

## Foraging Pattern of *Apis cerana indica* Fab. on CMS and RHA Parental Lines of Sunflower Hybrid KBSH-53 Under Varied Planting Ratio and Pollination Situations

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### ABSTRACT

The study was conducted to determine the foraging pattern of *A. cerana*, on different parental lines of the sunflower hybrid, KBSH-53 viz., male line: RHA 95C-1 and female line: CMS 335A, besides time spent on each parental line. Maximum movement of nectar foragers was recorded in M4 situation (female to female line), which produced only nectar, with 54.20 per cent in C1 followed by 51.17 per cent in C2 condition. In case of M1 situation (male to male line), it produced both nectar and pollen with 52.25 per cent in C4 followed by 51.19 per cent in C3 condition. However, negligible movement of bees was observed in M2 situation (male to female line) with 0.86 per cent in C1 followed by 0.94 per cent in C3 condition and under M3 situation (female to male line) with 0.56 per cent in C3 followed by 0.95 per cent in C1 condition across different row ratios. Maximum movement of pollen foragers was recorded in M1 situation (male to male line) with 98.01 per cent in C3 followed by 97.98 per cent in C1 condition. Least movement of bees was observed in M2 situation (male to female line) with 1.07 per cent in C1 followed by 0.15 per cent in C3 condition and in M3 situation with 0.83 per cent in C3 followed by 0.94 per cent in C1 condition. No movement of bees was observed in M4 situation (female to female line) for pollen foragers, wherein no pollen grains are produced in female line, CMS 335A.

The maximum mean time spent by bees was recorded in M4 situation, among nectar foragers with 69.13 per cent in C3 followed by 57.45 per cent in C2 condition and in M1 situation with 47.40 per cent in C4 followed by 44.27 per cent in C1 condition. In M2 situation, lowest mean time spent was 0.00 per cent in C1 followed by 0.21 per cent in C3 condition and M3 situation with 0.21 per cent in C3 followed by 0.29 per cent in C2 condition. The pollen foragers recorded maximum percentage time spent in M1 situation with 99.47 per cent in C3 followed by 99.28 per cent in C2 condition and in M2 and M3 with 0.00 and 1.22 per cent in C1 and 0.00 and 0.53 per cent in C3 condition.

*Keywords* : Sunflower, CMS 335A, RHA 95C-1, KBSH-53, pollination, *Apis cerana indica*

GLOBALLY, sunflower (*Helianthus annuus* L.) is the second most important oilseed crop and is dependent on insect pollination particularly, because of its allogamic nature. The pollen of the individual florets are sticky and heavy in nature and are not carried away easily by wind, so insects play a decisive role in cross pollination.

Unlike other insects, honeybees are most efficient in pollinating sunflower as they are in greater number and visit many flowers to fulfill their colony requirements (Muller *et al.*, 2006). Ishii (2006) observed that honeybees show floral constancy and most of the parental lines of hybrids show great morphological differences. Greater seed yield and more number of seeds per head was observed when

honeybees visited rows of R line by A line (Seetharam and Satyanarayana, 1983). Seed production involves cytoplasmic genetic male sterility (CGMS) of the male sterile A line (CMS) which is pollinated by male fertile B line for its maintenance and there afterwards it is crossed with RHA line (Restorer) for production of hybrid seed, which mimics dioecious plants in nature.

In general, for commercial hybrid production, A and R lines are sown separately in particular ratios. De Grandi-Hofman and Martin (1993) conducted studies on transfer of pollen by honeybees between parental lines which resulted in movement of bees from male fertile line to male sterile line. Nectar collecting bees have indiscriminate movement between male and female parental flower heads. This

idea was exploited by using different row ratio of A and R line under different conditions to see the cross movement of bees within and between the parental lines and thereby try to exploit this behavior of bees for enhancing seed set in hybrid seed production programmes. With this concept, the present investigation was conducted. The study conducted was novel in which there is no much supporting similar findings were recorded.

#### MATERIAL AND METHODS

The experiment was carried out using parental lines of sunflower hybrid KBSH-53, *i.e.*, cytoplasmic sterile (Female) A line: CMS 335A and fertility restorer (male) R line, RHA 95C-1, during *kharif* 2017 at Zonal Agricultural Research Station, UAS, GKVK, Bengaluru. The parental lines were sown in planting ratios of 1R:1A (R1), 1R:2A (R2) and 1R:5A (R3) as detailed below. The plot size of 4.2×3m was maintained with three replications.

Row Ratio (RR)	Male : Female
RR1:- 1R:1A	1RHA 95C-1 : 1CMS 335A
RR2:- 1R:2A	1RHA 95C-1 : 2CMS 335A
RR3:- 1R:5A	1RHA 95C-1 : 5CMS 335A

All agronomic practices except pollination situations were adopted as per the package of practices for sunflower (Anon., 2012). Normally R (restorer) lines produce many auxillary buds as compared to CMS lines, which produce only a single head. Manipulation of R line was done by removing auxillary buds and retaining single head to create similar condition for both R and A line. Four pollination situations were created, *viz.*, C1: open pollination + without removal of auxillary buds of R line (WRAB), C2: open pollination+removal of auxillary buds of R line (RAB), C3: Enclosed both parental lines with *A. cerana* colony+without removal of auxillary buds of R line (WRAB) and C4: Enclosed the treatment with *A. cerana* colony + removal of auxillary buds of R line (RAB). Honeybee movement was observed at one hourly interval during the day, for 5 min. by each bee *i.e.*, from 0600 to 1800 hrs, on ten capitula for *A. cerana* movement and data for the time spent (in sec) on each parental line was recorded from 0600 to 1900 hrs. The nectar and pollen foraging

bees were recorded separately. Bees carrying pollen in their pollen basket were considered as pollen foragers and others were counted as nectar foragers. Data was subjected to statistical analysis in order to determine the effect of planting ratios on movement of bees, within a specific row and also between parental lines *i.e.*, from of R to CMS line and *vice versa*. Based on this activity, the movement of bees collecting nectar and pollen were grouped into four categories, as indicated below.

- M1: Movement of honeybee from male to male parental lines
- M2: Movement of honeybee from male to female parental lines
- M3: Movement of honeybee from female to male parental lines
- M4: Movement of honeybee from female to female parental lines

#### RESULTS AND DISCUSSION

##### i) Movement of bees in open pollination + without removal of auxillary buds of R line (WRAB)

Movement of *A. cerana* was maximum in M4 situation (female to female lines) with mean percentage of 54.20 and within planting ratios, 1:1 showed maximum movement with 55.85 per cent foragers followed by 1:5 and 1:2 row ratios with 54.21 and 52.56 per cent, respectively. In M1 situation (male to male lines), mean percentage movement of bees was 43.65 and 1:2 row ratio recorded highest movement with 45.44 per cent, followed by 1:5 and 1:1 row ratios with 43.35 per cent and 42.17 per cent bee movement, respectively. The M2 situation (male to female lines) and M3 situation (female to male lines) recorded negligible movement with a mean of 0.86 and 0.95 per cent bee movement, respectively. No significant differences could be observed in bee movement between row ratios, with maximum of 1.71 per cent of bees moved in 1:5 row ratio in M2 situation. Greater tendency of bees was observed to move in M4 (female lines produce only nectar) and M1 situation (male lines produce both nectar and pollen) as compared to M2 and M3 situation indicating that bees showed greater floral constancy towards nectar foraging (Table I). These results were supported

TABLE I  
Effect of planting ratios of parental lines of sunflower hybrid KBSH-53 on foraging by *A. cerana*

Row Ratio(RR) of RHA:CMS lines	Nectar foragers (No.)				Pollen foragers (No.)			
	M1	M2	M3	M4	M1	M2	M3	M4
	Open pollination + WRAB							
RR1-1:1	99.67 (42.17)	2.00 (0.85)	2.67 (1.13)	132.00 (55.85)	95.33 (97.28)	1.67 (1.70)	1.00 (1.02)	0.00
RR2-1:2	106.33 (45.44)	2.33 (1.00)	2.33 (1.00)	123.00 (52.56)	102.67 (98.09)	1.00 (0.96)	1.00 (0.96)	0.00
RR3-1:5	118.33 (43.35)	4.67 (1.71)	2.00 (0.73)	148.00 (54.21)	116.00 (98.58)	0.67 (0.57)	1.00 (0.85)	0.00
Mean	108.11 (43.65)	3.00 (0.86)	2.33 (0.95)	134.33 (54.20)	104.67 (97.98)	1.11 (1.07)	1.00 (0.94)	0.00(0.00)
	Open pollination + RAB							
RR1-1:1	106.33 (45.44)	5.67 (2.42)	3.00 (1.28)	119.00 (50.85)	106.33 (97.26)	3.00 (2.74)	0.00 (0.00)	0.00
RR2-1:2	120.67 (46.41)	6.33 (2.44)	2.33 (0.90)	130.67 (50.26)	119.67 (96.51)	2.33 (1.88)	2.00 (1.61)	0.00
RR3-1:5	125.67 (43.33)	10.00 (3.45)	2.33 (0.80)	152.00 (52.41)	121.67 (96.05)	2.00 (1.58)	3.00 (2.37)	0.00
Mean	117.56 (45.06)	7.33 (2.77)	2.56 (0.99)	133.89 (51.17)	115.89 (96.60)	2.44 (2.06)	1.67 (1.32)	0.00(0.00)
	Enclosed with <i>A. cerana</i> colony+ WRAB							
RR1-1:1	210.00 (55.70)	3.33 (0.88)	2.67 (0.71)	161.00 (42.71)	178.00 (97.98)	2.00 (1.10)	1.67 (0.92)	0.00
RR2-1:2	202.33 (49.84)	3.33 (0.82)	2.00 (0.49)	198.33 (48.85)	167.00 (98.04)	1.67 (0.98)	1.67 (0.98)	0.00
RR3-1:5	196.67 (48.05)	4.67 (1.14)	2.00 (0.49)	206.00 (50.33)	164.00 (98.01)	2.33 (1.39)	1.00 (0.60)	0.00
Mean	203.00 (51.19)	3.78 (0.94)	2.22 (0.56)	188.44 (47.29)	169.67 (98.01)	2.00 (1.15)	1.44 (0.83)	0.00 (0.00)
	Enclosed with <i>A. cerana</i> colony+ RAB							
RR1-1:1	197.67 (54.30)	7.67 (2.11)	3.67 (1.01)	155.00 (42.58)	149.33 (96.14)	3.67 (2.36)	2.33 (1.50)	0.00
RR2-1:2	188.67 (52.70)	9.67 (2.70)	5.00 (1.40)	154.67 (43.20)	148.00 (95.07)	4.67 (3.00)	3.00 (1.93)	0.00
RR3-1:5	181.33 (49.77)	12.00 (3.29)	5.33 (1.46)	165.67 (45.47)	148.33 (94.88)	5.00 (3.20)	3.00 (1.92)	0.00
Mean	189.22 (52.25)	9.78 (2.70)	4.67 (1.29)	158.44 (43.75)	148.56 (95.36)	4.44 (2.85)	2.78 (1.78)	0.00 (0.00)
	Frequency % of <i>A. cerana</i> (Average over open pollinated and colony enclosed conditions)							
RR1-1:1	49.41	1.56	1.03	48.00	97.16	1.98	0.86	0.00
RR2-1:2	48.60	1.74	0.95	48.72	96.93	1.70	1.37	0.00
RR3-1:5	46.12	2.40	0.87	50.61	96.88	1.68	1.43	0.00
Mean	48.04	1.90	0.95	49.11	96.99	1.79	1.22	0.00

Note: WRAB=without removal of axillary buds; RAB= removal of axillary buds; Figures in the parentheses are percentage values. M1=Bee movement from male to male line, M2=Bee movement from male to female line, M3=Bee movement from female to male line and M4= Bee movement from female to female line

with the study of Rajasri *et al.* (2002) and Rajagopal *et al.* (1999) in which high frequency of nectar foraging bees visited within the parental lines.

In case of pollen foragers greater movement of bees (97.98%) was recorded in M1 situation (male to male lines) with maximum movement of 98.58 per cent (in 1:5 ratio) followed by 98.09 per cent (in 1:2 ratio) and 97.28 per cent (in 1:1 ratio). There was no movement of bees in M4 (female to female lines) since no pollen grains are produced by female lines. Least bee movement of 1.07 and 0.94 per cent were observed in M2 and M3 situation respectively and the differences in bee movement between the different row ratios was negligible (Table I). These observations were supported by the results of Yadav *et al.* (2002) and Mohan Rao *et al.* (1995) wherein high tendency of nectar foraging bees moved within and between the parental lines as compared to pollen foragers.

**ii) Movement of bees in open pollination + with removal of auxillary buds of R line (RAB)**

Movement of nectar foraging bees was maximum (51.17%) within parental lines under M4 situation (female to female lines) and within the row ratios it was 52.41, 50.85 and 50.26 per cent in 1:5, 1:1 and 1:2 row ratios, respectively, this is followed by M1 situation (male to male lines), with 46.41 (in 1:2 ratio), 45.44 (in 1:1 ratio) and 43.33 per cent (in 1:5 ratio), with a mean percentage of 45.06 (Table I). In case of M2 situation, bee movement from male to female line was 3.45 (in 1:5 ratio), 2.44 (in 1:2 ratio) and 2.42 per cent (in 1:1 ratio) and in M3 situation it was 1.28 (in 1:1 ratio), 0.90 (in 1:2 ratio) and 0.80 per cent (in 1:5 ratio) in nectar collecting bees (Table I).

In case of pollen foragers, M1 situation (male to male lines) the bee movement was 96.60 per cent with 97.26, 96.51 and 96.05 per cent recorded in 1:1, 1:2 and 1:5 row ratios of RHA:CMS lines, respectively. Whereas, in M2 situation (male to female lines), it was 2.74 per cent in 1:1 row ratio, followed by 1.88 and 1.58 per cent in 1:2 and 1:5 row ratio with a overall mean percentage of 2.06. The M3 situation recorded mean bee movement percentage of 1.32 per cent. No bee movement was observed in M4 situation from female to female lines (Table I).

**iii) Movement of bees when *A. cerana* colony is enclosed with parental lines+without removal of auxillary buds of R line (WRAB) condition**

In case of lines enclosed with *A. cerana* colony +WRAB condition, greater bee movement was observed in all the row ratios. The highest mean percentage of nectar foraging bees was recorded in M1 situation (male to male lines) with a mean of 51.19 per cent and it was highest in 1:1 row ratio (55.70%) followed by 49.84 per cent in 1:2 row ratio and 48.05 per cent in 1:5 row ratio. Whereas, in M4 situation (female to female lines) recorded mean movement of 47.29 per cent and highest bee movement was in 1:5 ratio with 50.33 per cent followed by 48.85 per cent in 1:2 row ratio and 42.71 per cent in 1:1 row ratio (Table1). Bee movement (mean %) in M2 and M3 situations was lowest among the planting ratios, 1:5 ratio recorded highest bee movement of 1.14 per cent in M2 situation and 0.71 per cent in M3 situation. Pollen collecting bees followed similar trend as in case of the previous condition *i.e.*, mean percentage movement within parental lines was higher in case of M1 situation (98.01%) followed by M2 (1.15%) and M3 situations (0.83%), however, it was nil in M4 situation (Table I). Martin and Farina (2016) and DeGrandi Hoffman and Martin (1993) reported similar results in which very low frequency of bees moved from male to female and *vice-versa*.

**iv) Movement of bees when *A. cerana* colony is enclosed with parental lines+removal of auxillary buds of R line (RAB)**

In this situation where auxillary buds were removed, comparatively higher bee movement was recorded in M1 (male to male lines) with 52.25 per cent followed by M4 situation (female to male lines) with 43.75 per cent movement of bees. However, in M2 situation (male to female lines) bee movement was only 2.70 per cent, with row ratio of 1:5 recording high bee movement (3.29%) followed by 1:2 row ratio (2.70%) and 1:1 row ratio (2.11%) in case of nectar collecting bees. Similar result was also observed in M3 situation *i.e.*, mean bee movement (%) from A line to R line was 1.29 per cent. Pollen foragers also recorded maximum movement in M1 situation (male to male lines) with 95.36 per cent bee movement. In M2 and M3 situations, mean percentage

movement of bees was 2.85 and 1.78 per cent, respectively. However in M4 situation bee movement was nil (Table I).

After removal of auxillary buds in the R line, it looks morphologically similar to A line, hence there was greater tendency of bee movement from R (male) line to A (female) line. Between the row ratios, as the number of A lines are more in 1R:5A, the bees showed greater tendency to move towards A line compared to that in the other row ratios (Table I). Since this was a novel study, there are no similar findings recorded earlier.

#### Analysis of variance for planting conditions and movement of honeybee (*A. cerana*) under open pollination and enclosure of *A. cerana* colony with parental lines of KBSH-53

The analysis of variance indicated that all the treatments showed statistically significant differences for bee movement, except M4 situation with respect to movement pattern of pollen foragers (Table II). Planting ratios showed highly significant differences in case of M1 (male to male lines), M2 (male to female lines) and M4 situations (female to female lines) with respect to nectar foragers, and in case of M1 situation

with respect to row ratios (male to male lines) for pollen foragers. However for M2, M3 and M4 situations, differences in bee movement pattern were non-significant.

In case of different pollination situations, all the situations were statistically significant except M4 (female to female lines) for pollen foragers, which was statistically non-significant, since in female lines there was no pollen production. Interaction between row ratio and pollination situations showed significant difference in M1 situation (male to male lines) and M4 situation (female to female lines) in case of nectar foraging bees and M1 situation (male to male lines) in case of pollen foraging bees wherein movement of bees was observed between parental lines (R and A line). All other situations *i.e.*, M2, M3 and M4) were statistically non-significant with respect to bee movement for pollen foragers (Table II).

#### Effect of planting conditions on movement of honeybee (*A. cerana*) and their interaction under open and enclosed conditions in case of parental lines of KBSH-53

In individual treatments, among the row ratios of 1:5, showed highly significant difference with

TABLE II

*Analysis of variance for bee movement pattern in different planting ratios under open pollinated and A. cerana colony enclosed conditions, on parental lines of sunflower hybrid, KBSH-53*

Source of Variance	DF	Mean Sum of Square							
		Nectar foragers (No.)				Pollen foragers (No.)			
		M1	M2	M3	M4	M1	M2	M3	M4
Replication	2	196.03	20.58	0.19	184.75	54.36	4.78	0.19	0.00
Treatment	11	6045.54 **	26.67 **	4.17 *	2397.70 **	2775.93 **	6.15 **	2.88 *	0.00
Row Ratio (RR)	2	51.19 **	13.58 **	0.03	1534.75 **	184.53 **	0.36	2.53	0.00
Pollination situation (C)	3	21769.81 **	86.74 **	13.74 **	7490.69 **	9825.96 **	19.51 **	5.36 **	0.00
R X C	6	181.53 **	0.99	0.77	138.86 **	114.71 **	1.40	1.75	0.00
Error	22	414.60	1.52	0.16	152.84	67.06	1.11	0.07	0.00
Total	35	2171.84	10.51	1.43	860.19	917.69	2.90	0.96	0.00

Note: M1=movement from male to male line, M2=movement from male to female line, M3=movement from female to male line and M4= movement from female to female line

\*Significant at 5 per cent; \*\* Significant at 1 per cent

respect to bee movement as that in 1:1 and 1:2 row ratio in case of M1 situation for nectar foragers and also in case of M1 and M3 situation for pollen foragers, indicating greater movement of bees in 1:5 row ratio as compared to that in 1:1 and 1:2 row ratios (Table III).

In case of different pollination conditions (*i.e.*, open pollination Vs. *A. cerana* pollination under enclosure) for nectar foragers, C1 showed highly significant differences in M1 situation (male to male lines) followed by C4 and C3 conditions. In case of M2 and M3 situations, C4 showed highly significant

TABLE III

*Effect of different planting ratios on movement of A. cerana and the interaction effect under open pollinated and A. cerana pollinated conditions on parental lines of KBSH-53*

Source of Variance	Nectar foragers				Pollen foragers			
	M1	M2	M3	M4	M1	M2	M3	M4
RR1(1:1)	454.50 <sup>a</sup>	14.25 <sup>a</sup>	9.00 <sup>b</sup>	438.50 <sup>a</sup>	397.50 <sup>a</sup>	7.50 <sup>b</sup>	3.50 <sup>a</sup>	0.00 <sup>a</sup>
RR2 (1:2)	459.00 <sup>a</sup>	16.25 <sup>b</sup>	8.75 <sup>a</sup>	455.00 <sup>b</sup>	412.25 <sup>b</sup>	6.75 <sup>a</sup>	5.75 <sup>b</sup>	0.00 <sup>a</sup>
RR3 (1:5)	466.75 <sup>b</sup>	20.50 <sup>c</sup>	8.75 <sup>a</sup>	503.75 <sup>c</sup>	420.75 <sup>c</sup>	6.50 <sup>a</sup>	6.00 <sup>c</sup>	0.00 <sup>a</sup>
Mean	460.08	17.00	8.83	465.75	410.17	6.92	5.08	0.00
CD	5.11	0.31	0.10	3.10	2.06	0.26	0.07	0.00
C1	328.67 <sup>a</sup>	9.00 <sup>a</sup>	7.00 <sup>b</sup>	403.00 <sup>a</sup>	315.33 <sup>a</sup>	3.33 <sup>a</sup>	3.00 <sup>a</sup>	0.00 <sup>a</sup>
C2	352.67 <sup>b</sup>	20.33 <sup>c</sup>	7.67 <sup>c</sup>	401.67 <sup>a</sup>	347.67 <sup>b</sup>	6.00 <sup>c</sup>	5.00 <sup>c</sup>	0.00 <sup>a</sup>
C3	642.67 <sup>d</sup>	10.00 <sup>b</sup>	6.33 <sup>a</sup>	585.67 <sup>c</sup>	534.67 <sup>d</sup>	5.00 <sup>b</sup>	4.00 <sup>b</sup>	0.00 <sup>a</sup>
C4	516.33 <sup>c</sup>	28.67 <sup>d</sup>	14.33 <sup>d</sup>	472.67 <sup>b</sup>	443.00 <sup>c</sup>	13.33 <sup>d</sup>	8.33 <sup>d</sup>	0.00 <sup>a</sup>
Mean	460.08	17.00	8.83	465.75	410.17	6.92	5.08	0.00
CD	6.82	0.41	0.14	4.14	2.74	0.35	0.09	0.00
RR1× C1	104.00 <sup>a</sup>	2.00 <sup>a</sup>	2.67 <sup>bc</sup>	132.00 <sup>ab</sup>	96.67 <sup>a</sup>	1.67 <sup>cd</sup>	1.00 <sup>ab</sup>	0.00 <sup>a</sup>
RR1 × C2	106.33 <sup>ab</sup>	5.67 <sup>ef</sup>	3.00 <sup>c</sup>	119.00 <sup>a</sup>	106.33 <sup>bc</sup>	3.00 <sup>ef</sup>	0.00 <sup>a</sup>	0.00 <sup>a</sup>
RR1 × C3	219.33 <sup>d</sup>	3.00 <sup>ab</sup>	2.33 <sup>ab</sup>	181.33 <sup>ef</sup>	180.33 <sup>e</sup>	1.67 <sup>cd</sup>	1.33 <sup>bc</sup>	0.00 <sup>a</sup>
RR1 × C4	176.33 <sup>c</sup>	8.33 <sup>g</sup>	4.00 <sup>d</sup>	152.33 <sup>cd</sup>	146.67 <sup>de</sup>	3.67 <sup>ef</sup>	2.33 <sup>ef</sup>	0.00 <sup>a</sup>
RR2 × C1	106.33 <sup>a</sup>	2.33 <sup>ab</sup>	2.33 <sup>ab</sup>	123.00 <sup>ab</sup>	102.67 <sup>ab</sup>	1.00 <sup>ab</sup>	1.00 <sup>ab</sup>	0.00 <sup>a</sup>
RR2 × C2	120.67 <sup>ab</sup>	6.33 <sup>f</sup>	2.33 <sup>ab</sup>	130.67 <sup>ab</sup>	119.67 <sup>cd</sup>	1.67 <sup>cd</sup>	2.00 <sup>de</sup>	0.00 <sup>a</sup>
RR2 × C3	213.67 <sup>d</sup>	3.33 <sup>bc</sup>	2.00 <sup>a</sup>	198.33 <sup>ef</sup>	179.33 <sup>e</sup>	1.67 <sup>cd</sup>	1.67 <sup>cd</sup>	0.00 <sup>a</sup>
RR2 × C4	171.33 <sup>c</sup>	9.67 <sup>h</sup>	5.00 <sup>ef</sup>	154.67 <sup>cd</sup>	148.00 <sup>de</sup>	4.67 <sup>fg</sup>	3.00 <sup>ef</sup>	0.00 <sup>a</sup>
RR3 × C1	118.33 <sup>ab</sup>	4.67 <sup>de</sup>	2.00 <sup>a</sup>	148.00 <sup>cd</sup>	116.00 <sup>cd</sup>	0.67 <sup>a</sup>	1.00 <sup>ab</sup>	0.00 <sup>a</sup>
RR3 × C2	125.67 <sup>b</sup>	8.33 <sup>g</sup>	2.33 <sup>ab</sup>	152.00 <sup>cd</sup>	121.67 <sup>cd</sup>	1.33 <sup>bc</sup>	3.00 <sup>ef</sup>	0.00 <sup>a</sup>
RR3 × C3	209.67 <sup>d</sup>	3.67 <sup>cd</sup>	2.00 <sup>a</sup>	206.00 <sup>f</sup>	175.00 <sup>e</sup>	1.67 <sup>cd</sup>	1.00 <sup>ab</sup>	0.00 <sup>a</sup>
RR3 × C4	168.67 <sup>c</sup>	10.67 <sup>h</sup>	5.33 <sup>f</sup>	165.67 <sup>d</sup>	148.33 <sup>ab</sup>	5.00 <sup>g</sup>	3.00 <sup>ef</sup>	0.00 <sup>a</sup>
Mean	153.36	5.67	2.94	155.25	136.72	2.31	1.69	0.00
CD	20.45	1.24	0.41	12.42	8.23	1.06	0.27	0.00

Note: M1=Bee movement from male to male line, M2=Bee movement from male to female line, M3=movement from female to male line and M4= Bee movement from female to female line; RR=Row Ratio; C=Pollination condition; C1: open pollination + without removal of auxillary buds of R line (WRAB); C2: open pollination +removal of auxillary buds of R line (RAB); C3: Enclosed with 5 frames of *A. cerana*+without removal of auxillary buds of R line (WRAB) and C4: Enclosed with 5 frames of *A. cerana* + removal of auxillary buds of R line (RAB); CD value calculated at 5 per cent significance;

differences followed by C2 and C3 conditions, which meant that the movement of bees from male to female lines and female to male lines was highest in C4 condition. In case of M4 situation, C3 condition registered significantly greater bee movement followed by C4 and C1 conditions. Similarly, it meant that, both male to male line bee movement and female to female line bee movement, was highest under C3 condition. For pollen foragers also, C3 had significantly higher bee movement in M1 situation, with highest movement of pollen foragers followed by C4, C2 and C1 conditions. In M2 and M3 situations, the same trend was seen in case of nectar foragers also, in which C3 showed highly significant bee movement followed by C2 and C3 conditions (Table III).

In nectar foragers, in case of interaction effect between row ratios and pollination conditions, RR1  $\times$  C3 interaction was statistically significant with respect to bee movement in M1 situation followed by RR2  $\times$  C3 and RR3  $\times$  C3 interactions, which meant that the combination of 1:1 row ratio and enclosure with *A. cerana* is more congenial for male to male line bee movement by nectar foragers. In M2 and M3 situation, RR3  $\times$  C4 interaction was significantly superior, followed by RR2  $\times$  C4 and RR1  $\times$  C4 in which 1:5 row ratio was maintained along with enclosure for *A. cerana* colony, coupled with removal of auxillary buds of R line, which seemed to be best for male to male line and male to female line movement of the bees. In case of M4 situation, RR3  $\times$  C3 interaction was significantly superior followed by RR2  $\times$  C3 and RR1  $\times$  C3 interaction which showed that 1:5 row ratio and enclosure with *A. cerana* colony greatly facilitates for nectar foragers movement from female to female lines. Under M1 situation in case of pollen foragers RR1  $\times$  C3 interaction showed highly significant difference in bee movement followed by RR2  $\times$  C3 and RR3  $\times$  C3 interaction, in which 1:1 row ratio enclosed with *A. cerana* colony was most congenial for bee movement between male to male parental lines. In both M2 and M3 situation, RR3  $\times$  C4 interaction showed highly significant condition, which meant that, it is more congenial for movement of bees from male to female line and female to male lines (Table III).

### **Time spent by *A. cerana* foragers on parental lines**

#### **i) Movement of bees under open pollination condition + without removal of auxillary buds of R line (WRAB) condition**

The mean time spent by honey bees was higher in nectar collecting bees in M4 situation during different hours of the day, followed by M1 situation. The maximum time spent for nectar collection in M4 during 11.00-12.00 hrs (144.33 sec) followed by M1 situation during 12.00-13.00 hrs (134.00 sec.). Lowest time spent was observed in M3 situation (3.00 sec) and almost no time was spent in M2 situation (Table IV). In case of pollen foragers M1 situation showed highest time spent with 44.00 sec (11.00-12.00 hrs) and lowest was in M3 situation with 3.00 sec. No pollen foraging bees were recorded in M2 and M4 condition, this is because there was no cross movement in M2 and only nectar was produced in M4 situation and no pollen was produced (Table IV). Similar results were observed by Rajasri *et al.* (2002), wherein, nectar foraging bees spent more time on female line than male line.

#### **ii) Movement of bees under open pollination condition + removal of auxillary buds of R line (RAB)**

Similar results were obtained in case of removal of auxillary buds condition, wherein nectar foragers spent more time in M4 situation with highest foraging time spent during 12.00-13.00 hrs (179.00 sec) and lowest was spent during 15.00-16.00 hrs (53.33 sec) followed by M1 situation with 131.67 sec (12.00-13.00 hrs) and lowest time of 21.33 sec was spent during 16.00-17.00 hrs (Table V). The M2 and M3 situations recorded highest time of 3.33 sec (during 9.00-10.00 hrs) and 3.00 sec (during 9.00-10.00 hrs), respectively. Pollen foragers spent maximum time of 37.00 sec (10.00-11.00 hrs) and lowest time of 13.00 sec (13.00-13.00 hrs). No bees were observed in M2 and M4 situations. In M3 situation maximum time spent was 2.33 sec during 11.00-12.00 hrs (Table V). This is due to the fact that there was no cross movement in M2 and only nectar was produced in M4 situation and no pollen was produced. No earlier study was supported similar to present findings in which it is seems novel work.

TABLE IV  
*Mean time spent by A. cerana under open pollinated condition+ without removal of auxillary buds (WRAB) across different planting ratios*

Source of Variance	Mean time spent on flowers (sec)							
	Nectar foragers				Pollen foragers			
	M1	M2	M3	M4	M1	M2	M3	M4
06.00-07.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07.00-08.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08.00-09.00	31.67	0.00	0.00	46.67	23.33	0.00	0.00	0.00
09.00-10.00	121.00	0.00	2.67	120.67	22.00	0.00	0.00	0.00
10.00-11.00	117.33	0.00	0.00	141.33	41.33	0.00	0.00	0.00
11.00-12.00	104.00	0.00	0.00	144.33	44.00	0.00	0.00	0.00
12.00-13.00	134.00	0.00	0.00	143.67	12.67	0.00	0.00	0.00
13.00-14.00	96.00	0.00	3.00	94.33	12.00	0.00	0.00	0.00
14.00-15.00	43.67	0.00	0.00	92.67	17.00	0.00	3.00	0.00
15.00-16.00	17.67	0.00	0.00	21.33	13.67	0.00	0.00	0.00
16.00-17.00	24.67	0.00	0.00	63.33	16.00	0.00	0.00	0.00
17.00-18.00	61.67	0.00	0.00	72.00	21.00	0.00	0.00	0.00
18.00-19.00	42.67	0.00	0.00	54.00	19.67	0.00	0.00	0.00
Total	794.33	0.00	5.67	994.33	242.67	0.00	3.00	0.00
Mean±SE	61.10 ± 13.23	0.00 ± 0.00	0.44 ± 0.29	76.49 ± 14.36	18.67 ± 3.58	0.00 ± 0.00	0.23 ± 0.23	0.00 ± 0.00
% Time spent	44.27	0.00	0.32	55.42	98.78	0.00	1.22	0.00

Note: M1=Bee movement from male to male line, M2=Bee movement from male to female line, M3=Bee movement from female to male line and M4=Bee movement from female to female line

TABLE V  
*Mean time spent by A. cerana under open pollinated condition + removal of auxillary buds (RAB) across different planting ratios*

Source of Variance	Mean time spent on flowers (sec)							
	Nectar foragers				Pollen foragers			
	M1	M2	M3	M4	M1	M2	M3	M4
06.00-07.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07.00-08.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08.00-09.00	33.67	0.00	0.00	56.33	24.33	0.00	0.00	0.00
09.00-10.00	113.33	3.33	3.00	127.67	24.00	0.00	0.00	0.00
10.00-11.00	131.33	0.00	0.00	144.67	37.00	0.00	0.00	0.00
11.00-12.00	124.33	0.00	0.00	178.67	36.67	0.00	2.33	0.00
12.00-13.00	131.67	1.67	0.00	179.00	16.00	0.00	0.00	0.00
13.00-14.00	97.33	0.00	3.00	149.00	13.00	0.00	0.00	0.00
14.00-15.00	92.67	0.00	0.00	115.00	16.33	0.00	2.00	0.00
15.00-16.00	22.67	0.00	0.00	53.33	22.00	0.00	0.00	0.00
16.00-17.00	21.33	2.00	0.00	75.33	21.33	0.00	0.00	0.00
17.00-18.00	59.33	0.00	0.00	71.00	19.33	0.00	0.00	0.00
18.00-19.00	44.33	0.00	0.00	44.67	17.33	0.00	0.00	0.00
Total	872.00	7.00	6.00	1194.67	247.33	0.00	4.33	0.00
Mean±SE	67.08 ± 13.87	0.54 ± 0.30	0.46 ± 0.31	91.90 ± 17.08	19.03 ± 3.08	0.00 ± 0.00	0.33 ± 0.22	0.00 ± 0.00
% Time spent	41.93	0.34	0.29	57.45	98.28	0.00	1.72	0.00

Note: M1=Bee movement from male to male line, M2=Bee movement from male to female line, M3=Bee movement from female to male line and M4=Bee movement from female to female line

TABLE VI  
 Mean time spent by *A. cerana* under colony enclosure condition + without removal of auxillary buds (WRAB) across different planting ratios

Source of Variance	Mean time spent on flowers (sec)							
	Nectar foragers				Pollen foragers			
	M1	M2	M3	M4	M1	M2	M3	M4
06.00-07.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07.00-08.00	9.33	0.00	0.00	7.00	6.00	0.00	0.00	0.00
08.00-09.00	15.67	0.00	0.00	92.00	28.00	0.00	0.00	0.00
09.00-10.00	56.67	0.00	0.00	83.67	40.00	0.00	0.00	0.00
10.00-11.00	56.67	0.00	0.00	127.00	43.33	0.00	0.00	0.00
11.00-12.00	54.00	0.00	0.00	179.00	57.00	0.00	0.00	0.00
12.00-13.00	94.67	0.00	0.00	203.00	43.33	0.00	0.00	0.00
13.00-14.00	85.33	3.00	2.67	219.00	53.33	0.00	0.00	0.00
14.00-15.00	116.67	2.67	0.00	208.67	47.00	0.00	3.00	0.00
15.00-16.00	99.33	0.00	0.00	199.00	56.00	0.00	0.00	0.00
16.00-17.00	103.33	0.00	3.00	192.00	56.00	0.00	0.00	0.00
17.00-18.00	98.33	0.00	0.00	182.67	68.00	0.00	0.00	0.00
18.00-19.00	29.67	0.00	0.00	168.00	61.00	0.00	0.00	0.00
Total	819.67	5.67	5.67	1861.00	559.00	0.00	3.00	0.00
Mean±SE	63.05 ± 11.01	0.44 ± 0.29	0.44 ± 0.29	143.15 ± 20.88	43.00 ± 5.69	0.00 ± 0.00	0.23 ± 0.23	0.00 ± 0.00
% Time spent	30.45	0.21	0.21	69.13	99.47	0.00	0.53	0.00

Note: M1=Bee movement from male to male line, M2=Bee movement from male to female line, M3=Bee movement from female to male line and M4= Bee movement from female to female line

### iii) Movement of bees in enclosure with *A. cerana* colony+without removal of auxillary buds of R line (WRAB) condition

When *A. cerana* colony was enclosed within net with parental lines, more time was spent by nectar foragers in M4 situation with highest of 219.00 sec during 13.00-14.00 hrs and lowest of 7.00 sec during 07.00-08.00 hrs followed by M1 situation with highest of 116.00 sec during 14.00-15.00 hrs and lowest of 9.33 sec recorded during 07.00-08.00 hrs. M2 and M3 situations recorded maximum of 3.00 sec each during 14.00-13.00 hrs and 16.00-17.00 hrs, respectively. Highest mean time spent was observed in M1 situation for pollen foragers, with maximum of 68.00 sec (17.00-18.00 hrs) followed by M3 situation with 3.00

sec (14.00-15.00 hrs) (Table VI). This is because bees spent longest foraging time for nectar collection as compared to pollen in parental lines of sunflower hybrids. Similar findings caused by Martin and Farina (2016).

### iv) Movement of bees in enclosure with *A. cerana* colony+removal of auxillary buds of R line (RAB) condition

Nectar foragers in M4 situation spent maximum time of 237.33 sec (11.00-12.00 hrs) followed by M1 situation with maximum of 218.66 sec (12.00-13.00 hrs). In M2 and M3 situations, bees spent maximum time of 2.67 sec (08.00-09.00 hrs) and 3.67 sec (09.00-10.00 hrs). Pollen foragers spent maximum in M1 condition with highest of 48.33 sec followed by M2

TABLE VII  
*Mean time spent (in secs) by A. cerana colony under enclosed condition + removal of auxillary buds (RAB) across different planting ratios*

Source of Variance	Mean time spent on flowers (sec)							
	Nectar foragers				Pollen foragers			
	M1	M2	M3	M4	M1	M2	M3	M4
06.00-07.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07.00-08.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08.00-09.00	12.67	2.67	0.00	14.67	7.67	0.00	0.00	0.00
09.00-10.00	103.00	2.33	3.67	194.00	27.67	2.67	0.00	0.00
10.00-11.00	190.67	2.00	0.00	228.67	40.33	0.00	2.00	0.00
11.00-12.00	199.00	0.00	2.33	237.33	39.33	1.33	0.00	0.00
12.00-13.00	218.67	2.33	0.00	177.00	31.67	0.00	0.00	0.00
13.00-14.00	187.00	2.67	1.67	193.67	48.33	0.00	0.00	0.00
14.00-15.00	170.00	0.00	0.00	141.33	36.00	2.67	1.33	0.00
15.00-16.00	168.00	1.67	0.00	169.67	41.67	0.00	0.00	0.00
16.00-17.00	140.67	2.00	2.67	153.67	42.00	3.00	0.00	0.00
17.00-18.00	128.33	0.00	0.00	157.33	31.67	0.00	0.00	0.00
18.00-19.00	113.67	0.00	0.00	117.67	5.33	0.00	0.00	0.00
Total	1631.67	15.67	10.33	1785.00	351.67	9.67	3.33	0.00
Mean±SE	125.51 ± 21.33	1.21 ± 0.33	0.79 ± 0.36	137.31 ± 22.81	27.05 ± 4.83	3.74 ± 0.33	0.26 ± 0.17	0.00 ± 0.00
% Time spent	47.40	0.46	0.30	51.85	96.44	2.65	0.91	0.00

Note: M1=Bee movement from male to male line, M2=Bee movement from male to female line, M3=Bee movement from female to male line and M4=Bee movement from female to female line

with 3.00 sec (16.00-17.00 hrs) and M3 with 2.00 sec (10.00-11.00 hrs) (Table VII). The study conducted was novel in which no supporting findings were reported.

The overall findings of the study implied that, nectar foraging bees spent more or less equal time on both male (RHA) and female (CMS) parental lines, as compared to pollen foragers. In nectar foragers, M4 situation recorded highest mean time spent, because only nectar is produced in A line (M4), this was followed by M1 situation wherein both nectar and pollen are produced. In M2 and M3 situation, least time was spent by bees because, bees switched over from R line to A line and *vice-versa*. There was a sudden movement of bees and the condition where

time spent was very less and bees moved away, this can be attributed to floral constancy of bees. In the condition where auxillary buds were removed, the R line looked morphologically almost similar to the A line.

In a nut shell, the results of this investigation showed that, cross movement of nectar foraging bees was observed in 1:5 row ratio when enclosed with *A. cerana* + removal of auxillary buds of R line (RAB) condition. Besides, the bees tend to spend more time in nectar foraging. This is likely to play a key role in transfer of pollen from R line to A line. This could be further exploited fruitfully for hybrid seed production programmes in sunflower.

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