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Studies on impact of different pollinators in pumpkin (*Cucurbita moschata* Duch. ex Poir)

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Abstract

A research investigation was conducted to study the impact of different pollinators in pumpkin (*Cucurbita moschata* Duch. ex Poir). The experiment was laid out in Randomized Block Design (RBD) with 4 replication and 6 treatments *viz*., *Apis mellifera*, *Apis cerana*, *Tetragonula iridipennis*, *Lepidotrigona arcifera* including open pollinated and control. The foraging rate and foraging speed was found to be highest in *Apis cerana* as compared to other pollinators. From pollination efficiency index (PEI) of the pollinators, it revealed that *Apis cerana* had the highest pollination efficiency and least efficiency was found to be *T. iridipennis* and *L. arcifera*. Experimental findings revealed that the bee pollinated plots were much higher in fruit setting as compared to natural pollination. T_2 (caged with *A cerana*) had the maximum percent fruit (77.50%), fruit length (20.17 cm), healthy fruit (89.73%), number of seeds (162), weight of 100 seeds (15.63 g) and fruit weight (1.71 kg). However, crooked fruit% was recorded to be highest in T_5 *i.e*., open pollination. The *A. cerana* bee pollinated treatments resulted in numerous increases in all parameters over control plots.

Keywords: *Cucurbita moschata*, treatments, pollination, pollinators, foraging activity, percent increase

Introduction

Pumpkin (*Cucurbita moschata* Duch. ex Poir.) is an annual summer vegetable. The name ‘pumpkin’ is derived from the Greek word ‘Pepon’ which is used for long melon (Bahadur and Singh, 2014) [2]. The flowers of pumpkin are considered to have higher nutritive value than the fruits (Rana, 2014) [26]. Pumpkin fruits are rich source of minerals and vitamins, particularly vitamin A while the seeds are rich in protein (40.27%), crude fibre (34.59%) and ash (44.5%).

Pollination is the process of pollen transfer from the anther of one flower to the stigma of same or another flower which can be either self-pollination or cross-pollination. Pollinators provide a vital ecological service for agricultural crop production systems and in natural systems by maintaining flowering plant communities (Potts *et al.*, 2010) [23]. Very often insects are viewed as scourge of agriculture yet, insects particularly bees are crucial for pollination in many crops to set fruit (Klein *et al.*, 2007) [13]. Farmers rely on pollinators directly or indirectly for approximately 30% of the world’s food production (Kremen *et al.*, 2002) [14], where pollinators provide essential service in 8-9% of the global total crop production contributing over $190 billion to the global economy (Gallai *et al.*, 2009) [7]. The role of pollinators is well appreciated in cross pollination of important of agro-horticultural crops. It improves uniform crops and quality of fruits by insect pollination. Among the cross-pollinated flowers, about 85% are dependent on insect pollination. The purpose of bees in increasing crop yield is well acknowledged and accounts for about 80% of pollination. Among honeybee, different species have proven to be production pollinators *A. florea*, *A. cerana*, *A. dorsata* and *T. iridipennis* (stingless bees) are also an important pollinator found all over the world (Zych *et al.*, 2013) [32].

Nagaland, offering opportunities for both sustainable livelihoods and ecological benefits. It is considered an ideal region for beekeeping due to its rich biodiversity and favourable climatic conditions. Therefore, taking into account its positive aspects and considering the potential of pollinators in pumpkin, the present studies “Studies on Impact of different pollinators in pumpkin (*Cucurbita moschata* Duch. ex Poir)” were undertaken under protected conditions.

Materials and Methods

The investigation was carried out at the experimental cum research farm, Department of Entomology, School of Agricultural Sciences, Nagaland University, Medziphema campus during the year 2022 and 2023.

The experimental site was located at 23° 45' 43'' N latitude and 93° 53' 04'' E longitudes at an altitude of 310m above mean sea level. All agronomical practices for crop were followed as per good agricultural practices for crop raising. One colony each for different pollinators was introduced when 10% of the plants started blooming. The pollination index was calculated as per the method propounded by Bohart and Nye (1960).

Pollination efficiency = RA(FR+FS+LPG)

Where,

RA = Relative abundance

FR = Foraging rate

FS = Foraging speed

LPG = Loosen pollen grains

The impact of different pollinators was evaluated using different parameters. Ten plants from each treatment *viz*., *Apis mellifera*, *Apis cerana*, *Tetragonula iridipennis*, *Lepidotrigona arcifera* including open pollinated and control were selected and tagged randomly. The fruit set on these plants were recorded and total yield was calculated. In the same way percent and crooked fruit was also calculated from the total fruit set. The fruit diameter, length and weight were measured with the scale, digital Vernier caliper and digital weighing balance, respectively. For counting the number of seeds, 10 fruits from each treatment were selected, seeds were removed and kept separately in water for 24 hr. After washing the seeds, these were dried in temperature-controlled chambers for 24 hr, and then counted. Weight of 100 dried seeds from each treatment was also observed. The percent increase in fruit set, healthy fruits, decrease in crooked, fruits diameter, weight, number of seeds, weight of 100 seeds was also calculated. The data were statistically analysed with suitable transformation in RBD design as per Gomez and Gomez (1984).

Results and Discussion

The experimental result under open condition obtained during the investigation period (2022 and 2023) revealed that the highest mean relative abundance of insect pollinator was recorded in *A. mellifera* with 11.05 followed by *A. cerana* with 7.73. Whereas, the least mean relative abundance of insect pollinator was recorded in *Musca sp*. with 1.33 and 0.79 during 2022 and 2023, respectively. Pateel and Sattagi (2007) [20] also observed that the most frequent insect pollinators visiting Rabi cucumber flowers were *A. florea*, *A. cerana* and *A. dorsata* with abundance of 8.03, 6.03 and 3.43 bees/m²/5 minutes, respectively. The highest relative abundance of insect visitor on pumpkin under closed condition was observed with *A. mellifera* on all days of observations for both years of experiment (2022 and 2023). The overall mean data was observed maximum in *A. mellifera* with 20.91 in 2022 and 20.32 in 2023 and the minimum was recorded in *L. arcifera* with 11.20 and 11.91 during 2022 and 2023, respectively. The results are in accordance with Gahlawat *et al*. (2002) [8] who also reported that the most abundant insect pollinator on cucumber flowers was *A. mellifera* with 0.08, 2.58, 1.75 and 0.83 bee/m²/5 minutes at 0600, 0800, 1000 and 1200 h of the day, respectively. Nicodemo *et al*., (2009) also reported that the most frequent insect visitors on the flowers of pumpkin plant were *A. mellifera*, *Diabrotica speciosa* (Germ.) and *Trigona spinipes* (fab.) where *A. mellifera* accounted for 73.4 percent and *T. spinipes* represented 26.6 percent of the total bee visitors. Under open conditions, the foraging rate recorded was highest in *A. mellifera* with 4.83 flowers/minute during 2022 and 9.15 flowers/minute during 2023. Whereas, the lowest rate was recorded in *Musca sp*. with 0.87 flowers/minute and 1.70 flowers/minute during 2022 and 2023 respectively. Carillo *et al*. (2018) [3] observed that collection of pollen by *A. mellifera* was higher in the early morning hours and declined during the afternoon time. On contrary, Pernal and Currie (2010) [21] recorded that mean foraging rate during the afternoon hours (36.02 foragers/min) were higher than the morning hours (17.66 foragers/min). The mean foraging speed under open conditions revealed that the maximum time spent/flower in sec was in *A. mellifera* with a foraging speed of 19.93 secs and 20.83 secs during 2022 and 2023, respectively. On the contrary, the minimum time spent/flower in sec was in *Musca sp*. with 1.30 sec in 2022 and 4.64 sec in 2023. However, the present findings are in conformity with Ahmad *et al*., (2017) [1] who observed that *A. mellifera* spent 8.44 seconds per apple flower at 0900 h and 10.05 second per flower at 1200 h. Girish (1981) [9] also observed that *A. cerana* and *A. dorsata* spent 34 and 38 seconds per flower, respectively on *Cucurbita pepo* L. The number of loose pollen grains attached to the body was more or less same for the honeybees. The pooled data revealed that highest loose pollen grains were recorded in *A. cerana* (1804.83) on their body followed by *T. iridipennis* (1736.00), *A. mellifera* (1734.00) and L. arcifera carried about 1696.67 loose number of pollen grains on their body. The results are in agreement with the findings of Jamir (2021) who also recorded that *T. iridipennis* carry a mean of pollen grain of (1618), *A. mellifera* (2015) and *T. laeviceps* (1405). Similar observations were also recorded by Rani (2017) on summer squash (*Cucurbita pepo* L.) who observed that the number of loose pollen grains sticking to the body of pollinators was highest in *A. cerana* (1977) followed by *A. mellifera* (1650), *A. dorsata* (1600), *A. florea* (1480). Canto-Aguilar and Parra-Tabla (2000) [4] reported that on an average *A. mellifera*, entrapped 1282.9 pollen grain and transferred 253.4 pollen grains on to the stigma of female flower. It was observed that the activity of different pollinators on pumpkin crops started at 0600 h with its maximum activity at 1000 h and started decreasing by 1400 h and was minimum at 1600 h. In both the years of experimental trials during 2022 and 2023, the pollination efficiency index of the pollinators showed that *A. cerana* had the highest pollination efficiency of 30.00 PEI and 32.00 PEI respectively, which characterized them as true pollinators of pumpkin and the least efficiency was observed in *T. iridipennis* with 7 PEI during 2022 and *L. arcifera* with 6 PEI during 2023. In contrast to present finding, Singh and Mall (2020) [27] also documented the maximum pollination index in *A. mellifera* on cucumber. Rao and Suryanarayana (1988) [25] observed that the principal pollinating insect of watermelon was *A. cerana* (87% of bee population) and observed to be more efficient pollinator than *A. florea* and *Trigona irridipennis* which is in agreement with the present findings. The highest fruit set was recorded in *A. cerana* (77.50%), followed by *A. mellifera* (64.00%), *L. arcifera* (60.00%), open pollination (58.00%), *T. iridipennis* (56.00%) and control (48.00%). (Table). Likewise, the highest healthy fruit (89.73%) and less crooked fruit (10.26%) was recorded in *A. cerana* (T2). The highest fruit length (20.17 cm), fruit diameter (46.41 cm), fruit weight (1.71 kg) was recorded in (T2) *A. cerana*. Whereas, in open pollination with (50.00%) healthy fruit and crooked fruit (21.04%). The lowest fruit length (14.50 cm), fruit diameter (37.16 cm), fruit weight (1.12 kg) was recorded in T6 *i.e*. control. Dorjay *et al.* (2017) [6] reported maximum fruit set of 87.14% under bee pollination condition and 65.21% under open pollination condition respectively which is almost similar to the present finding. Girish (1981) [9] also observed that plots of *C. pepo* caged without bees failed to set any fruit, compared to 46.00 percent fruit set in plants caged with *A. cerana* and 57.00 percent fruit set in plots which were not caged. The lowest percent healthy fruit and maximum crooked fruits observed in open pollination condition maybe due to the fact that less pollinators have visited the flowers resulting in the adequate pollination leading to the formation of malformed fruits (Hodges and Baxendale, 1995) [10]. Mattu and Nirala (2013) [16] who also reported that weight, length, breadth, volume and number of seeds per fruit developed were significantly maximum in honeybee pollinated flowers. Bee pollinated plot results in higher fruit size and weigh as compared to open pollinated and hand pollinated plots (Prakash *et al*., 2004, Santos *et al*., 2008 and Thakur and Rana, 2008) [22, 28, 30]. Plots netted with bees resulted in increased number of fruits/m^2 and healthier and higher quality fruits than other plots had been reported by several other researchers such as Nogueira and Calmona (1993) [19] and Walters and Taylor (2006) [31]. The increased number of seeds per fruit with *A. cerana* could be due to the fact that sufficient amount of pollen grains was deposited on the flowers by the honeybees in caged conditions as compared to open pollination resulting in adequate pollination (Prakash *et al.,* 2004) [22]. The most important pollinators of *Cucurbita spp.*, are honeybees and as the number of bee visits to *Cucurbita* flowers increases, the fruit set and seed number generally increased (Delaplane and Mayer, 2000) [5]. Bee visitation rates strongly influenced fruit set and seed production (Mayfeld *et al*. 2001, Karron *et al*. 2009) [17, 11]. Mattu and Nirala (2013) [16] also observed that honeybee pollinated flowers significantly influenced the number of seeds per fruit. The results of the present studies entitled, "Studies on impact of different pollinators in pumpkin (*Cucurbita moschata* Duch. ex Poir)" under protected conditions revealed that insect pollinators play a major role in pollinating the pumpkin crop. Therefore, use of *A. cerana* for pollination of pumpkin crop should be inculcated and practiced. A comprehensive study of potential of *A. cerana* for pollination of other crops is still required.

Table 1: Relative abundance of insect visitors on pumpkin in open conditions during 2022 and 2023

Sl. No.	Time (hours)	Number of foragers /5 mins /m^2													
		2022							2023						
		Apis mellifera	*Apis cerana*	*Tetragonula iridipennis*	*Lepidotrigona arcifera*	*Aulacophora foveicollis*	*Bactrocera dorsalis*	*Musca* sp.	*Apis mellifera*	*Apis cerana*	*Tetragonula iridipennis*	*Lepidotrigona arcifera*	*Aulacophora foveicollis*	*Bactrocera dorsalis*	*Musca* sp.
1.	0600	12.23	10.39	0.83	2.50	4.19	8.55	0.50	10.79	9.10	0.67	0.67	0.66	7.71	0.17
2.	0800	16.81	14.03	2.32	1.82	3.67	8.03	1.66	11.98	12.82	1.67	1.67	1.66	8.05	0.67
3.	1000	12.00	12.54	2.00	1.50	4.33	11.83	3.82	8.31	8.66	3.05	2.33	1.67	8.40	1.17
4.	1200	8.35	6.35	1.50	1.67	5.82	9.48	0.83	6.99	7.61	1.33	1.33	1.34	5.70	1.00
5.	1400	8.74	9.53	0.83	1.00	3.49	9.12	0.67	4.33	4.99	1.00	1.00	1.33	4.18	1.00
6.	1600	8.15	9.12	0.67	0.33	2.66	6.02	0.50	1.50	3.17	0.00	0.00	1.00	0.67	0.70
	Mean	11.05	10.33	1.36	1.47	4.03	8.84	1.33	7.32	7.73	1.29	1.17	1.28	5.79	*0.79*
		Forager	Time	Forager x Time		-	-	-		Forager	Time	Forager x Time	-	-	-
	SEm±	0.02	0.03	0.09		-	-	-		0.03	0.03	0.07	-	-	-
	CD (p = 0.05)	0.06	0.10	0.26		-	-	-		0.08	0.08	0.21	-	-	-

Table 2: Relative abundance of insect pollinators on pumpkin under closed conditions during 2022 and 2023

Sl. No.	Time (hours)	Number of foragers /5 mins /m^2							
		Apis mellifera	*Apis cerana*	*Tetragonula iridipennis*	*Lepidotrigona arcifera*	*Apis mellifera*	*Apis cerana*	*Tetragonula iridipennis*	*Lepidotrigona arcifera*
1.	0600	22.69	17.97	14.07	8.77	16.54	16.83	11.57	11.3
2.	0800	26.79	21.34	15.00	14.26	22.77	21.95	16.61	13.57
3.	1000	27.13	29.79	17.91	14.53	28.29	22.79	16.81	17.89
4.	1200	17.49	20.3	14.16	10.38	25.29	20.34	16.33	11.88
5.	1400	15.98	15.32	12.71	9.88	18.56	15.86	12.17	8.45
6.	1600	15.36	11.61	11.42	9.40	10.45	9.06	10.03	8.36
	Mean	*20.91*	*19.39*	*14.21*	*11.20*	*20.32*	*17.81*	*13.92*	*11.91*
		Forager	Time	Forager x Time		Forager	Time	Forager x Time	
	SEm±	0.08	0.10	0.23		0.10	0.09	0.20	
	CD (p = 0.05)	0.23	0.29	0.66		0.29	0.24	0.56	

Table 3: Foraging rate of different insect pollinators on pumpkin in open conditions during 2022 and 2023

Sl. No.	Time (hours)	Number of flowers visited by foragers per 5 minutes									
		2022					2023				
		Apis mellifera	*Apis cerana*	*Tetragonula iridipennis*	*Lepidotrigona arcifera*	*Musca* sp.	*Apis mellifera*	*Apis cerana*	*Tetragonula iridipennis*	*Lepidotrigona arcifera*	*Musca* sp.
1.	0600	6.54	4.31	3.34	2.37	1.03	11.46	8.49	7.40	6.37	2.20
2.	0800	8.23	5.94	4.94	3.97	1.43	13.26	10.06	9.29	8.14	3.80
3.	1000	5.46	3.46	2.63	2.00	1.00	9.57	7.74	6.63	5.97	1.57
4.	1200	4.31	1.77	1.34	1.23	0.71	8.11	5.77	4.77	1.86	1.17
5.	1400	2.94	1.40	1.29	1.34	0.60	7.09	5.34	4.54	1.83	0.97
6.	1600	1.49	1.34	1.26	1.20	0.43	5.43	4.71	2.77	1.54	0.49
	Mean	4.83	3.04	2.47	2.02	0.87	9.15	7.02	5.90	4.29	1.70
		Forager	Time	Forager x Time		-	Forager	Time	Forager x Time		-
	SEm±	0.02	0.03	0.09		-	0.03	0.03	0.07		-
	CD (p = 0.05)	0.05	0.10	0.25		-	0.08	0.07	0.19		-

Table 4: Foraging speed of different insect pollinators on pumpkin in open conditions during 2022 and 2023

Sl. No.	Time (hours)	Time spent per flower (in sec.)									
		2022					2023				
		Apis mellifera	*Apis cerana*	*Tetragonula iridipennis*	*Lepidotrigona arcifera*	*Musca* sp.	*Apis mellifera*	*Apis cerana*	*Tetragonula iridipennis*	*Lepidotrigona arcifera*	*Musca* sp.
1.	0600	21.22	17.46	17.82	13.96	1.17	22.57	17.86	14.00	8.71	3.43
2.	0800	23.36	19.85	18.25	11.81	2.73	27.00	29.57	17.86	14.57	8.57
3.	1000	20.61	17.48	18.06	11.3	1.06	26.71	21.29	15.00	14.14	5.71
4.	1200	20.36	16.39	15.55	9.89	1.22	17.43	20.14	14.14	10.43	3.86
5.	1400	19.99	15.44	15.22	9.16	0.98	16.00	15.29	12.71	9.43	3.57
6.	1600	14.04	9.62	13.25	7.33	0.65	15.29	11.57	11.43	9.86	2.71
	Mean	19.93	16.04	16.36	10.58	1.30	20.83	19.29	14.19	11.19	4.64
		Forager	Time	Forager x Time		-	Forager	Time	Forager x Time		-
	SEm±	0.06	0.11	0.29		-	0.06	0.07	0.18		-
	CD (p = 0.05)	0.18	0.30	0.80		-	0.17	0.19	0.50		-

Table 5: Number of loose pollen grains collected by insect pollinators on pumpkin during 2022 and 2023

Sl. No.	Number of loose pollen grains per forager											
	Apis mellifera			*Apis cerana*			*Tetragonula iridipennis*			*Lepidotrigona arcifera*		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
1.	1864.00	1982.00	1923.00	2403.00	1896.00	2149.50	1921.00	2146.00	2033.50	2062.00	2008.00	2035.00
2.	1743.00	2014.00	1878.50	1862.00	1927.00	1894.50	2106.00	1906.00	2006.00	1903.00	1903.00	1903.00
3.	964.00	1837.00	1400.50	1320.00	1421.00	1370.50	1173.00	1164.00	1168.50	1152.00	1152.00	1152.00
Mean	1523.67	1944.33	1734.00	1861.67	1748.00	1804.83	1733.33	1738.67	1736.00	1705.67	1687.67	1696.67
SD	488.45	94.32	289.68	541.50	283.61	397.17	494.00	511.94	491.66	486.04	466.86	476.29
SEm±	282.00	54.46	167.24	312.64	163.74	229.30	285.21	295.57	283.86	280.61	269.54	274.99

Table 6: Pollination efficiency index of insect pollinators on pumpkin during 2022 and 2023

Sl. No.	Pollinator	2022					2023				
		Relative abundance (RA)	Foraging rate (FR)	Foraging speed (FS)	Loose pollen grains (LPG)	Pollination efficiency index (PEI)	Relative abundance (RA)	Foraging rate (FR)	Foraging speed (FS)	Loose pollen grains (LPG)	Pollination efficiency index (PEI)
1.	*Apis mellifera*	11.05 (4)	4.83 (4)	19.93 (1)	1523.67 (1)	24.00	7.32(3)	9.15 (4)	20.83(1)	1944.33 (4)	27.00
2.	*Apis cerana*	10.33 (3)	3.04 (3)	16.04 (3)	1861.67 (4)	30.00	7.73(4)	7.02 (3)	19.29(2)	1748.00 (3)	32.00
3.	*Tetragonula iridipennis*	1.36 (1)	2.47 (2)	16.36 (2)	1733.33 (3)	7.00	1.29(2)	5.90 (2)	14.19(3)	1738.67 (2)	14.00
4.	*Lepidotrigona arcifera*	1.47 (2)	2.02 (1)	10.58 (4)	1705.67 (2)	14.00	1.17(1)	4.29 (1)	11.19(4)	1687.67 (1)	6.00

RA= Relative Abundance, FR=Foraging Rate, FS=Foraging Speed, LPG=Loose Pollen Grains
*Value in parenthesis are ranked

Table 7: Pooled data on Impact of pollination on fruit quality and production of pumpkin during 2022 and 2023

Sl. No.	Treatments	Fruit setting (%)	Healthy fruit (%)	Crooked fruit (%)	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (kg)	Number of seeds per fruit	100 seed weight (g)
		Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
1.	*Apis mellifera*	64.00	87.24	12.76	19.10	43.90	1.54	145.65	14.25
2.	*Apis cerana*	77.50	89.73	10.26	20.17	46.41	1.71	162.40	15.14
3.	*Tetragonula iridipennis*	56.00	82.54	17.46	16.56	39.40	1.25	116.00	15.63
4.	*Lepidotrigona arcifera*	62.50	85.54	14.46	18.76	42.17	1.59	124.35	14.53
5.	Open pollination	60.00	78.96	21.04	17.11	40.88	1.46	117.50	14.59
6.	Control	50.00	84.36	15.64	14.50	37.16	1.12	108.50	13.39
	SEm±	0.46	0.61	0.13	0.19	0.28	0.015	1.24	0.11
	CD (p = 0.05)	1.34	1.76	0.36	0.56	0.81	0.043	3.57	0.31

Conclusion
The study demonstrated that *Apis cerana* was the most efficient pollinator for pumpkin (*Cucurbita moschata*) based on foraging behavior and pollination efficiency. Plots caged with *A. cerana* showed the highest fruit setting (77.5%), fruit length (20.17 cm), and healthy fruit percentage (89.73%), along with improved seed count (162) and seed weight (15.63 g). Compared to open pollination and other treatments, bee-pollinated plots significantly outperformed in fruit quality and yield, highlighting the role of managed pollination. These findings emphasize the importance of *A. cerana* as a key pollinator for enhancing crop productivity and quality under controlled conditions.

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