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(RESEARCH ARTICLE)

Impact of *Apis mellifera* L. 1758 (Hymenoptera, Apidae) foraging activities on fruit and seed yields on the Goudami variety of *Allium cepa* L. 1753 (Liliaceae) in Mokong (Mayo Tsanaga, Far North Region; Cameroon)

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Abstract

The aim of this study was to assess the impact of *Apis mellifera* foraging activities on fruit and seed yields on the Goudami variety of *Allium cepa* in Mokong (Far North Region of Cameroon). The different treatments were the umbels left to pollinate freely, the flowers visited exclusively once by *Ap. mellifera* and those not visited. The activities of *Ap. mellifera* were carried out on the free umbels in 2020 and 2021. The fruiting rate, average number of seeds per fruit, mass of 100 seeds and germination rate were recorded. The correlation between the rate of visits of *Ap. mellifera* and the rate of flowers bloomed was very highly significant positive ($r = 0.95$; $df = 52$; $p < 0.001$). *Apis mellifera* harvested a lot of nectar and very little pollen. The direct pollination efficiency of *Ap. mellifera* on fruiting rate, average number of seeds per fruit, percentage of normal seeds and germination rate was 69.49%, 24.33%, 65.57%, 33.57% respectively. A single visit of *Ap. mellifera* significantly increased the fruiting rate, average number of seeds per fruit, percentage normal seeds and germination rate of this variety of onion

Keywords: *Apis mellifera*; Goudami; Mokong; Pollination; Yields

1. Introduction

In Africa, and particularly in sub-Saharan African countries, fruit and seed production is characterized by low yields [1]. In general, this low yield is the consequence of the lack or insufficient number of pollinators during the flowering period [2]. Pollination impacts on the quantity and quality of a large proportion of entomophilic plants [3]. Onion (*Allium cepa*) is a monocotyledonous, allogamous, entomophilous plant [4]. It is generally consumed as a condiment, in salads for its therapeutic and nutritional properties and cosmetic uses [5]. The crop cycle of onion is biennial for seed production and annual for bulb production [4]. Protandry does not allow its flowers to self-pollinate [2]. The action of wind and gravity is almost zero on its pollination [6], because the pollen is the sticky type [7]. Obtaining good quality seeds of onion necessarily involves entomophilic pollination [7].

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In the literature, there is little information on relationships between *Al. cepa* and insects. Some works done on the relationships between this plant and insects are those made by [8], [2], [9] [6]. The results of these works showed that insects improve seed and fruit yields of *Al*. *cepa*.

In Cameroon, *Al*. *cepa* seeds are not produced in quantity and quality despite the fact that insect pollinators are known to improve fruit and seed yields. Any work was done on relations between *Ap. mellifera* and the most cultivated varieties of *Al. cepa*. Furthermore, although known as the major pollinator of this plant, the pollination efficiency of *Ap*. *mellifera* is not evaluated in this locality. The objective of this research is to evaluate the pollination efficiency of *Ap*. *mellifera* in the fruit and seed yields of Goudami.

2. Material and methods

The investigations were carried out in Mokong, a village in the subdivision of Mokolo, Division of Mayo-Tsanaga, Far North Region of Cameroon (Figure1). The plot was an area 8 m long and 4.50 m wide (Figure 2A) with geographical coordinates point: Latitude 10°58.69'N, Longitude 14°02.961'E and Altitude 517 m.

The plant material was represented by Goudami bulbs provided by a planter in Mokong and identified at IRAD of Maroua (Figure 2B).

The plot was a ploughed. Twelve 1.5 m2 sub-plots were formed. The onion bulbs were planted in rows, with one bulb per bunch. The distance between rows was 50 cm and between bunches was 20 cm. The plot was watered every three days. From planting to the opening of the first flower, weeding was carried out regularly with a hoe. From the opening of the first flower to the maturity of the seeds, the weeds were regularly pulled out by hand.

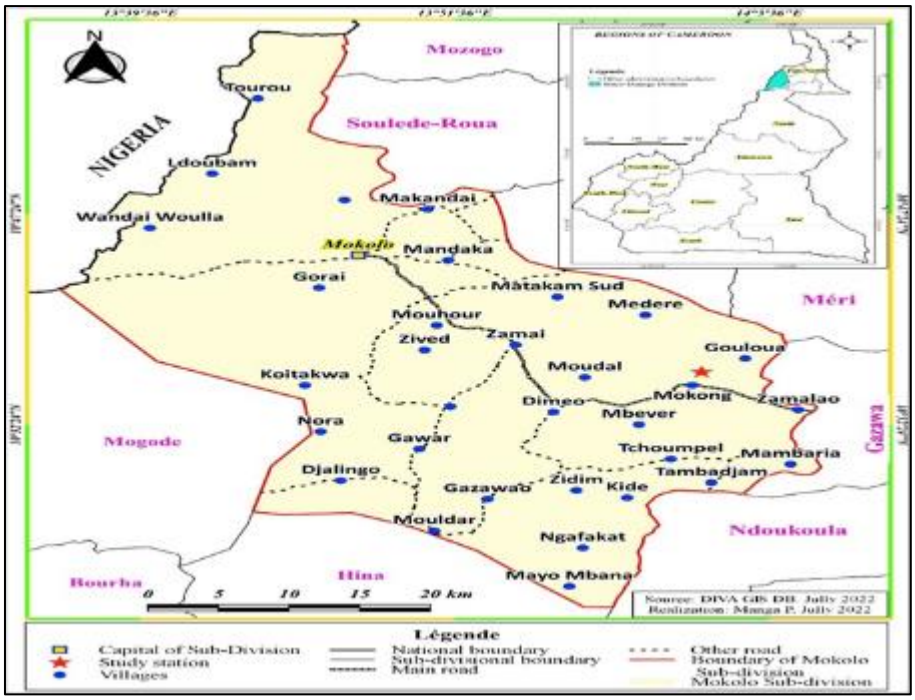

Figure 1 Map of the subdivision of Mokolo showing study station

The animal material was represented by all insects that visited the Goudami flowers and those that were in the vicinity of the experimental plot.

(A)

(B)

Figure 2 Partial view of the experimental plot (A) and bulbs of Goudami (B) in Mokong in 2020

At the flower bud stage, 40 umbels were isolated using gauze bags. During the flowering period, the activities of *Apis mellifera* were carried out on the treatment 1 and treatment 1' of 2020 and 2021 constituted of 40 free umbels each. The observations were made every 2 days according to six daily time slots: 7A.M. – 8 A.M., 9 A.M. – 10A.M., 11A.M. – 12A.M., 1P.M. – 2P.M., 3P.M. – 4P.M. and 5P.M. – 6P.M. For each time slot, one pass was made on each umbel. At each pass, *Ap. mellifera* found on the flowers were counted. The temperature and hygrometry of the study station were recorded every 30 minutes from 7A.M. to 6P.M. using a Technoline portable thermo-hygrometer (WS9119) installed in the shade.

Each isolated umbel was reopened and closed again after a single visit from *Ap. mellifera* between 11 A.M. and 12 P.M., the time slot corresponding to the peak of *Ap. mellifera* activity in Mokong. The evaluation of the direct pollination efficiency of *Ap*. *mellifera* was based on the comparison of the yields of the fruit and seed of the following treatments of each year:

- treatments 2 and 2' in 2020 and 2021, made by flowers (from 40 umbels) each which were not visited;
- treatments 3 and 3' in 2020 and 2021, made by flowers each of the same umbels of treatments 2 and 2' respectively, visited exclusively by *Ap*. *mellifera* and marked.

Ten days after the last labelled umbel has bloomed, the number of fruits per umbel of treatments 2, 2', 3 and 3' was counted. The direct pollination efficiency of *Ap*. *mellifera* in the fruiting rate (Dpefr) was calculated according to the following formula: Dpefr = $\frac{(frT3-frT2)}{frT3}$ x100 , where frT2 and frT3 were respectively the fruiting rates of treatments 2 and 3 [10].

At maturity, the number of seeds per fruit, number of normal seeds of treatments 2, 2', 3 and 3' were counted. The average mass of 100 seeds was known after weighing by using a digital scale.

The direct pollination efficiency of *Ap*. *mellifera* in the average seeds per fruit (Dpesf) was calculated according to the following formula: Dpesf = $\frac{(sfT3-sfT2)}{sfT3}$x100, where sfT2 and sfT3 were the average number of seeds per fruit of treatments 2 and 3 respectivly.

The direct pollination efficiency of *Ap*. *mellifera* in the percentage of normal seeds (Dpens) was calculated according to the following formula: Dpens = $\frac{(pnsT3-pnsT2)}{pnsT3}$x100, where pnsT2 and pnsT3 were the percentage of the normal seeds of treatments 2 and 3 respectivly.

The direct pollination efficiency of *Ap*. *mellifera* in the average mass of 100 seeds (Dpems) was calculated according to the following formula: Dpems = $\frac{(mT3-mT2)}{mT3}$ x100, where mT2 and mT3 were the average mass of 100 seeds of treatments 2 and 3 respectivly.

One hundred seeds were collected and spread in a Petri dish with a cotton lining soaked with water [11]. Each day, the number of germinated seeds was counted and they were removed from the dish. The cotton lining of the Petri dish was moistened whenever dryness was noted. The direct pollination efficiency of *Ap*. *mellifera* in the germination rate

(Dpegr) was calculated according to the following formula: Dpegr = $\frac{(grT3-grT2)}{grT3}$ x100, where grT2 and grT3 were the germination rate of treatments 2 and 3 respectivly.

3. Results and discussion

Apis mellifera visited Goudami umbels between 7A.M. and 6P.M. with the peak of activity located in the 11A.M. -12A.M. time slot for both years (Table 1).

The peak of activity would correspond to the maximum availability of nectar and/or pollen in the flowers [12]. These results are similar to [13]. In Maroua, the peak activity of *Ap. mellifera* on *Al. cepa* was between 9A.M. and 10A.M [9]. The variation of the peak activity would be explained by the variation of weather conditions which changed the maximum availability of flowers product. According to [2], the peak activity of *Ap. mellifera* varies to the availability of floral products in the flowers to be exploited.

Table 1 Rhythm of visits of *Apis mellifera* on the Goudami according daily time frames

Years	**Visits**	**Daily time frames (hours)**						
		7-8	**9-10**	**11-12**	**13-14**	**15-16**	**17-18**	**Total**
2020	Number	1	26	86 *	67	33	4	217
	%	0.46	11.98	39.63	30.88	15.21	1.84	100
2021	Number	6	85	104 *	55	25	3	278
	%	2.16	30.58	37.41	19.78	9.00	1.08	100
Cumulate of two years	Number	7	111	190 *	122	58	7	495
	%	1.41	22.42	38.38	24.65	11.72	1.41	100

3.1. Activity peak

Figure 3A and 3B show that the rate of *Ap. mellifera* visits increases with the number of flowers opened on Goudami umbels. Statistical analyses revealed a very highly significant positive correlation in 2020 ($p < 0.001$) and 2021 ($p < 0.001$) between the number of *Ap. mellifera* visits and the number of bloomed flowers. The attractiveness of Goudami would be fluctuated by the number of the opened flowers. In fact, *Ap. mellifera* have the ability to recruit a high number of foragers to exploit an interesting source of food and the number of foragers required depends on the number of flowers available [2]. These results are according to [14] on *Agave sisalana* in Ngaoundéré.

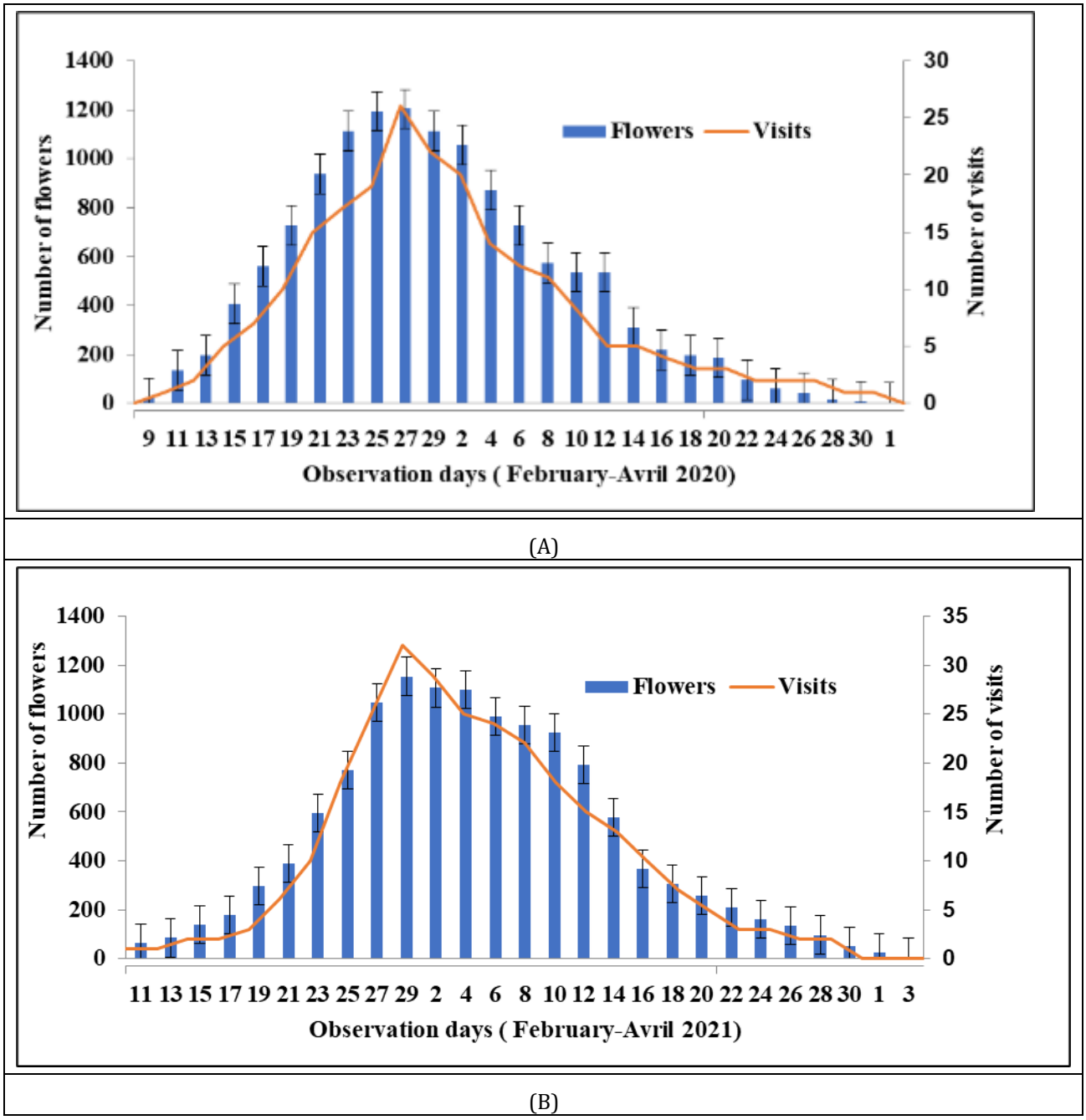

Figure 3 Rhythm of visits of *Apis mellifera* depending of opened flowers in 2020 (A) and 2021(B)

Observations on Goudami flowers in 2020 revealed those 217 visits including 185 (85.25%) visits and 32 (14.75%) visits to collect respectively the nectar and pollen. Out of 278 visits to Goudami umbels in 2021, *Ap. mellifera* used 233 (83.81%) visits and 45 (16.19%) visits to collect nectar and pollen respectively. This preference of *Ap. mellifera* for the nectar could be attributed to its availability. In addition, the nectar is sweeter than pollen [15]. The nectar of onion is produced in large quantities and is easily digested [2]. These results are in agreement with observations made by [9] (84.14% nectar visits, 6.18% pollen visits and 9.67% nectar and pollen visits).

Figure 4A and 3B represent the rate of visits of *Ap. mellifera* on Goudami flowers as a function of the daily variation of hygrometry and temperature during flowering in 2020 and 2021 respectively. In 2020, the correlation between the number of visits and the temperature was significant ($p < 0.05$) and the correlation between the number of visits and hygrometry was significant ($p < 0.05$).

In 2021, the correlation between the number of visits and the temperature was non - significant ($p > 0.05$) and the correlation between the number of visits and hygrometry was non- significant ($p > 0.05$). The number of *Ap. mellifera*

visits would be influenced by the temperature and hygrometry. In fact, the increase of temperature follows by the diminution of the hygrometry and then the nectar become sweeter and more attractive. According to [15], the attractiveness of flower product is affected by its concentration in sugar

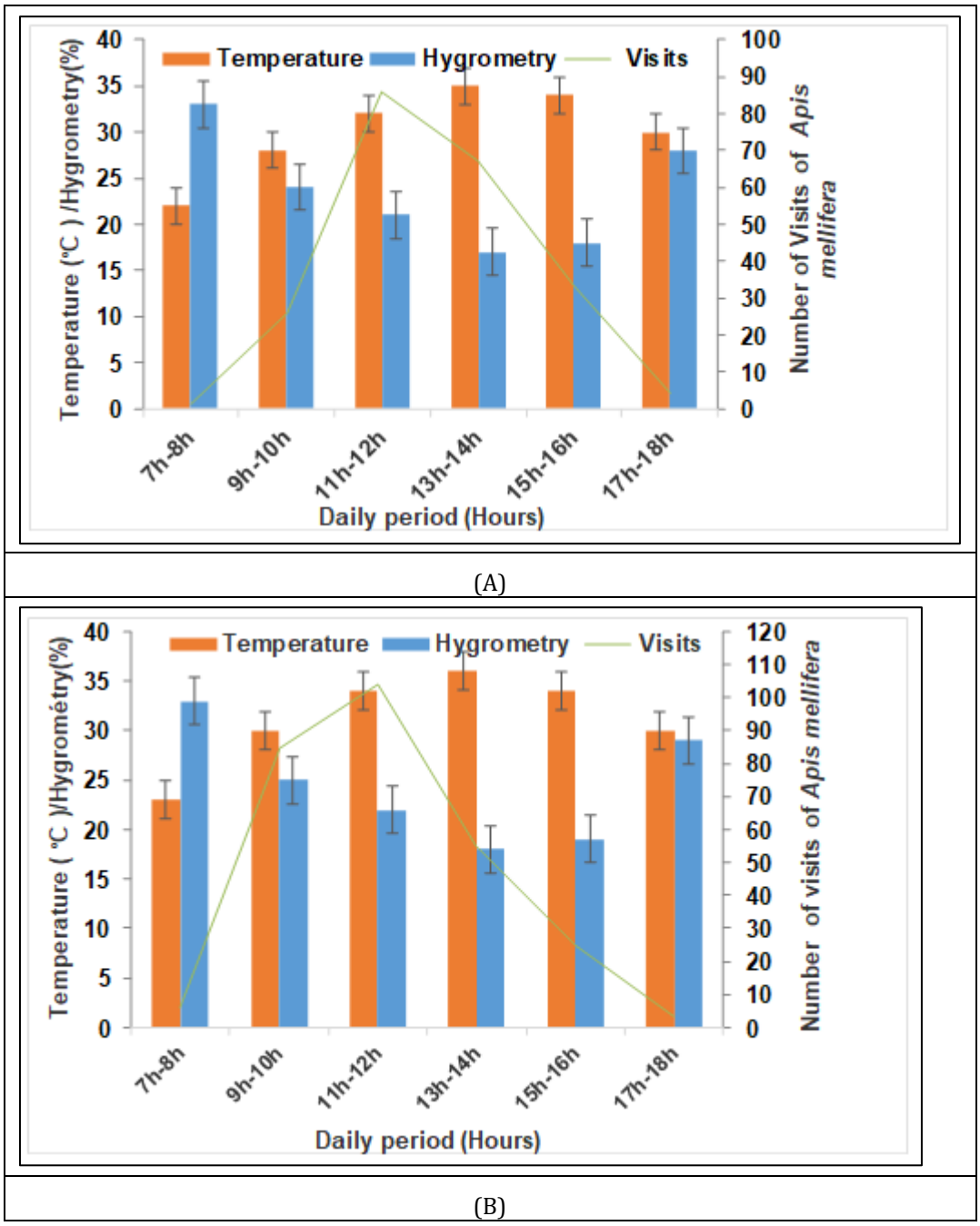

Figure 4 Daily rhythm of visits of *Apis mellifera* on the umbels of Goudami according to temperature and hygrometry in 2020 (A) and 2021(B)

In 2020, the fruiting rate of treatment 2 (flowers not visited) and treatment 3 (flowers visited exclusively by *Ap. mellifera*) were 21.63% and 78.46% respectively **(**Table 2). In 2021, the fruiting rate of treatment 2' (flowers not visited) and treatment 3' (flowers visited exclusively by *Ap. mellifera*) were 22.59% and 67.53% respectively **(**Table 2). The difference was very highly significant between the treatments 2 and 3 ($p < 0.001$) and between the treatments 2' and 3' ($p < 0.001$). The foraging activity of the workers would shake the flowers by facilitating the optimal release of pollen for the occupation of the stigma. According to [2], the transfer of pollen grains from the stamens to the stigma involves vectors such as insects and that the absence of pollination or failed pollination results in the absence of fruits. These results are in agreement with the works of [16] *on Glycine max* L. The direct pollination efficiency of *Ap. mellifera* in the fruiting rate (Dpefr) of Goudami was 72.43% in 2020 and 66.55% in 2021. The difference was non- significant between

these direct pollination efficiencies ($p > 0.05$). The direct pollination efficiency of *Ap. mellifera* in the fruiting rate for the two cumulative periods was 69.49%. This result shows that one visit of *Ap. mellifera* have a significative growing on fruiting rate. The lack of pollination reduces yields of entomophilous crops [6].

In 2020, the average number seeds per fruit of treatments 2 and 3 were 2.43 ($n = 400$; $s = 1.78$) and 3.47($n = 204$; $s = 1.41$) respectively **(**Table 2). In 2021, the average number seeds per fruit of treatments 2' and 3' were 2.35 ($n = 400$; $s = 1.05$) and 2.89 ($n = 104$; $s = 1.13$) respectively **(**Table 2). The difference was very highly significant between treatments 2 and 3 ($p < 0.001$) and between treatments 2' and 3' ($p < 0.001$). *Apis mellifera* activity would increase the number of seeds per fruit of Goudami through pollination. Indeed, *Ap. mellifera* frequently transported pollen from flower to flower using the fur, legs and mouthparts and would thus play a positive role in geitonogamy and xenogamy [17]. The number of seeds per fruit resulted of flowers visited by insects is highly greater than those resulted of flowers non-visited [2], [18]. The direct pollination efficiency of *Ap*. *mellifera* on the number average of seeds per fruit (Dpesf) of Goudami in 2020 and 2021 was 29.97% and 18.69% respectively. The difference between these direct pollination efficiencies was non-significant ($p > 0.05$). The direct pollination efficiency of *Ap*. *mellifera* in the number average of seeds per fruit of Goudami for two cumulative years was 24.33%. This result shows that a single visit of *Ap. mellifera* has a significative growing on the number average of seeds per fruit. [9] obtained similar result.

In 2020, the percentage of normal seeds of treatments 2 and 3 were 19.69% and 55.87 % respectively **(**Table 2). In 2021, the percentage of normal seeds of treatments 2' and 3' were 17.43% and 51.83% respectively **(**Table 2). The difference was very highly significant between treatments 2 and 3 ($p < 0.001$) and between treatments 2' and 3' ($p < 0.001$). This difference could be explained that one visit *of Ap. mellifera* on Goudami flowers eased the pollination which increased the percentage of normal seeds. During the harvest of flower products, the workers regularly come into contact with stigma and anthers and boost the possibility to fertilize a lot of ovules, consequently the percentage of normal seeds [2]. The direct pollination efficiency of *Ap*. *mellifera* in the percentage normal seeds (Dpens) was 64.76% and 66.37% in 2020 and 2021 respectively. The difference between these direct pollination efficiencies was non-significant ($p > 0.05$). The direct pollination efficiency of *Ap*. *mellifera* in the percentage of normal seeds for two cumulate years was 65.57%. Through its visits, *Ap. mellifera* could increase the percentage of normal seeds. [19] obtained the similar result on *Arachis hypogaea*.

In 2020, the average mass of 100 seeds of treatments 2 and 3 were 0.28g ($n = 9$; $s = 0.01$) and 0.29g ($n = 7$; $s = 0.01$) respectively **(**Table 2). In 2021, the average mass of 100 seeds of treatments 2' and 3' were 0.28g ($n = 9$; $s = 0.01$) and 0.29g ($n = 3$; $s = 0.02$) respectively **(**Table 2). The difference was non-significant between the treatments 2 and 3 ($p > 0.05$) than treatments 2' and 3' ($p > 0.05$).

In 2020, the germination rate of treatments 2 and 3 were 19.25% and 28.75% respectively **(**Table 2). In 2021, the germination rate of treatments 2' and 3' were 18.67% and 28.33% respectively **(**Table 2). The difference was significant between treatments 2 and 3 ($p < 0.05$) than treatment 2' and 3' ($p < 0.05$). The significant difference between the germination rate of treatments visited exclusively by *Ap. mellifera* and the treatments not visited could be attributed to the action of the honeybee on pollination. In fact, the foragers frequently transported pollen from flower to flower and thus play a positive role in geitonogamy and xenogamy [17]. These large amounts of pollen contact the stigma with opportunities for pollen tube selection in the style before fertilizing the ovules. The germinative power of seeds from umbels left to free pollination is higher than umbels isolated from insect visits [7]. The direct pollination efficiency of *Ap*. *mellifera* in the germination rate (Dpegr) in 2020 and 2021 was 33.04% and 34.10% respectively. The difference between these direct pollination efficiencies was non- significant ($p > 0.05$). For both years combined, the direct pollination efficiency of *Ap*. *mellifera* in germination rate was 33.57%.

Table 2 Fruiting rate, average number of seeds by fruit, normal seeds rate, average mass of 100 seeds and germination rate of treatments 1, 1', 2 and 2' of Goudami in Mokong

T	Parameters studied														
	Fruiting rate			Seeds per fruit				Number of normal seeds		Average mass of 100 seeds			Germination rate		
	Nfs	Nff	Fr (%)	Nf	Ns	m	s	Nns	Pns (%)	n	m(g)	s	Nss	Ngs	Gr (%)
2	11677	2526	21.63	400	970	2.43	1.78	191	19.69	9	0.28	0.01	400	77	19.25
3	260	204	78.46	204	707	3.47	1.41	395	55.87	7	0.29	0.01	400	115	28.75
2'	11332	2560	22.59	400	941	2.35	1.05	164	17.43	9	0.28	0.01	300	56	18.67
3'	154	104	67.53	104	301	2.89	1.13	156	51.83	3	0.29	0.02	300	85	28.33

T = treatment; 2 and 3 = in 2020; 2' and 3' = in 2021; Nfs = number of flowers studied; Nff: number of fruits formed; Fr = fruiting rate; Nf = number of fruits; Ns = number of seeds; m = medium; s = standard deviation; Nns = number of normal seeds; Pns = Percentage of normal seeds; Nss = number of seeds sowed; n = size of sample, Ngs = Number of germinated seeds; Tr = germination rate.

4. Conclusion

In Mokong, *Apis mellifera* collected nectar and pollen from the flowers of the Goudami onion variety. According to the number of visits devoted to nectar or pollen collection, *Allium cepa* variety of Goudami can be classified between highly nectariferous and lowly polliniferous bee plants. A single visit of *Ap. mellifera* significantly increased the fruiting rate, average number of seeds per fruit, percentage normal seeds and germination rate of this variety of onion. To boost onion fruit and seed yields, it is advisable to set up colonies of *Ap. mellifera* near fields.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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