integrating conservation and managed bees, is therefore crucial to sustain agriculture productions through optimized management of agronomic inputs and biodiversity-based ecosystem services such as enhancing agro- ecolological context for pollinators, reduce synthetic pesticides, plant hedgerow and flowering strips,employ drip irrigaition, provide nesting resources, conserve semi-natural areas ,enhance within field floral resources and farmland heterogeneity , organic farming, small crop fields, sow flowring crops increase crop diversity across landscape inter-temporary stagger crop floral activity as suggested by researhers [38] [39] [40] [58] [47]. Furthermore, beebread protein content correlates with land use suggests that landscape composition may impact on insect pollinator well-being [39]. Hence, the suitable hibernating places, availability of pollen and nectar source, less human intervention and less chemical pesticide resulted in the higher population of flowers visitors.

## Acknowledgements

My sincere thanks goes to the Dean Prof. Dr. Keshav Raj Adhikari and Asst. Dean (Academic), Prof. Dr. Gopal Bahadur K.C. of IAAS, Tribhuvan University, Nepal for their valuable suggestions and support. I express my gratitude to Mr. Milan Subedi, Assistant Professor of IAAS, TU, Nepal for his regular support and motivation. I am thankful to all the farmers' groups and key informants of the research areas without their help the research will not be completed.

## References

[1] T.R. Mulicha, "A situational context on buckwheat cultivation in Dolkha". *In: Proc.* Ecoprint vol 15, 2008. 46th *National Workshop on Research and Development on Buckwheat*. (eds.) Bimb, H.P. and B.K. Joshi. Kathmandu, Nepal, 48 p. 2008.

[2] V. Cawoy, J. Kinet and A. Jacquemart. "Morphology of nectaries and biology of nectar production in the distylous species *Fagopyrum esculentum*." *Annals of Botany,* vol. 102, pp. 675–684, 2008.

[3] B.O. Eggum, I. Kreft and B. Javornik. "Chemical composition and protein quality of buckwheat (*Fagopyrum esculentum Moench*)". *Plant Foods for Human Nutrition*, vol. 30, pp. 175-179, 1981.

[4] M.L Francischi, J.M. Salfado and R. F. Leitao, "Chemical, nutritional and technological characteristics of buckwheat and non-prolamine buckwheat flours in comparison of wheat flour". *Plant Foods and Human Nutrition*, vol 46, pp. 323–329, 1994.

[5] H. M. J. Jiang, P. K. Whelton, J. P. Mo, J. Y. Chen, M. C. Quian, P. S. Mo and G. Q. He," Oats and buckwheat intakes and cardiovascular disease risk factors in an ethnic minority in China", *American J. of Clinical Nutrition*, vol. 61, pp. 366–372, 1995.

[6] D. Treadwell, and P. Huang." Buckwheat: a cool-season cover crop for Florida vegetable systems". University of Florida IFAS Extension Document HS1135, 2008.

[7] MoAD, "Statistical information on Nepalese agriculture", Government of Nepal, Ministry of Agricultural Development. Agri-business Promotion and Statistics Division, Durbar, Kathmandu, Nepal. 151p. 2012.

[8] A. F. Yakimenko, "Buckwheat″, Kolos Moscow, 196 pp., 1982.

[9] D.R. Bhandari and S.K. Sah. "Cyme, flower cluster and seed setting dynamics on buckwheat and their relation to grain yield", *In*: Proceeding of National Workshop. Research and Development on Buckwheat. (eds.) Bimb, H.P. and B.K. Joshi. pp. 58-61, 2001.

[10] M.M. Singh. 2008. Foraging behavior of the Himalayan honeybee (*Apis cerana* F.) on flowers of buckwheat (*Fagopyrum esculentum*) and its impact onf grain quality and yield. *Ecoprint*, vol. 15, pp. 37-46.

[11] H.Taki, K. Okabe, S. Makino, Y. Yamaura and M. Sueyoshi. "Contribution of small insects to pollination of common buckwheat, a distylous crop. *Annals of Applied Botany*, vol. 155: 121–129, 2009.

[12] H.B. Lovell, *Honey Plants Manual* (Second Edition). A.I. Root Co. Medina, OH, USA. 64 p, 1977.

[13] E. F. Phillips and G. S. Demuth. "Beekeeping in the buckwheat in the buckwheat region. U.S Department of Agricultural Farmers". Bulletin vol.1216, No. 26, 1922.

[14] U. Partap, "Bee Flora of the Hindu KushHimalayas: Inventory and Management". International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal. 1997.

[15] V. Grigorenko,' Okratnosti posešèenija pèelami greèichi". *Pèelovodstvo, vol.* 10, pp 18-19, 1979.

[16] B. P. Rajbhandari," Buckwheat in the land of Everest", Himalayan College of Agricultural Sciences and Technology (HICAST), Kathmandu, Nepal, 132p, 2010.

[17] T. Bjorkman, "Pollen competition in buckwheat". XV International Botanical Congress, Yokohama, Japan pp. 289 *In*: Bjorkman, T. 1995a. The effect of pollen load and pollen tube competition in fertilization *success* and progeny performance in *Fagopyrum esculentum*. 1995.

[18] K. Bangyu, "T. Ken and K. Haiou. "Main Nectar Plants of the Himalayan Region of China." ICIMOD, 1996, Commissioned Studies (Unpublished).

[19] J. Racys and R. Montviliene. "Effect of bee-pollinators in buckwheat (Fagopyrum esculentum Moench.) crops", *Journal of Apicultural Science* , vol. 49 , no. 1, 47-51, 2001.

**[20] F.E. Moeller and C.F. Koval. Honeybee, "Pollination of Strawberries in Wisconsin resource report", Co-operative Extension, University of Wisconsin No. A 2549, 1973.**

[21] L. Aryal, "Effect of insect pollination on growth and yield of buckwheat (*Fagopyrum esculentum* Moench.) in Chitwan," *Nepal. Intern. J. of Res. (IJR),* vol.1, no. 4, pp 957-964, 2014.

[22] C.G. Campbell, Buckwheat. *Fagopyrum esculentum* Moench. Promoting the conservation and use of underutilized and neglected crops. International Plant Genetic Resources Institute, Rome, 1997.

[23] C. Carvell, W. R. Meek, R. F. Pywell, D. Goulson and M. Nowakowski "Comparing the efficacy of agri-environment schemes to enhance bumble bee abundance and diversity on arable field margins. *Journal of Applied Ecology*, vol. 44, pp. 29-40, 2007.

[24] S.G. Potts, J.C. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger and W.E. Kunin "Global pollinator declines: trends, impacts and drivers. Trends in Ecology and Evolution", vol. 25, pp. 345-353, 2010.

[25] J. Ollerton, R. Winfree and S. Tarrant, "How many flowering plants are pollinated by animals?" *Oikos* vol. 120: 321-326, 2011.

[26] FAO, "Protocol to detect and assess pollination deficits in crops: a handbook for its use. Food and Agriculture Organization Rome Italy", pp. 82, 2011.

[27] O. Ohnishi, "Search for the wild ancestor of buckwheat III. The wild ancestor of cultivated common buckwheat, and of tartary buckwheat". *Economic Botany*, vol. 52, pp. 123–133, 1998.

[28] R. Wang and C.A. Li. "Insect pollinators and yield of common buckwheat", pp. 25–28, *In:* Campbell C. , Przybylski R. [eds.], Proceedings of the 7th International Symposium on Buckwheat, Advances in Buckwheat Research, 12–14 Aug, 1998, Winnipeg, Manitoba, Canada.

[29] A. Ssymank, C.A. Kearns, T. Pape and F.C. Thompson. 2008, 'Pollinating flies (Diptera): a major contribution to plant diversity and agricultural production". *Biodiversity and Agriculture*, vol. 9, pp. 86–89.

[30] Horn D. 1981. "Effect of weedy backgrounds on colonization of collards by green peach aphid, *Myzus persicae*, and its major predators. Environmental Entomology", vol.10, pp 285–296.

[31] N. Miller, S. Al-Dobai, J. Legaspi and J. Sivinski. "Estimating attraction of Syrphidae (Diptera) to flowering plants with interception traps", *Biocontrol Science and Technology*, vol. 23, pp. 1040–1052, 2013.

[32] K.A. Orford, I.P Vaughan, J. Memmott, "The forgotten flies: the importance of non-syrphid Diptera as pollinators". Proceedings of the Royal Society B 282: 20142934, 2015.

[33] J. Racys and R. Montviliene . "Effect of bees pollinators in buckwheat (*Fagopyrum esculentum* Moench) crops" *Journal of apiculture science*, vol 49, no.1 , 2005.

[34] Bjorkman, T. and K. Pearson. 1995. "The Inefficiency of. Honeybees in the Pollination of Buckwheat Current Advances in Buckwheat Research" , pp 453 – 462, 1995.

[35] H.G. Marshall. "Isolation of self-fertile, homomorphic forms in buckwheat *Fagopyrum sagittatum Gilib". Crop. Sci.* **9**:651-653, 1969.

[36] H. Namai, "Pollination biology and seed multiplication method of buckwheat genetic resources". 3rd International Symposium on Buckwheat *Research*, Pulawy, Poland pp. 180-186, International Symposium on Buckwheat Committee, Pulawy. 1986.

[37] G. Dhakal, "Efficiency of *Apis mellifera* L. and *Apis cerana* F. for pollinating mustard and buckwheat", M. Sc. Thesis submitted to Institute of Agriculture and Animal Sciences, Rampur, Chitwan, Nepal, 59p. 2003.

[38] B.R. Blaauw and R. Isaacs, Wildflowers enhance pollinator services, available at http://dx.doi.org/10.6084/m9.figshare.966566. 2014.

[39] L.A. Garibaldi, I. Steffan-Dewenter , C. Kremen, J.M. Morales, R. Bommarco, S.A. Cunningham, L.G. Carvalheiro, N.P. Chacoff, J.H. Dudenh¨ offer, S.S. Greenleaf, A. Holzschuh, R. Isaacs, K.Krewenka, Y. Mandelik, M. Mayfield, L.A. Morandin, S.G. Potts, T.H. Ricketts, H. Szentgy¨orgyi, B.F. Viana, C. Westphal, R.Winfree and A.M. Klein,. Stability of pollination services decreases with isolation from natural areas despite honey bee visits. *Ecology Letters,* vol. 14, No. 10, pp. 1062–1072, 2011

[39] P. Donkersley, G. Rhodes, R.W. Pickup, K. C. Jones and K. Wilson . 2014. Honeybee nutrition is linked to landscape composition. *Ecology and Evolution,* vol. 4, no. 21, pp. 4195-4206.

[40] L. A., Garibaldi, I. Steffan-Dewenter, R. Winfree, M. A. Aizen, R. Bommarco, S. A. Cunningham and A. M. Klein. "Wild pollinators enhance fruit set of crops regardless of honey bee abundance", *Science,* vol. 339: pp. 1608–1611, 2013.

[41] T. H. Ricketts, J. Regetz, I. Steffan-Dewenter, S. A. Cunningham, C. Kremen, A. Bogdanski, B. Gemmill-Herren, S. S. Greenleaf, A. M. Klein, M. M. Mayfield, L. A. Morandin, A. Ochieng, and B. F. Viana. "Landscape effects on crop pollination services: are there general patterns?" *Ecology Letters* vol. 11: pp. 499-515, 2008.

[42] M. M. Glukhov. "Honey plants", Perer. Dop. Moskva, Gos. Izd-vo Selkhoz Litry, 512, p. 6, 1955

[43] G. V. Kopel'kievsky, "Pollination of buckwheat by bees". *Pchelovodstvo,* vol. 32, pp. 41 – 48, 1960.

[44] A. Klein, B. Vaissiere, J. Cane, I. Steffan-Dewenter, S. Cunningham, C. Kremen and T. Tscharntke, "Importance of pollinators in changing landscapes for world crops", *In: Proceedings of the Royal Society of London*. Kopel'kievskii, G.V. 1953. Timely locations of bees for pollinations of buckwheat and the honey crop. *Pchelovodstvo. Mosk.* Vol. **30, pp.** 28-31. 2006.

[45] A. Holzschuh, J. Dudenh€ offer and T. Tscharntke, Landscapes with wild bee habitats enhance pollination, fruit set and yield of sweet cherry" Conserv. 153, 101–107. 2012.

[46] A.M. Klein, C. Brittain, S.D. Hendrix, R. Thorp, N. Williams and C. Kremen. 'Wild pollination services to California almond rely onsemi-natural habitat. Journal of Applied Ecology, 49, 723–732", 2012.

[47] J. D. Petersen and B. A. Nault. "Landscape diversity moderates the effects of bee visitation frequency to ßowers on crop production". *Journal of Applied Ecology*, vol. 51, pp. 1347–1356, 2014.

[48] J.C. Watson, A.T. Wolf and J. S. Ascher. "Forested Landscapes Promote Richness and Abundance of Native Bees (Hymenoptera: Apoidea: Anthophila) in Wisconsin Apple Orchards", *Environmental Entomology,* vol. 40, no. 3, pp. 621–632, 2011.

[49] V.Le Feon, A. Schermann-Legionnet, Y. Delettre, S. Aviron, R. Billeter, R. Bugter, F. Hendrickx and F. Burel," Intensification of agriculture, landscape composition and wild bee communities: a large scale study in four European countries". *Agriculture Ecosystems & Environment*, vol. 137, pp. 143–150, 2010.

[50] I. Bartomeus, S.G. Potts, I. Steffan-Dewenter, B.E. Vaissière, M. Woyciechowski, K.M. Krewenka, T. Tscheulin, S.P.M. Roberts, H. Szentgyörgyi, C. Westphal, R. Bommarco," Contribution of insect pollinators to crop yield and quality varies with agricultural intensification". PeerJ 2:e328 2014, available at https://doi.org/10.7717/peerj 328, January 10, 2017.

[51] H. Grab., K. Poveda and G. M. Loeb, " Landscape simplification decreases wild bee pollination services to strawberry', *Agriculture, Ecosystems and Environment*, vol. 211, pp 51-56. 2015.

[52] M. Eeraerts, I. Meeus, S. V. D. Berge and G. Smagghe "Landscapes with High Intensive Fruit Cultivation Reduce Wild Pollinator Services to Sweet Cherry." *Agriculture Ecosystems & Environment*, vol. 239, pp. 342–348, 2017.

[53] H. Namai, "Pollination biology and reproductive ecology for improving genetics and breeding common buckwheat, Fagopyrum escu/entum (1). Fagopyrum 10: 23-46. 1990.

[54] C Hedtke, G Pritsch, "Qualitative and quantitative investigation of insects foraging on buckwheat (*Fagopyrum esculentum* Moench)". *Apidologie* , vol. 24, 476–477. 1993.

[55] S. Ogasahara, C. Kaji, M. Hagiwara and T. Matamo. "Pollination of common buckwheat (Fagopyrum esculentum Moench) as influenced by meteorological conditions". *In:* Matano T, Ujihara A (Eds) Current Advances in Buckwheat Research, Proceedings of the 6th International Symposium on Buckwheat, 24-29 August 1995, Shinshu, Shinshu University Press, Shinshu, Japan, pp. 475-481, 1995.

[56] Carreck, N.L. and I.H. Williams, "Food for insect pollinators on farmland: insect visits to flowers of annual seed mixtures". *Journal of Insect Conservation*, vol. 6, pp. 13–23. 2002.

[57] J.C. Lee and G.E. Heimpel. "Impact of flowering buckwheat on lepidopteran cabbage pests and their parasitoids at two spatial scales", *Biological Control*, vol. 34, pp. 290–301. 2005.

[58] R. Isaacs, and A.K. Kirk. "Pollination services provided to small and large highbush blueberry fields by wild and managed bees". *Journal of Applied Ecology. vol.* 47, pp. 841-849, 2010.