HONEYBEE (*APIS* SPP.) POLLINATION IN SUNFLOWER HYBRID SEED PRODUCTION: EFFECT OF PLANTING DESIGNS ON HONEYBEE MOVEMENT AND ITS OPERATIONAL AREA

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Introduction

Sunflower is the second most important oilseed crop of the world next to soybean. It is an important crop in temperate countries like Russia, Bulgaria, Romania, Canada and the USA. In view of non-cholesterol and anti cholesterol properties, demand for sunflower oil in the world market, is increasing day by day. In India it was grown over an area of 1.33m ha in 1999-2000 with production of 0.8 m tonnes and productivity of 601 kg/ha.

Hybrid seed in sunflower is produced by exploitation of Cytoplasmic Genetic Male Sterility (CGMS). The CMS line (A line) is pollinated with maintainer line (B line) for its maintenance and with restorer line (R line) for hybrid seed production. In both cases, pollen is transferred across line. Sunflower pollen is heavy and sticky so cannot be carried by wind. Honeybees are the main agency responsible for transfer of pollen from male to female line. Most of the time, phantom seed set, that is no kernel inside seed coat or unfilled seeds, occurs mainly due to inadequate pollination.

Generally A and R lines are planted in separate rows in a particular planting ratio for commercial hybrid seed production. PARKER (1981) reported indiscriminate movement of honeybees between male and female flower heads. This nature of nectar collecting honeybees can be exploited in pollen transfer from R line to A line by manipulating location of these plants in the seed plot. SEETHARAM and SATYANARAYANA (1983) observed higher seed setting in rows of A line flanked by pollen parent (R line) on one or both sides. This indicated that honeybees transferred pollen more efficiently on plants nearer to pollen source. So an alteration in relative position of A and R line plants (planting design) is required to increase number of A line plants flanked by pollen parent on at least one side, without change in proportion of the parental lines.

For this the R line row may be fragmented in small blocks and such blocks can be located uniformly in A line rows. The R line row may be further fragmented in to the smallest blocks (i.e. blocks having one plant only) and these blocks can be placed randomly in seed parent rows. In other words seeds of A and R lines can be mixed for sowing. This will increase proportion of seed parent plants flanked by pollen parent on at least one side. In sunflower, the R line plants can be easily identified on morphological basis because the restorer lines of most of the released hybrids are multi-branched and have many flower heads as against mono-branch and single flower head of seed parent line. So the R line plants may be completely removed from seed plot once pollination is over. This will eliminate chances of mechanical mixing of R line seed with that of hybrid seed.

Materials and Methods

The experiment was conducted using parental lines (seed parent : CMS 7-1A, and pollen parent : RHA 271) of a public sector sunflower hybrid APSH 11, during Rabi-spring of 1999-2000 and 2000-2001 at the farm of IARI, Regional Station, Karnal (India). The parental lines were sown in planting ratio of 1R : 3A, 1R : 5A and 1R : 8A each with isolation of more than 600m. The seed crop was sown on ridges by dibbling in rows of five-meter length on 15th and 19th January 2000 and 2001, respectively. The rows were kept 60cm apart while plant-to-plant distance was 30cm. There were three planting designs in each planting ratio.

The planting designs were:

- separate rows (D1): The seed parent and pollen parent were planted in separate rows.
- mixed planting (D2): The parental lines were planted in mixture.
- blocks (D3): The pollen parent plants were planted in blocks scattered uniformly in the seed plot.

Observations on honeybees (*Apis mellifera*) were made for 15 minutes in each planting design in all the planting ratios between 0900 to 1100 hr for their movement and operational area. The pollen and nectar collecting bees were counted separately. The honeybees with pollen in their pollen basket were recorded as pollen gatherer while others as nectar collector. The data were pooled over planting ratios to see effect of the three planting designs. The movement of pollen as well nectar-collecting bees were grouped in to four.

M1 : Honeybees moving from male to male line flower head.
M2 : Honeybees moving from male to female flower head.
M3 : Honeybees moving from female to male flower head.
M4 : Honeybees moving from female to female flower head.

A honeybee foraging on male line flower head was continuously watched until it left that flower head and landed on another, for operational area. The distance covered by the bee in such flight was measured; and the number of flower heads flown over in the flight was counted. The bee that hopped to next plant was considered landed on the "nearest plant", and on the "distant plant" when one or more plants were flown over in the flight.

Five female flower heads at different distances (30, 60, 120 and 180 cm) from male plants were tagged in different planting designs in planting ratio of 1R : 8A. These plants were harvested and threshed individually to calculate per cent seed setting.

Per cent seed setting = (number of filled achenes/no. of filled + unfilled achenes) X 100

Results and Discussion

Honeybee movement

Movement of honeybees in sunflower hybrid seed plot is defined as flight of a honeybee from one flower head to another irrespective of distance and parental line. In hybrid seed production since two parental lines are planted, there are four combinations of flower heads and movement of honeybees. The pollen gathering bees confined their activities on male flowers and showed little interest in nectar or its movement towards female line. Also, it was observed that pollen gatherers collected pollen from top of the anther tube and packed it in their corbicula, which was of no use for pollination. Therefore, they were considered less important from the point of view of pollination. On the contrary, the nectar collectors get dusted with pollen while pushing their head and tongue down between corollas and anther tubes (FREE, 1964). Thus results on only nectar collecting and the total bees are being presented and discussed herein for their movement.

Table I

Effect of planting designs on movement of *Apis mellifera* in parental lines of sunflower hybrid APSH 11

Planting designs	Number of *Apis mellifera* in 2000							
	Nectar collector				Pollen or nectar collector			
	M1	M2	M3	M4	M1	M2	M3	M4
Separate rows (D1)	31	22	19	57	46	26	20	58
	(24)	(17)	(15)	(44)	(31)	(17)	(13)	(39)
Mixed planting (D2)	38	25	11	47	47	27	13	47
	(31)	(21)	(9)	(39)	(35)	(20)	(10)	(35)
Blocks (D3)	36	19	22	42	47	24	24	45
	(30)	(16)	(18)	(35)	(34)	(17)	(17)	(32)
Mean	35	22	17.3	48.7	46.7	25.7	19	50
	(28)	(18)	(14)	(40)	(33)	(18)	(13)	(35)
	Number of *Apis mellifera* in 2001							
Separate rows (D1)	21	5	4	25	24	5	4	25
	(38)	(9)	(7)	(45)	(41)	(9)	(7)	(43)
Mixed planting (D2)	15	9	6	28	17	9	6	28
	(26)	(16)	(10)	(48)	(28)	(15)	(10)	(47)
Blocks (D3)	18	7	3	23	22	7	3	23
	(35)	(14)	(6)	(45)	(40)	(13)	(5)	(42)
Mean	18	7	4.3	25.3	20	7	4.3	25.3
	(33)	(13)	(8)	(46)	(35)	(12)	(8)	(45)
	Frequency (%) of *Apis mellifera* (average over years)							
D1	31.0	13.0	11.0	44.5	36.0	13.0	10.0	41.0
D2	28.5	18.5	9.5	43.5	31.5	17.5	10.0	41.0
D3	32.5	15.0	12.0	40.0	37.0	15.0	11.0	37.0
Mean	30.7	15.5	10.8	42.7	34.8	15.2	10.3	39.7

The parentheses are the percentage values. M1= movement from male to male, M2= male to female, M3= female to male, and M4= female to female

The frequencies of total honeybees (Table I) moving with in the parental lines (M1 + M4) were 68 and 80% and those moving across line (M2 + M4) were 31 and 20% in 2000 and 2001, respectively. The mean over planting designs indicate that 33 and 35% of the honeybees moved with in male parental line (M1) and 35 and 45% moved with in female parental line (M4) in the year 2000 and 2001, respectively. The frequencies of honeybees moving from male to female line (M2) were 18 and 12% while those moving from female to male (M3) were 13 and 8% in the two years. Nearly 30% of the nectar collecting bees (average over designs and years) moved with in male line. The frequency of bees (average over years) with M1 movement was the lowest (28.5%) in D2 (mixed planting) as against 31% in D1 (separate rows) and 32.5% in D3 (blocks). The low frequency of bees moving with in male line in mixed planting may be because of male line plants being scattered in this design. In hybrid seed production movement of bees from male line to female line (M2) is most important from pollination point of view. The frequency of nectar collecting honeybees moving from male to female line (M2) was the highest (21 and 16%) in D2 followed by D3 (16 and 14%) and then D1 (17 and 9%) in 2000 and 2001, respectively. The mean values over planting designs reveal that only a small fraction (12 18%) of the total honeybees moved from male to female parent flower heads. DEGRANDI HOFFMAN and MARTIN (1993) reported 6.5 to 12.8% frequency of bees moving from male to female while MUÑOZ RODRIGUEZ (1979) reporting it to 4.2% only. Proportion of total honeybees (pollen or nectar collector) was also maximum (17.5%) in D2 as against 15 % in D3 and 13% in D1 (average over years). The higher frequency of honeybees with such behaviour (M2) was because the male line plants were surrounded all around by the female line plants in mixed planting.

Movement of honeybees from female to female line flower head is also critical for pollination as pollen transferred vertically from male to female may also spread horizontally from female to female line. DEGRANDI HOFFMAN and MARTIN (1995) in their studies observed that honeybees foraging on male sterile plants obtained much of the sunflower pollen on their bodies from previously visited male sterile capitula. A large number of bees moved with in female line in all the planting designs in the present study. The frequency of nectar collecting honeybees with such behaviour (M4) was the highest in D1 (44.5%) closely followed by D2 (43.5%) and then D3 (40%) over the two years. The high frequency in D1 was because all the female plants are planted together.

Operational area

Higher is the number of seed parent plants, better will be the seed yield per unit area if yield per plant does not change. So planting ratio of female to male line is important. It is decided by pollen production in R line and its dispersal by pollinators. Operational area of honeybees means by how far it spreads pollen for effective pollination. In the present study, the operational area was estimated in three different ways.

1. Flight distance: Flight distance is the distance between two successively visited flower heads. The data (Table II) revealed that the largest proportion (41 and 52%) of bees operated with in 30cm followed by 31-60 cm (20%) , 61-90 cm (13 and 18%) and then beyond 90 cm (18-20%) in the year 2000 and 2001, respectively. RIBBANDS (1964), reported honeybees to restrict their foraging (operational) area in small patches when flowers were abundantly available and foraged with in rows of plants. SEETHARAM and SATHYANARAYANA (1983) reported higher seed setting on A line rows flanked by R line rows on one or both sides, indicating that honeybees operated on the nearest plants. Highest frequency (72%) of pollen gathering bees operating with in 30 cm was observed in D1 followed by 60% in D3 and 22% in D2 in the year 2000. In the second year only a little number of honeybees foraging for pollen was observed. The high frequency of pollen gathering bees operating with in 30 cm in D1 planting design was because all the male plants are planted nearby. Beyond 90 cm, frequency of both nectar collecting and pollen gathering bees was maximum in D2 planting design (25 and 33%) followed by D3 (13 and 20%) and then D1 (13 and 11%) in the year 2000. Similar trend for the three planting designs was observed in the second year (2001) also. This suggests suitability of mixed planting in wider planting ratios because the distance between male and female is more.

Table II

Effect of planting designs (D) on frequency of honeybees with different flight distances in seed production plot of sunflower hybrid APSH 11

Planting designs	Number of *Apis mellifera* (2000)											
	Flight distance (cm) of											
	Pollen gatherer (P)				Nectar collector (N)				Total (P+N)			
	<30	31-60	61-90	>90	<30	31-60	61-90	>90	<30	31-60	61-90	>90
Separate rows	13	3	0	2	6	4	3	2	19	7	3	4
(D1)	(72)	(17)	(0)	(11)	(40)	(26)	(20)	(13)	(58)	(21)	(9)	(12)
Mixed planting	2	1	3	3	10	3	2	5	12	4	5	8
(D2)	(22)	(11)	(33)	(33)	(50)	(15)	(10)	(25)	(41)	(14)	(17)	(28)
Blocks	6	2	0	2	13	6	2	3	19	8	2	5
(D3)	(60)	(20)	(0)	(20)	(54)	(25)	(8)	(13)	(56)	(24)	(6)	(15)
Mean	7	2	1	2.3	9.7	4.3	2.3	3.3	16.7	6.3	3.3	5.7
	(57)	(16)	(8)	(19)	(49)	(22)	(12)	(17)	(52)	(20)	(10)	(18)
	Number of *Apis mellifera* (2001)											
Separate rows	0	2	1	1	17	6	6	4	17	8	7	5
(D1)	(0)	(50)	(25)	(25)	(52)	(18)	(18)	(12)	(45)	(22)	(19)	(14)
Mixed planting	0	2	0	3	14	6	7	8	14	8	7	11
(D2)	(0)	(40)	(0)	(60)	(40)	(17)	(20)	(23)	(35)	(20)	(18)	(27)
Blocks	5	0	1	1	11	7	6	6	16	7	7	7
(D3)	(71)	(0)	(14)	(14)	(37)	(23)	(20)	(20)	(43)	(19)	(19)	(19)
Mean	1.7	1.3	0.7	1.7	14	6.3	6.3	6.0	15.7	7.7	7	7.7
	(32)	(25)	(13)	(32)	(43)	(19)	(19)	(18)	(41)	(20)	(18)	(20)

The parentheses are the percentage values

2. Landing of honeybees on nearest/distant flower head: Immediately after visiting male flower, where does a honeybee land next, is very important for effective pollination. After taking off from male flower head, when the bee flew over no plant, it was taken as landing on nearest plant. But when it flew over at least one plant, it was taken as landing on distant plant. Nearly 83% (Table III) of nectar collecting and 64% of pollen gathering honeybees hopped to the nearest plant perhaps to save energy. ROBINSON (1984) also reported that honeybees after finishing work on male plant are more likely to move to the nearby than to a remote male sterile plant. Around 55% of the pollen gathering bees landed on the nearest plant in D2 as against 62.5% in D1 and 75.5% in D3 (average over years). Less number of the honeybees in D2 was because the pollen plants are scattered in the plot. Very high frequency of nectar collecting bees landing on the nearest plant in all the three planting designs was because of indiscriminate movement of these bees between male and female flower heads.

Table III

Frequency (%) of honeybees landing on nearest/distant flower heads in different planting designs after taking off from pollen parent of sunflower Hybrid APSH 11

Planting designs	Frequency (%) of honeybees (over years) landing on					
	Nearest flower head			Distant flower head		
	P	N	T	P	N	T
Separate rows (D1)	62.5	88.5	83.0	37.5	11.5	17.0
Mixed planting (D2)	55.0	82.5	77.0	45.0	17.5	23.0
Blocks (D3)	75.5	77.5	76.5	24.5	22.5	23.5
Mean	64.3	82.8	78.8	35.7	17.2	21.2

Where, P= pollen gatherer, N= nectar collector and T= total (P+N)

3. Seed Setting at various distances from pollen parent: Generally availability of pollen is not a problem in sunflower as a single plant produces very large number (125-250 million) of pollen grains (DEODIKAR et al., 1977). There was decline in seed setting as distance from pollen source was increased (Figure 1). The magnitude of decline in seed set with increasing distance from pollen source was lower in D2 as compared to D3 and D1. It may be due to more scattered pollen plants in this design. ROBINSON (1984) and SKINNER (1988) also found decline in seed yield with increase in distance from pollen source.

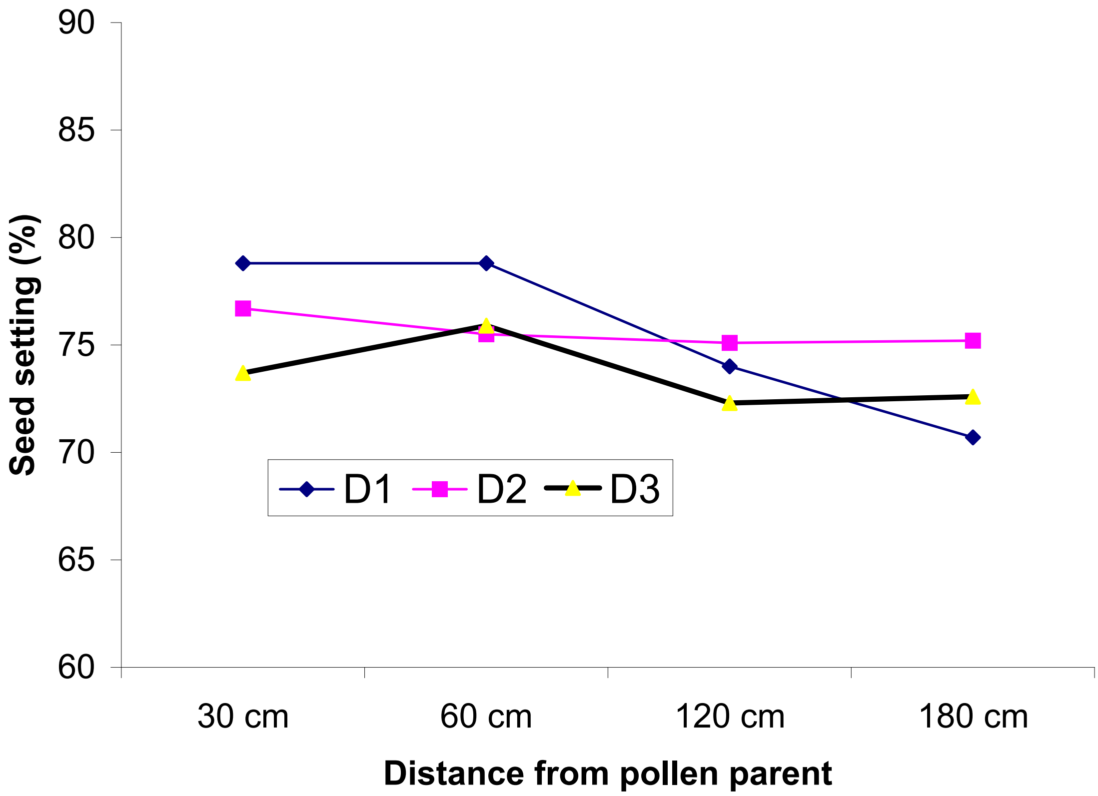

Figure 1 - Seed setting (%) in female parent at various distances from pollen parent

The results on seed setting and operational area of honeybees in different planting designs suggest that plant populations of female and male parents can be accommodated in wider planting ratios following mixed planting (D2) with lesser loss in seed set. This design is, of course, operationally tedious and requires more attention of the seed producer. Hence, higher seed yield per unit area can be realised with a little compromise in operational ease in seed production by sowing, in mixture, the parental lines in wider planting ratios.

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