SEED SETTING AND FILLING PROBLEM IN SUNFLOWER AND ITS MANAGEMENT

SEMINAR WRITE UP

SUBMITTED TO

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ABSTRACT

Seed setting and filling problem is one of the most important constraints in sunflower production and often considered to be a major reason for low productivity. Besides poor agronomic management, there are several genetic, physiological and environmental factors causing poor seed setting and filling in sunflower.

The sporophytic type of self-incompatibility mechanism is one of the genetic reasons for poor seed setting in sunflower (Chopra, 2001). One of the means to alleviate this problem is to identify the self-fertile lines and thus increase seed set and productivity (Rathod *et al.*, 2002).

The physiological mechanisms that regulate seed setting and filling in sunflower are complex. Studies carried out on source-sink relationship and photoassimilate distribution pattern revealed that the photoassimilate supply in the capitulum largely depends on the phyllotaxy of source leaves and the position of sinks in developing inflorescences. A higher proportion of empty achenes (up to 60%), especially in the centre of capitulum result from source limitation. During seed filling, maximum import of photoassimilate appeared in intermediate whorls, while central whorls always exhibited the lowest import leading to poor seed filling (Alkio *et al*., 2002; Alkio *et al*., 2003). Nanja Reddy *et al*. (2003) reported that biomass production after anthesis has a significant role in seed setting and filling in sunflower, therefore, increasing post anthesis biomass, reducing thalamus weight and increasing partitioning of photosynthates to sink by applying TIBA alone or TIBA with NAA would result in higher seed yield. A new chemical Brassinolide (1 ppm) sprayed in combination with fertilizers (N: P: K at 70:35:35: kg/ha, respectively) at the ray floret opening stage led to the highest filled seeds percentage (Chinnamuthu *et al*., 2000). The studies carried out on correlation of the metric traits helped in identifying the characters associated with seed setting and filling. The number of filled seeds per head can be increased up to a certain limit by increasing stem girth and head diameter (Ravi *et al*., 2006).

Good agronomic practices play an important role in production and productivity of any crop. A crop geometry of 60 cm x 20 cm recorded significantly higher values of growth and yield attributes and seed yield compared to 40 cm x 30 cm (Patel and Thakur, 2003). To get synchronized flowering of male and female plants, sowing of male parent seven days early recorded higher seed setting and filling in RSFH-1 sunflower (Umesh *et al*., 2007). Water stress caused by deficit irrigation from early flowering to early seed formation leads to reduced LAI and thus reduces yield attributes (Mohan Reddy *et al*., 2003). Application of insecticides affects the pollinators visit and pollination thus decreases the seed yield of sunflower (Jyothi, 2004).

Potential yield of sunflower is highly dependent on environmental conditions during life cycle of the crop. Most of the research workers (Chaudhary and Anand, 1989; Sumangala and Giriraj, 2003; Umesh *et al*., 2007) reported summer or *rabi* season better than *kharif* because of better environmental conditions. Pollinators (Honeybees) are also influenced by weather conditions. Precipitation had negative impact on honeybees visit. The most frequent visits were estimated at 20 to 25^0C and humidity at 65-75% (Puskadija *et al*., 2007).

Based on the above mentioned discussion it can be concluded that breeding for the fertile lines, plant physiological manipulations, environmental control and good agronomic management can alleviate up to some extent the problem of seed setting and filling in sunflower.

Introduction

- Sunflower was introduced in India during 1969 and to start with four Russian varieties and one Canadian variety were evaluated in various parts of the country.
- The commercial cultivation of this crop started in 1972. Presently, the crop is cultivated in an area of 20.7 L. hectares with a production of 12.5 L. tonnes.
- The crop is fourth most important oilseed crop in the country after groundnut, rapeseed-mustard and soybean.
- The phenomenal increase in area and production of sunflower in the country since its introduction is due to following merits of the crop.

Importance of the crop

- Wide adaptability or wide-ranging agro climatic conditions and soil type.
- Short duration (90-100 days) which enables fitting in different cropping systems.
- Photo-insensitivity which enables its cultivation in rainy, post-rainy and spring/summer seasons.
- Availability of varieties/hybrids with diverse duration and high yield potential which enables the crop to fit into multiple and intercropping systems.
- Easy cultivation and crop management.
- High seed multiplication ratio of more than 1:80. Drought tolerance and the ability to revive rapidly after prolonged period of drought.
- Ideal crop for contingency plans. Remunerative market price.
- Good quality oil with high polyunsaturated fatty acids and non-cholesterols properties.

The increase in the productivity of the crop during the last 7-8 years was mainly due to continuous increase in sunflower area in high productive zones in North India. If one considers the changes in sunflower productivity in traditional areas of Karnataka, Maharashtra and Andhra Pradesh which account for nearly four-fifths of total crop area, the situation is really not gratifying. This is because the crop suffers from several production constraints of different kinds mainly in these traditional areas.

Production constraints

- Planting material constraints
- Crop adoption constraints
- Crop husbandry constraints
- Nutrition constraints
- Plant protection constraints
- Seed setting and filling constraints

Among all the above-mentioned constraints seed setting and filling is the most important constraint generally faced by sunflower growers.

Following are major factors causing seed setting and filling problem in sunflower

(A) GENETIC

- Low autogamy (Protandrous nature)
- Self-incompatibility (Combining ability)

$$\text{Autogamy \%} = \frac{\text{\% seed set under autogamous pollination}}{\text{\% seed set under open pollination}} \times 100$$

(Autogamous pollination is pollination under just covering the head).

$$\text{Self incompatibility \%} = \frac{\text{\% seed set under assisted self pollination}}{\text{\% seed set under open pollination}} \times 100$$

(B) PHYSIOLOGICAL

- Poor vascularization
- High photorespiration
- Uneven distribution of photoassimilates
- Decreased translocation of photosynthates to sink (source limitation)

(C) ENVIRONMENTAL

-Abiotic stresses

- Season

(D) AGRONOMIC MANAGEMENT

(E) POLLINATION MANAGEMENT

(A) GENETIC FACTORS AND THEIR MANAGEMENT

(i) Low autogamy

Low autogamy is one of the genetic reasons for poor seed setting and filling in sunflower. Therefore, evaluation of hybrids and their parental lines for their autogamy becomes necessary before releasing any genotype or hybrid. Rathod *et al*. (2002) in one of the autogamy study in sunflower reported that hybrid produced significantly more autogamous seeds over better parent (Table-01). Therefore, it suggested that one should grow hybrids for commercial cultivation of sunflower.

Table: 01. Autogamy studies of sunflower genotypes under bagged and open conditions

Genotypes	% of filled seed set under bagged condition		% seed set under open pollination		Autogamy percentage	
	1998-99	1999-2000	1998-99	1999-2000	1998-99	1999-2000
PKVSH-40	54.45	52.15	84.16	80.07	64.82	65.09
336-B	40.08	37.65	78.86	75.07	50.86	51.87
270-R	45.61	40.23	79.00	75.20	57.72	53.65
PKVSH-41	54.56	51.2	85.02	81.15	64.16	59.64
IB-60-B	40.70	41.26	84.00	80.16	48.46	51.59
IBK-196/2R	36.95	40.64	79.94	76.32	46.23	53.65
PKVSH-27	59.30	59.00	88.93	84.90	66.67	69.76
CMS-2B	42.99	41.86	70.90	77.07	53.08	54.39
AK-1R	46.10	42.63	78.93	75.01	58.35	57.11
CD at 5%	8.432	5.457	2.866	-	10.483	-

Rathod *et al*., 2002

(ii) Self-incompatibility

Self-incompatibility is the inability of fully functional pollen grains to fertilize and seed set on self-pollination. Self-incompatibility of sporophytic nature is reported in sunflower that is major cause for poor seed setting in the crop. Identification of self-fertile lines is one of the means for improving seed setting and productivity in sunflower. Combining ability analysis helps in the identification of suitable parents for further exploitation in breeding programme. Vara Prasad *et al*. (2006) in one of this type of study reported that hybrids are generally more vigorous, uniform, self fertile and resistant to many pests and diseases. In their study the cross combinations, DCMS-18 x DSI 216, DCMS-23 x DSI 180 and DCMS-14 x DSI 220 were found to be the best specific combiners for most of the yield and yield contributing characters (Table-02). It is therefore, suggested that hybrids/genotypes should be tested for their combining ability prior to grow for commercial purpose.

Table: 02. Specific combining ability for seed yield attributes

Cross	No. of filled seeds	100 seed weight (g)	Seed yield per plant (g)
DCMS-18 x DSI-204	174.25	0.28	10.78
DCMS-18 x DSI-216	213.25	0.91	16.43
DCMS-23 x DSI-180	49.57	0.08	2.48
DCMS-23 x DSI-208	62.57	-0.10	2.31
DCMS-14 x DSI-220	377.64	0.29	17.45
DCMS-14 x DSI-225	191.81	0.52	13.51
SE±	23.50	0.10	0.83

Vara Prasad *et al*., 2006

(iii) Breeding on the basis of character association

Seed yield is a complex character governed by several contributing characters. Hence, character association study becomes useful to assess the relationship among yield and its components for enhancing the usefulness of selection criterion to be followed while developing varieties. Ravi *et al*. (2006) reported a strong positive association of seed yield with filled seeds/plant, seed set percentage, head diameter and harvest index (Table-03). They suggested that selection for high number of filled seeds/capitulum, moderate capitulum diameter, more test weight, medium plant height with more leaf area and high total drymatter/plant would be effective for improving the seed yield in sunflower.

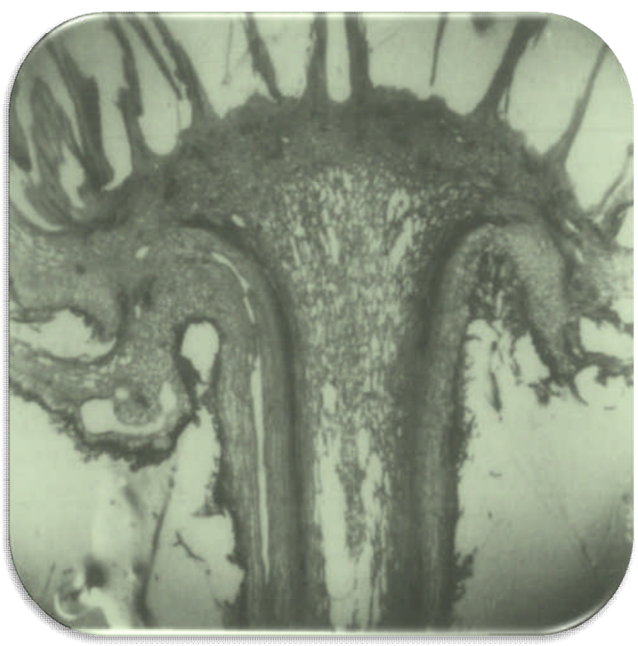
Table: 03. Correlation coefficients (P&G) between yield and yield contributing characters in sunflower

Character		Head diameter (cm)	100-seeds weight (g)	Total dry matter per plant (g)	Filled seeds per plant	Unfilled seeds per plant	Seed set (%)	Seed yield per plant (g)
Plant height (cm)	**P**	**0.39**	**0.26**	**0.34**	**0.19**	**0.09**	**0.12**	**0.37**
	G	**0.40**	**0.27**	**0.35**	**0.20**	**0.12**	**0.12**	**0.38**
Head diameter (cm)	**P**	**1.00**	**0.10**	**0.25**	**0.57**	**-0.14**	**0.46**	**0.59**
	G	**1.00**	**0.11**	**0.25**	**0.60**	**-0.25**	**0.54**	**0.61**
100-seeds weight (g)	**P**		**1.00**	**0.39**	**-0.04**	**-0.06**	**0.10**	**0.45**
	G		**1.00**	**0.41**	**-0.05**	**-0.13**	**-0.05**	**0.47**
Total dry matter/plant (g)	**P**			**1.00**	**0.20**	**0.16**	**0.15**	**0.44**
	G			**1.00**	**0.21**	**0.24**	**0.07**	**0.45**
Filled seeds/plant	**P**				**1.00**	**-0.21**	**0.65**	**0.81**
	G				**1.00**	**-0.30**	**0.70**	**0.82**
Unfilled seeds/plant	**P**					**1.00**	**-0.45**	**-0.15**
	G					**1.00**	**-0.77**	**-0.24**
Seed set (%)	**P**						**1.00**	**0.53**
	G						**1.00**	**0.55**

P= Phenotypic; G = Genotypic Ravi *et al.*, 2006

(B) PHYSIOLOGICAL FACTORS AND THEIR MANAGEMENT

(i)Vascularization



Several possible physiological reasons may be responsible for empty achenes in the capitulum of sunflower. Goffner *et al.* (1988) illustrated the ^{14}C partitioning in developing sunflower seeds and reported that peripheral seeds were more developmentally mature than intermediary and central seeds. This developmental gradient is due to the poor vascularization of the central flower head. There are no vascular bundles present in the centre of the flower head (figure-1). Therefore, intermediary and centrally located seeds must receive solutes indirectly by horizontal transport from peripherally located vascular bundles. However, it is interesting to note that centrally located seeds are able to 'catch up' with peripheral seeds during mid-flowering stage.

Figure-1. Light micrograph of sunflower capitulum (x 6). After staining with Safranin red/Fast green, the darkened vascular bundles are readily visualized.

Beltrano *et al*. (1994) applied foliar spray of gibberellic acid (GA) and benzyladenine (BA) for enhancing vascular connections between the outer and inner parts of the capitulum and to increase grain yield by reductions in the percentage of empty achenes in the inner portion of the capitulum. They reported that BA 150 mg/l + GA 150 mg/l applied at 40 days after emergence significantly reduced the percentage of empty achenes and increased achene weight (Table-04).

Table: 04. Characteristics of the capitulum after foliar application of BA and GA to hybrid SPS 894

Treatments	Inner portion of the Capitulum			1000 achene weight (inner)
	Empty achenes (%)	Achene weight (g)	Achene number	
control	30a	6.5a	220a	29.5a
20 days after emergence				
GA 150	26a	6.4a	223a	28.7a
GA + BA 150	26a	7.5a	235a	31.2ab
BA 150	27a	8.3b	203a	40.1c
BA 250	24ab	9.2c	237a	38.8c
40 days after emergence				
GA 150	27a	6.2a	243a	25.5a
GA + BA 150	13c	8.0b	250b	32.1ab
BA 150	17b	7.0b	233a	33.2b
BA 250	21b	7.7b	251b	27.9a
60 days after emergence				
GA 150	28a	7.1b	240a	29.6a
GA + BA 150	29a	7.1b	245ab	22.6a
BA 150	20b	8.4c	269c	31.2ab

Averages followed by the same letter, in the same column are not significantly different (P=0.05)

Beltrano *et al*., 1994

(ii) High photorespiration

Though sunflower is C_3 plant there is a degree of wastage of photoassimilates due to photorespiration which can otherwise be utilized for building yields. Sairam and Srivastava (1984) measured photorespiratory activity in the leaves of two sunflower genotypes on the basis of glycolate oxidase and catalase activities. The activity of both the enzymes was found to be comparatively higher throughout the growth period in Orange Red, a low yielding genotype as compared to EC 68413 a comparatively better yielder, at post flowering and particularly at the time of seed filling. (Table-05)

Table: 05. Glycolate content at various stages of growth and development (values are mean of three observations and expressed as mg per gram fresh weight of leaf)

Variety	Days after sowing						
	15	30	45	60	75	90	105
Orange Red	2.53±0.05	3.26±0.02	2.90±0	3.46±0.02	2.35±0.07	2.50±0	2.80±0.04
EC 68413	3.41±0.02	3.55±0.04	3.30±0	4.76±0.02	3.53±0.05	4.11±0.10	3.63±0.02

Sairam and Srivastava, 1984

(iii) Sectorial photoassimilate distribution pattern

Alkio *et al*. (2002) investigated the Photoassimilate transport from source leaves to the capitulum in sunflower (*Helianthus annuus*) during anthesis and seed filling and found that a single floret is typically connected with the leaves of three neighbouring ortostichies in sunflower. The upper 10 (to 15) leaves mainly exported photoassimilates into the capitulum. Photoassimilate distribution patterns were sectorial: each leaf supplied a defined 2/8–3/8 sector of the capitulum (Figure-03). During early and late stages of anthesis, strong sinks were staminate florets and young achenes, respectively. During seed filling, an import maximum and minimum appeared in the intermediate and central whorls, respectively (figure-04). They concluded that photoassimilate distribution patterns demonstrated here generally might reflect the functional relationships between the phyllotaxy of source leaves and the position of sinks in developing inflorescences.

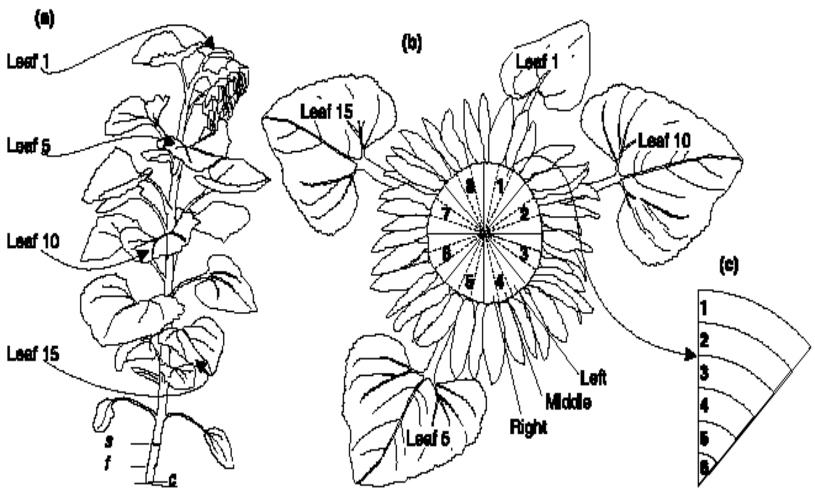


Fig.02 Nomenclature in 13/14C-photoassimilate transport experiments. (a) Typical sunflower plant used, total number of leaves ranged from 22 to 27 per plant; *c*, *f* and s, remnants of cotyledons, first and second pair of true leaves, respectively. Leaf positions were numbered basipetally; leaf 1 is the most apical true leaf clearly different from involucral bracts. A single leaf between 1 and 15 was exposed either to 13CO2 or 14CO2. (b) For 13C-analysis the capitulum was divided into eight main sectors (1–8), corresponding to the 3/8 phyllotaxy. The orientations of leaves 1, 5, 10 and 15 are shown in relation to the sectors. Each main sector was further divided into three subsectors (left, middle and right). (c) Sectors were divided into six zones (1–6)

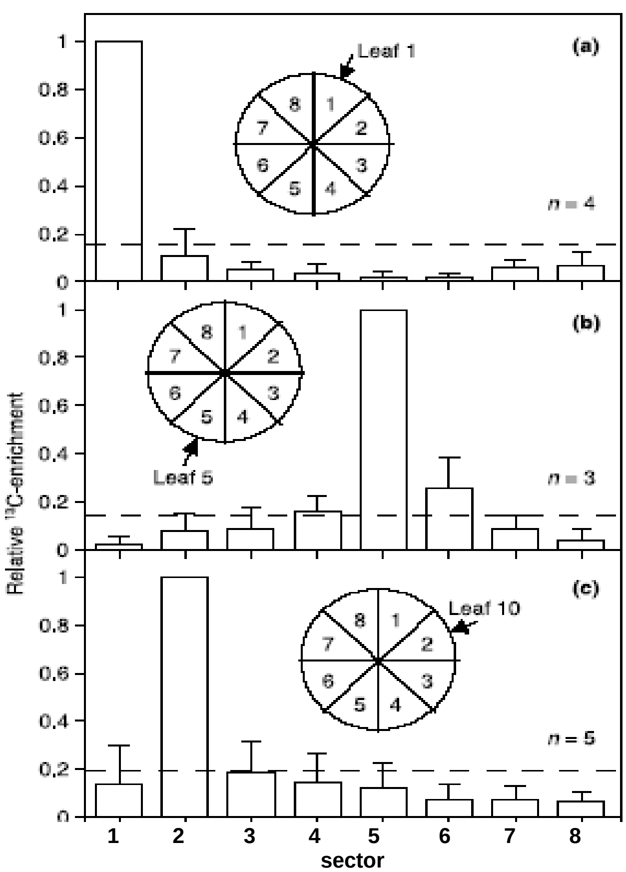


Fig. 03 Transport of photoassimilates into the sunflower capitulum following 13CO2-application to leaf 1, 5 and 10 at different stages of seed filling. The leaf chamber for 13CO2-exposure was fixed to the centre of the leaf blade. After a chase period of 24 h samples were taken from the capitulum and analysed for □13C using a mass spectrometer. For sampling and orientation of the exposed leaves, see Fig. 02. Data for the zones of maximum 13C-import are displayed for the middle subsectors (a–c). Background (dashed lines) = 2 [‰-points]/13Cmax [‰-points]; 13Cmax is the highest 13C-enrichment measured in the given capitulum.

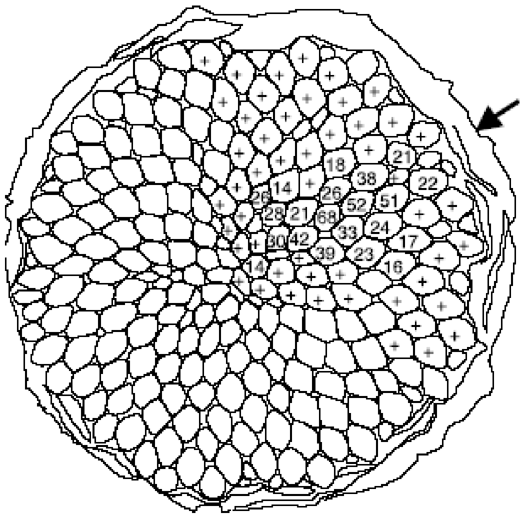
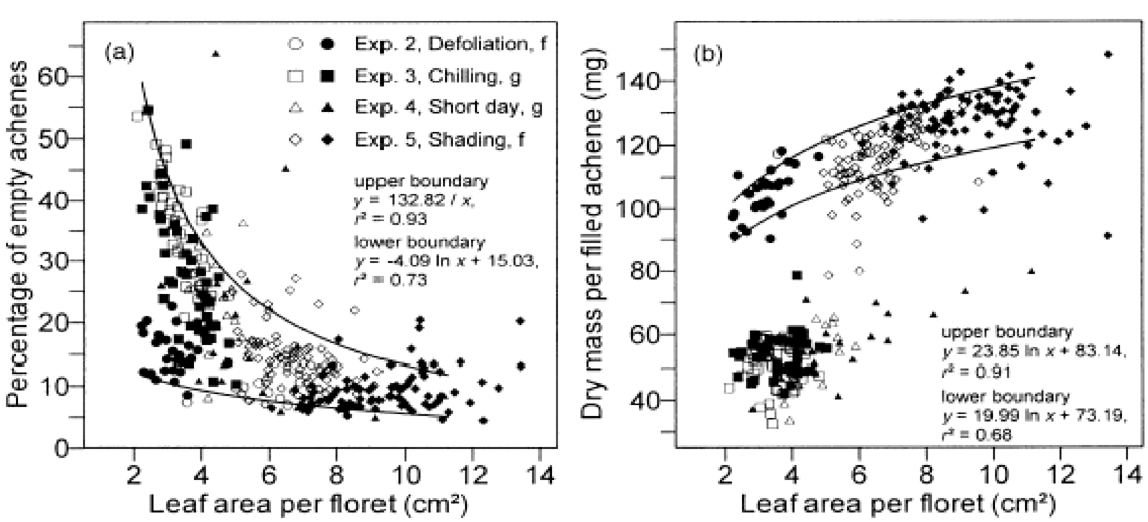


Fig. 04 Transport of photoassimilates into the sunflower capitulum following 14CO2-application to leaf during seed filling. The leaf chamber for 14CO2-exposure was fixed to the centre of the leaf blade. The arrow indicates the orientation of the insertion site of the exposed leaf. After a chase period of 3 h every single achene was taken from the capitulum and analysed for radioactivity using a phosphorimager. The distribution pattern shown was obtained from one plant; altogether, nine plants were investigated, with similar results. Achenes without symbol, radioactivity < 1 PSL/mm; achenes with crosses, 1 PSL/mm < 14 PSL/mm; achenes with figures, radioactivity in PSL/mm; PSL = quantity of photostimulated luminescence.

(iv) Effect of source – sink ratio

Poor seed development in sunflower may result from insufficient assimilate supply (source limitation). To test this hypothesis, the effects of changed source–sink ratio on seed set (measured as percentage of empty achenes) and seed filling (measured as dry mass per filled achene) in individual plants were investigated by Alkio *et al*. (2003). Source–sink ratio, defined as leaf area per floret (LAF), was experimentally altered using invasive (floret removal, defoliation) and non-invasive (pulse of chilling, short days or shading during leaf or floret initiation) treatments. They reported that shading at floret initiation proved the most effective non-invasive method (figure 05). Generally, an increase, or decrease, in LAF improved, or impaired, both seed set and filling. Increasing LAF by 2.0 cm^2 [95% confidence interval (1.5, 2.5)] decreased the percentage of empty achenes by 36.9%-points (− 41.9, −30.9) and increased dry mass per filled achene by 20.1 mg (13.6, 26.7) in the capitulum centre. The effect of source–sink ratio on seed set was always strongest in the centre, whereas peripheral whorls were not affected (Figure 06). Achene mass was affected in all parts of the capitulum. They concluded that source limitation was a major cause for empty achenes in sunflower plants grown under non-stress conditions.

Figure 05. Plot of leaf area per floret versus percentage of empty achenes in the capitulum (a) and versus average dry mass per filled achene (b), data from experiments 2–5. Source–sink ratio is given as the green area of the upper 60% of the leaves per floret at the end of flowering. Achenes were counted and weighed at maturity. The lines represent the results of boundary line analysis selecting the minimum and maximum percentage of empty achenes (a) and average dry mass of a filled achene in field-grown plants (b). For calculation, 0.5/cm^2 intervals of leaf area per floret were used. Each symbol represents one plant; open symbols, control; filled symbols, treated; f, field-grown plants; g,greenhouse-grown plants; n = 343.



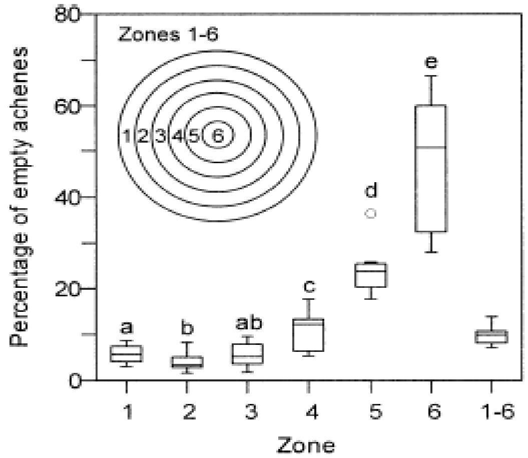


Figure 06. Percentage of empty achenes from total number of achenes in untreated, field-grown sunflowers. Achenes were counted in six zones of the capitulum (see inset) at maturity. Data are displayed as box–whisker plots, with minimum (lower whisker), 25th percentile (box, lower bound), median (line in box), 75th percentile (box, upper bound) and maximum (upper whisker). Values outside the interval [median ± 1.5 · (75th percentile − 25th percentile)] were defined as outliers (circles). Medians of data marked with the same letter are not significantly different ($P < 0.05$); $n = 10$.

(iv) Physiological approaches to improve seed setting and filling in sunflower

Based on several studies and reports Nanja Reddy *et al*. (2003) proposed a schematic figure for improving HI in sunflower (Figure 07). In which the possible approaches are (a) reducing thalamus weight, (b) increasing post anthesis biomass production and (c) increased partitioning of biomass to sink by improving sink characters. Figure 8a shows that high yielders maintain high HI mainly by decreased partitioning of biomass to leaf, stem and thalamus. A negative significant relationship was observed between percent biomass allocation to stem plus thalamus and grain yield (r=-0.82, P<0.05) or HI (r=-0.75, P<0.05) (Figure 8b). This indicates that the partitioning of dry matter to stem and thalamus should be less to achieve high HI. However, the exact percent of accumulation of biomass in stem plus thalamus must be optimized, since thalamus weight is also important as a space for putting a large seed number and stem to hold the weight of the seed-bearing head.

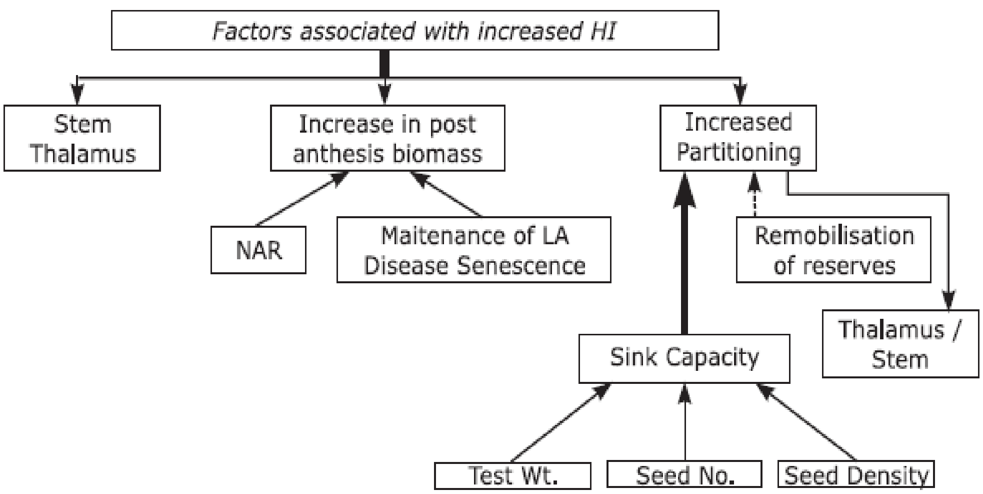


***Figure 07**: Schematic representation showing the factors associated with an increased harvest index in sunflower*

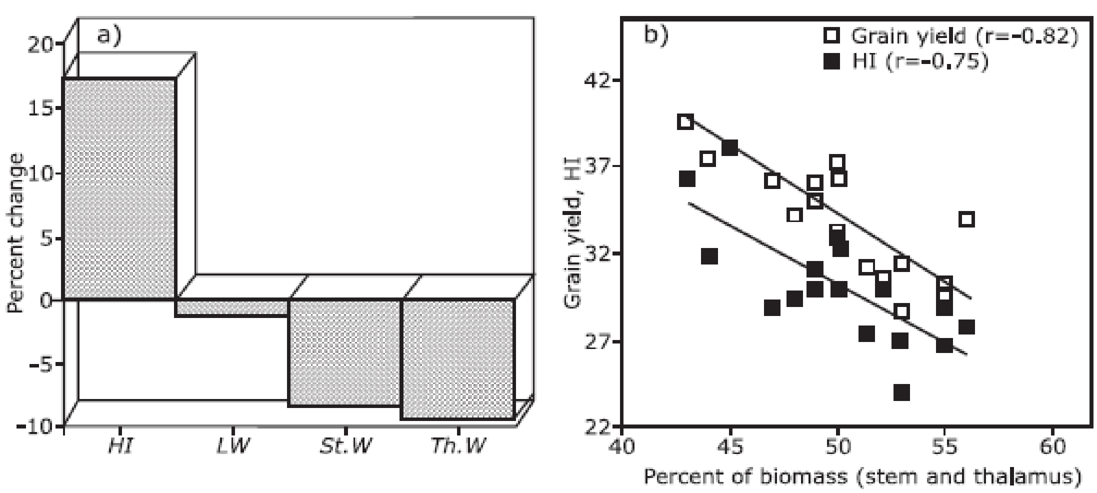
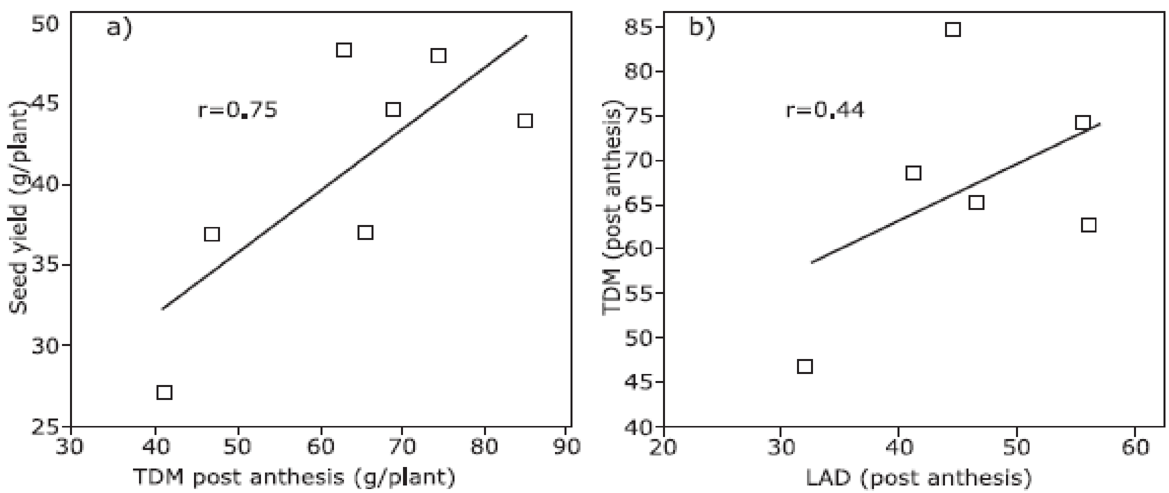


***Figure : 08** Comparative partition showing the factors associated with an increased harvest index in sunflower*

Another feature which determines the HI and productivity is the extent of post anthesis biomass production. In sunflower, by anthesis stage, vegetative growth and reproductive structures development is almost completed. Therefore, the dry matter produced after anthesis is probably allocated more towards seed filling process. Thus selecting a genotype for high biomass production during post-anthesis would result in high HI and seed yields. In their experiments with seven genotypes, they observed a highly positive significant relationship between seed yield and post anthesis dry matter (r=0.75, P<0.05) and the TDM with LAD (r=0.49, P<0.05) (Figures 9a and 9b). This indicates that the maintenance of high LAD during post- anthesis period either by decreased leaf senescence or by reduced leaf disease incidence. They emphasized that the maintenance of high post-anthesis LAD is an important prerequisite to achieve high productivity in sunflower.

Figure 09. Relationship between post-anthesis biomass production and seed yield (a) and post-anthesis LAD and post-anthesis dry matter production in sunflower (b)



Yet another parameter which influences HI is partitioning efficiency which is dependent on remobilization of reserved carbohydrates from stem and thalamus and the increased sink capacity. Exogenous application of growth regulators to the developing head was shown to increase the transport of photosynthate from leaf to the developing head. Tri-iodobenzoic acid (TIBA), an inhibitor of polar transport of auxins, increased the sink capacity of the head and thus movement of metabolites from vegetative organs to the head. Nanja Reddy *et al*. (2003) reported that application of TIBA alone or TIBA with NAA increased seed yield by 29 and 34% respectively (Table 06).

Table 06: Effect of TIBA and NAA application on sink characters and seed yield of sunflower (cv. Morden) at constant source size

Treatment	Head diameter (cm)	Filled seed no./head	Weight of filled seed (g)	1000-seed weight (g)	Seed yield (kg ha^{-1})
Control	15.0	624	31.2	49.9	968
TIBA (240 ppm)	16.8	701	48.8	60.7	1246
TIBA (240 ppm) + NAA (50 ppm)	18.3	764	52.6	68.8	1295
CD (P<0.05)	2.1	84	6.3	3.3	44

The capitulum size varies to greater extent in the multibranched types and has non-synchronous maturity resulting in variation in inter capitulum seed size. This ultimately leads to higher proportion of smaller seeds, which are lost during seed processing. Significant improvements in seed yield and components have been reported due to removal of auxillary buds in restorer lines. By removing auxillary flower buds, the moisture and nutrients that would be utilized by these flower buds may be transferred to development of main capitulum. Vyakaranahal *et al*. (2002) reported that continuous nipping of auxillary flower buds (from 40 to 68 DAS) significantly increased the capitulum diameter and thus seed yield (Table 07).

Table: 07. Effect of nipping of auxillary buds on seed yield of sunflower

Treatment	Capitulum diameter (cm)	Filled seed Number/ Capitulum	Seed set (%)	Seed wt/plant (g)
kharif 1997-98				
N0- control	**9.04**	**306.1**	**61.68**	**9.79**
N1-once nipping	**1235**	**350.7**	**70.28**	**20.57**
N2- continuous nipping	**13.56**	**396.7**	**79.71**	**24.72**
CD (P=0.05)	**0.41**	**8.8**	**1.79**	**0.97**
Spring 1997-98				
N0-control	**9.06**	**310.2**	**62.14**	**6.53**
N1-once nipping	**11.51**	**363.9**	**73.20**	**17.31**
N2-continuous nipping	**13.81**	**423.8**	**84.51**	**21.9**
CD (P=0.05)	**0.27**	**9.7**	**1.34**	**0.53**

Vyakaranahal *et al.,* 2002

Brassinolide, first isolated from the pollen of rape as a plant promoting substance, has been found to be widely distributed in the plant kingdom. As a new class of plant hormones, brassinosteriods show not only growth promoting activity but also other physiological effects on the growth and development of plants and draw attention as promising chemicals for practical application in agriculture. Studies conducted by Chinnamuthu *et al*. (2000) at TNU, Coimbatore revealed that spraying Brassinolide 1 ppm (S_3) at the ray floret opening stage led to the highest filled seeds percentage and was superior to other seed setting treatments (Table 08).

Table: 08. Effect of fertilizer (N) levels and Brassinolide(S) on seed filling percentage of sunflower

Treatments	Summer97						South west monsoon 97					
	N1	N2	N3	N4	N5	S mean	N1	N2	N3	N4	N5	S mean
S1	**74.3**	**76.4**	**78.2**	**79.8**	**80.5**	**77.8**	**73.5**	**75.8**	**77.7**	**79.4**	**80.2**	**77.3**
S2	**81.7**	**83.8**	**85.8**	**87.7**	**88.6**	**85.5**	**81.1**	**83.3**	**85.4**	**87.4**	**88.5**	**85.2**
S3	**86.3**	**89.9**	**91.8**	**93.9**	**94.4**	**91.3**	**85.6**	**89.3**	**91.3**	**93.5**	**94.2**	**90.7**
S4	**83.8**	**86.3**	**88.6**	**90.4**	**90.8**	**87.9**	**83.2**	**85.8**	**88.2**	**90.1**	**90.7**	**87.6**
N mean	**81.5**	**84.1**	**86.1**	**87.9**	**88.6**		**80.5**	**83.5**	**85.7**	**87.6**	**88.5**	
			CD								**CD**	
N mean			**0.40**								**0.08**	
S mean			**0.37**								**0.14**	
N at S			**0.83**								**0.30**	
S at N			**0.84**								**0.33**	

N1 – N:P:K: :40:20:20 kg/ha N2 – N:P:K: :50:25:25 kg/ha S1 – Control Chinnamuthu *et al*., 2000

N3 – N:P:K: :60:30:30 kg/ha N4 – N:P:K: :70:35:35 kg/ha S2 – Hand pollination

N5 – N:P:K: :80:40:40 kg/ha S3 – Spraying 1 ppm Brassinolide

S4 – 0.2% borax + 2% DAP at ray floret opening stage

(C) ENVIRONMENTAL FACTORS AND THEIR MANAGEMENT

(i) Moisture stress

Productivity of sunflower is often affected by various environmental stresses, of which moisture stress is the most important one. Mohan Reddy *et al*. (2003) reported that there was maximum decline in LAI and dry matter accumulation in sunflower subjected to moisture stress at flowering stage resulting reduction in yield (Table-09).

Table: 09. Effect of moisture stress on yield attributes of sunflower

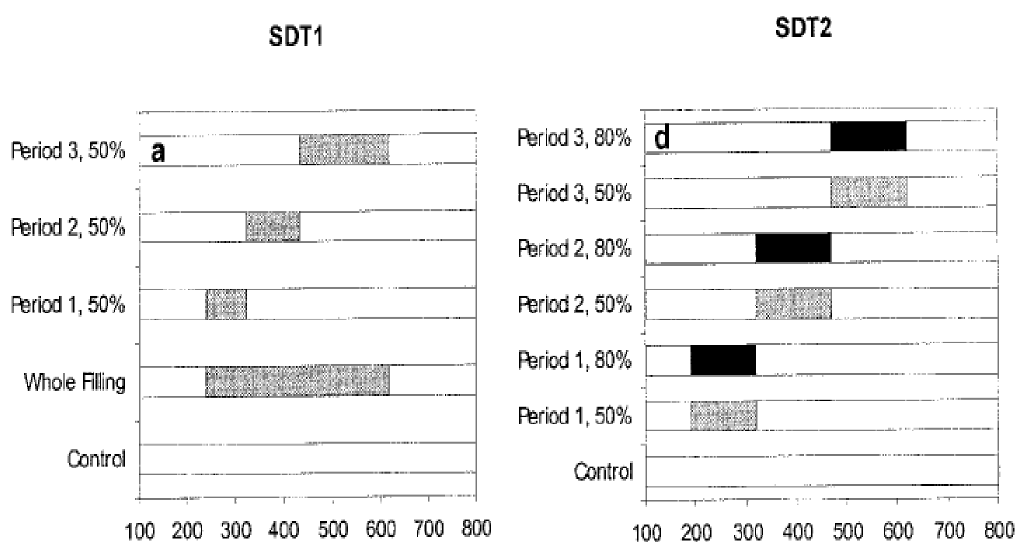
Treatment/character	DAS	T1	T2	T3	T4	T5	CD (P=0.05)
LAI	65	3.2	2.4	2.5	2.3	3.1	0.07
	87	2.4	1.7	1.9	1.7	2.1	0.06
Head Diameter (cm)	-	10.9	15.7	15.7	13.5	14.3	0.21
Seed filling (%)	-	85	80	80	75	76	0.8
100 seed weight (g)	-	4.0	3.6	3.8	3.6	3.6	0.7
Seed yield per plant	-	27.5	22.9	24.3	21.4	22.2	0.6

T1= No stress
T2= Stress at vegetative stage
Mohan Reddy *et al*., 2003
T3= Stress at bud initiation stage
T4= Stress at flowering stage
T5= stress at seed filling stage

(ii) Intercepted solar radiation

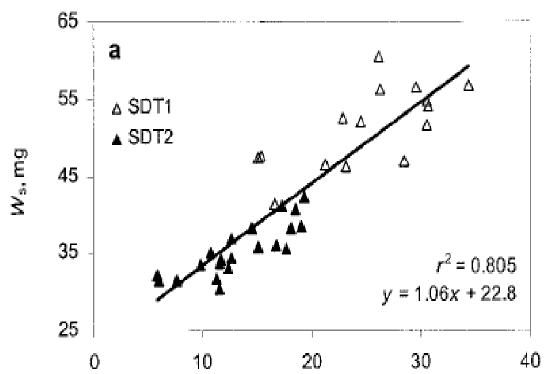
A reduction in intercepted photosynthetically active radiation (PAR) during a short period of seed filling could affect weight per seed in sunflower (*Helianthus annuus* L.) depending when the reduction occurs. Luis *et al*. (2003) in their research work intercepted PAR was modified by shading (0, 50, or 80%) field grown crops during different periods of seed filling (Figure10). They reported that final weight per seed was linearly related to cumulative intercepted radiation (Figure 11) and largely determined by intercepted radiation from 250 to 450 ^{0}C days after flowering (Figure 12)

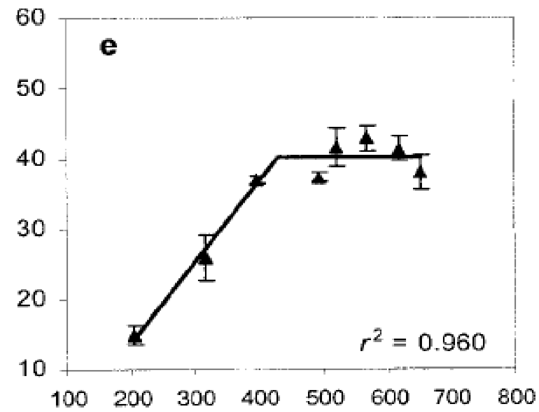
Figure 10. Chronogram of radiation treatments. Exp. SDT1 and SDT2. For a, d: each horizontal bar indicates the timing and duration of the shading period in thermal time with respect to flowering (^{0}C d, base temperature = 6^{0}C) for a single treatment. Gray bar: 50% shading intensity, black bar: 80% shading intensity, open bar: no shading (control).



Thermal time after flowering ^{0}C d

Figures 11 and 12. Final weight per seed and intercepted radiation





Intercepted radiation per plant, MJ Thermal time after flowering ^{0}C d

(iii) Influence of environmental factors on pollinators

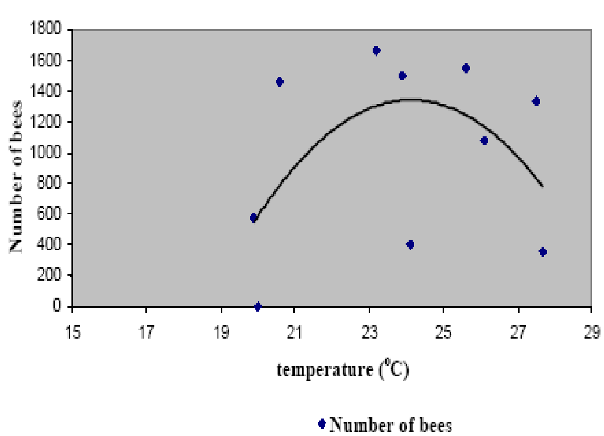
The weather conditions have evident influence on sunflower inflorescence visit by honeybees or other pollinators. Total daily visit of the bees depended on weather conditions. Puškadija *et al.* (2007) reported that the most frequent visits by honeybees were estimated at 20 to 25 degrees centigrade (Figure-13) and humidity at 65-75% (Figure-14). Precipitation had negative impact on honeybees visit (Fig-15). Statistical analysis showed strong positive correlation between average as well as maximum daily temperature and the honeybee's visits (Table 10). Higher humidity, heavy rain fall, wind, and low temperature had negative influence on sunflower inflorescences visits.

Table: 10. The relationship between weather conditions and honey bees visit of sunflower inflorescences during flowering time

Weather indicator	*Spearman's correlation coefficient*	
Air temperature	0.420	NS
Humidity	-0.252	NS
Precipitation	-0.321	NS
Maximum air temperature	0.030	NS
Minimum air temperature	-0.085	NS
Max/min air temp.(DTR)	-0.030	NS
Wind	-0.210	NS
Wind strength	-0.114	NS

NS – non significant

Figures: 13 and 14. Influence of air temperature and humidity on honey bees visit of sunflower inflorescences during flowering time



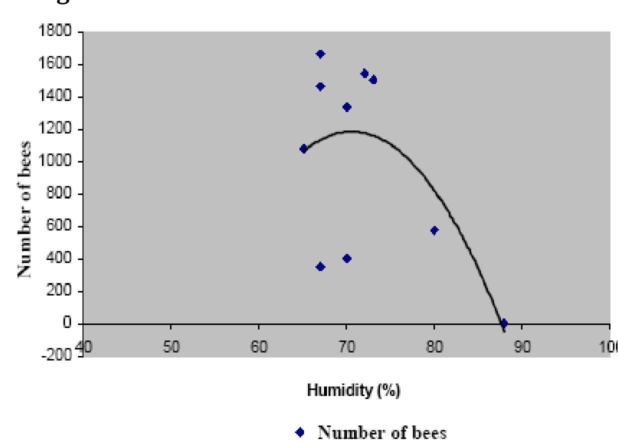
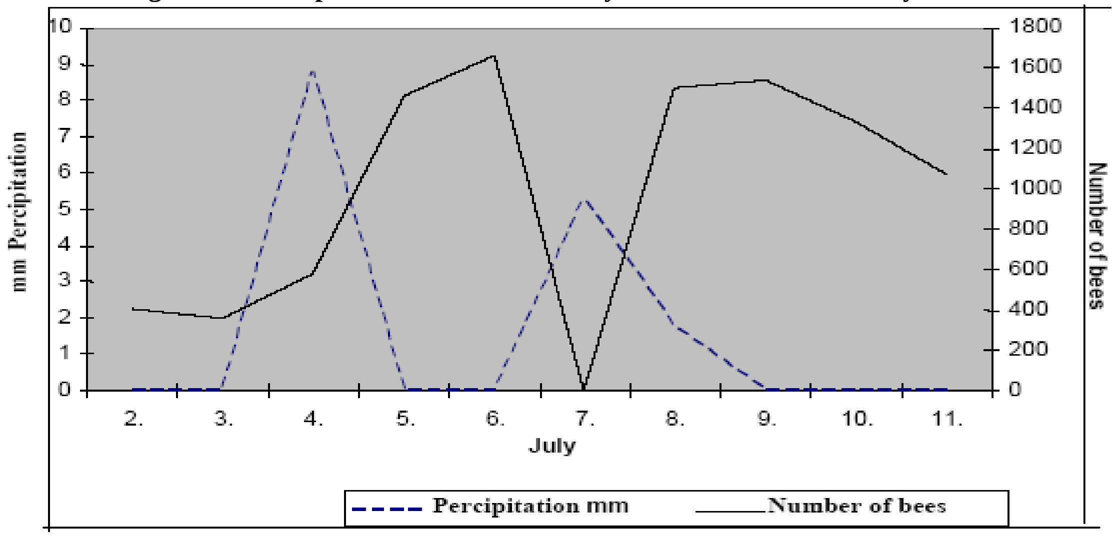


Figure: 15. Precipitation influence of honey bees visit on sunflower hybrids



(iv) Season

Environmental factors make a particular season fit for any crop. Chaudhary and Anand (1989) studied on seasonal influence on seed set in 13 sunflower genotypes and reported that under open pollination seed set varied from 71.2 to 89.4 % in *kharif*, 45.4 to 87.2 % in *rabi* and 60.7 to 91.8 % in spring (Table 11). The mean seed set under self-pollination was highest in *rabi*, followed by spring and *kharif*. Under open pollination, it was highest in *kharif* followed by spring and *rabi*. The high percentage of seed filling during *kharif* under open pollination may possibly be due to the abundance pollen production and bee activities coupled with high temperature and bright sunshine hours at reproductive phase.

Table: 11. Percent seed filling under self and open pollination during *kharif, rabi,* and spring seasons in sunflower

Genotype	Self pollination			Open pollination		
	Kharif	Rabi	Spring	Kharif	Rabi	Spring
Peredovik	12.3	**29.6**	3.8	**84.2**	70.2	73.7
Arrowhead	12.9	1.3	**23.3**	81.6	77.6	**85.2**
Smena	**25.2**	11.5	13.6	82.5	67.7	**83.0**
White Africa	0.3	**11.2**	0.7	84.4	57.3	**87.6**
Krasnodar	2.7	**5.8**	1.9	86.4	75.0	79.6
K 989	0.0	**33.4**	2.0	81.5	77.2	80.9
K 2128	0.0	**34.7**	8.8	87.1	**87.2**	60.7
EC99231B	0.4	58.3	**61.8**	87.6	45.4	67.5
EC102318	29.6	2.0	**42.2**	80.8	77.1	**87.6**
EC113790	16.7	26.6	**77.0**	71.2	66.8	69.8
Mean	12.1	**20.6**	19.6	**83.7**	71.3	78.4
CD (0.05)	3.3	7	5.2	10.3	7.7	7

Choudhary and Anand, 1989

In an another experiment, Sumangala and Giriraj (2003) reported that the genotypes, in general, recorded significantly higher seed yield in summer season irrespective of pollination treatment (Table 12). Environmental factors like number of rainy days, rainfall, temperature, relative humidity, longer day length played an important role on final seed yield. During rainy season, rainfall during peak flowering period brought about poor pollen movement in both exposed and covered heads resulting in poor seed yield. In contrast, the crop raised during summer under irrigation ensured favorable conditions like high temperature, low relative humidity, more sunshine hours and low disease incidence during flowering and seed setting period resulting in increased seed set and seed yield.

Table: 12. Mean seed yield of sunflower genotypes under different pollination methods over seasons

Season/treatment	Hybrid	Inbreds	Morden	Mean
Rainy				
Cloth bag	**22.58**	**7.22**	**11.50**	**10.21**
Cloth bag + assisted pollination	**29.19**	**11.33**	**14.74**	**14.74**
Cloth bag + bulk pollen pollination	**35.68**	**14.62**	**18.96**	**18.96**
Open pollination	**54.39**	**20.41**	**27.14**	**27.14**
Mean	**35.46**	**13.39**	**17.76**	**17.78**
Summer				
Cloth bag	**30.44**	**15.87**	**18.35**	**18.35**
Cloth bag + assisted pollination	**37.91**	**18.70**	**22.57**	**22.57**
Cloth bag + bulk pollen pollination	**43.82**	**20.38**	**21.60**	**24.70**
Open pollination	**49.62**	**23.55**	**31.57**	**28.50**
Mean	**40.44**	**19.28**	**21.94**	**23.48**
CD at 5%	Between 2 means	Between 2 sub means	Between 2 submeans at same main mean	Between 2 main means at same or different submeans
Rainy	**2.12**	**0.79**	**3.71**	**3.82**
Summer	**2.60**	**1.06**	**4.93**	**4.98**

Sumangala and Giriraj, 2003

The higher yield obtained from the Spring crop confirms the results of Hassan *et al*. (2005), (Table 13) who reported that Spring crops have the overall advantage of better plant structure, better environmental condition during crop growth period and maturity over Fall crops. Better environmental conditions of Spring crop include also the slow and gradual rise in cumulative growing degree days.

Table:13.Effect of seasonal variations on growth and development of sunflower

	Season							
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Hybrid	Stem girth (cm)		Plant height (cm)		Dry matter (gm^2)		Yield (kg/ha)	
PARSUN-1	7.13 a*	6.36 a*	136.61 b*	110.53 b*	2953.20 a*	1491.93 a*	1757 b	1628 b
SMH-9706	7.40 a	6.23 a	148.21 ab	123.91 a	3183.62 a	1435.70 a	2122 a	1631 b
SMH-9707	7.10 a	6.06 a	137.63 b	108.84 b	3223.03 a	1467.38 a	1738 b	1353 c
Suncross-42	9.96 a	5.86 a	156.73 a	126.83 a	3355.86 a	1600.63 a	2175 a	1827 a
XF-263	4.50 b	4.26 b	86.41 c	72.98 c	1182.01 b	787.50 b	940 c	768 d

* Any two means sharing a common letter are non significant at 5% level of probability.

(D) AGRONOMIC MANAGEMENT

(i) Pre sowing treatments

Seed invigoration treatment helps to improve the germination and vigour of the seed and ultimately it establishes a good field stand and yields higher. Shivanker *et al*. (2003) reported that *Trichoderma harzianum* is the antagonistic agent which suppresses the growth of many fungi found on seed and in soil. Thus, the protection given by *Trichoderma harzianum* helped in germination of poor vigour sunflower seeds and subsequently increased the yield. Another seed treatments like KCl (0.5%), $MnSO_4$ (0.5%), GA_3 (50 ppm), Thiram are also effective in increasing seed yield of sunflower. (Table-14).

Table: 14. Effect of pre sowing treatments on seed yield of sunflower (cv Morden)

Treatment	Disc size(cm2)	Number of filled seeds	Number of unfilled seeds	100 seed weight (g)	Seed yield (kg/ha)
Control	**318**	**481**	**106**	**4.1**	**1276**
Kcl	**325**	**301**	**103**	**4.2**	**1484**
MnSO4	**324**	**492**	**101**	**4.3**	**1578**
KNO3	**321**	**487**	**104**	**4.1**	**1378**
Thiourea	**301**	**440**	**97**	**4.1**	**527**
GA3	**324**	**494**	**110**	**4.2**	**1460**
Kinetin	**335**	**493**	**106**	**4.1**	**1407**
Hydration	**322**	**490**	**102**	**4.1**	**1410**
Hydration + Thiram	**330**	**490**	**102**	**4.2**	**1461**
Thiram	**367**	**504**	**106**	**4.2**	**1527**
Trichoderm herzianum	**368**	**515**	**105**	**4.1**	**1657**
CD (P=0.05)	**6.8**	**17.8**	**7.4**	**0.06**	**56.59**

Shivanker *et al*., 2003

(ii) Planting time and planting design

Among several crop production practices, planting date decides the correct expression of a genotype for all morphological characters and physiological processes. Vyakaranahal *et al*. (2002) observed a significant increase in the seed yield due to early planting (July/December) for both the seasons (*Kharif*/Spring) over late planting (August/January) (Table-15). The increase in seed yield was due to increase germination percentage and seedling vigour, which subsequently increased the yield components and yield. Sinha and Atwal (2000) reported that sunflower crop sown in the month of December flowered between March-April and since during these months honeybee activity was maximum, which resulted in better pollination and thus good seed setting (Table-16).

Table: 15. Effect of planting date on seed yield of sunflower

Date of planting (D)	Capitulum diameter (cm)	Filled seed Number/ Capitulum	Seed set (%)	Seed wt/plant (g)
kharif 1997-98				
D1- July	**13.03**	**381.2**	**76.36**	**21.16**
D2- August	**10.27**	**321.0**	**64.75**	**15.56**
CD (P=0.05)	**0.61**	**10.6**	**3.85**	**3.56**
Spring 1997-98				
D1- Dec.	**12.27**	**383.4**	**76.33**	**17.86**
D2- Jan.	**10.63**	**348.5**	**70.24**	**12.63**
CD (P=0.05)	**0.33**	**34.2**	**5.43**	**1.00**

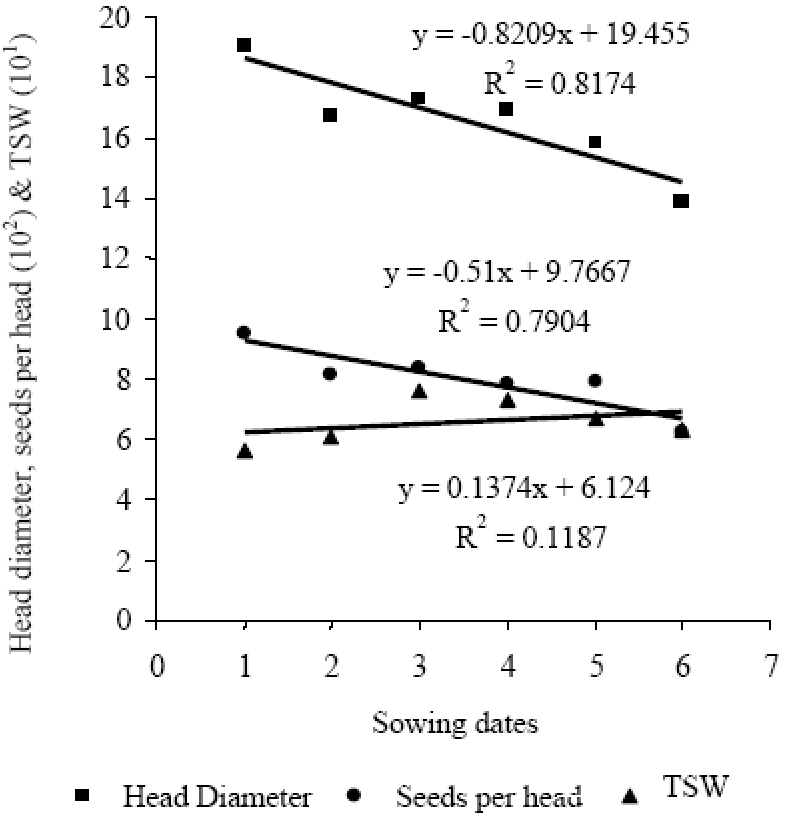
Vyakaranahal *et al.*, 2002

Table:16. Effect of date of sowing on honey bee visit on different sunflower hybrids.

Date of sowing 1992-93	Hybrid seed plot	Duration of flowering (day/month)	Number of bees visiting flowers/day*
December 15	KBSH-1	23/03-12/04 (21 days)	90.4
	APSH-11		106.3
	LSH-3		86.7
	Total		283.4
January 15	KBSH-1	14/04-30/04 (16 days)	54.8
	APSH-11		59.6
	LSH-3		51.7
	Total		166.1
February 15	KBSH-1	28/04-07/05 (10 days)	38.4
	APSH-11		42.1
	LSH-3		32.5
	Total		113

Sinha and Atwal, 2000

Figure:16. Relationship among sowing dates, head diameter, seeds/head and total seed weight (TSW). (Ahmad *et al.*, 2005). (1,2,3,4,5,6,7 are 22 June, 4July, 14July, 30 July, 10 August, 21 August sowing dates respectively)



Relationship among sowing dates, head diameter, seeds/head and TSW.

A significant relationship between sowing dates and seeds per head was reported by Ahmad *et al.* (2005). In the early plantation total number of seeds/head was maximum but total seed weight (TSW) was minimum. The minimum TSW produced by early plantation may be due the fact that plants of this particular sowing produced the plants with larger heads those ultimately encouraged the maximum number of seeds but assimilates were not supplied in an enough quantities to fully nourish large number of seeds. Ultimately seeds remained under nourished and had less TSW (Figure-16).

Seed setting is not only affected by planting time but planting design also. Yadav *et al.* (2006) reported that there was decline in seed setting as distance from pollen source was increased due to planting design. The magnitude of decline in seed set with increasing distance from pollen source was lower in mixed planting (D2) as compared to blocks (D3) and separate row planting (D1) of male and female plants. It may be due to more scattered pollen plants in mixed planting design (Figure-17)..

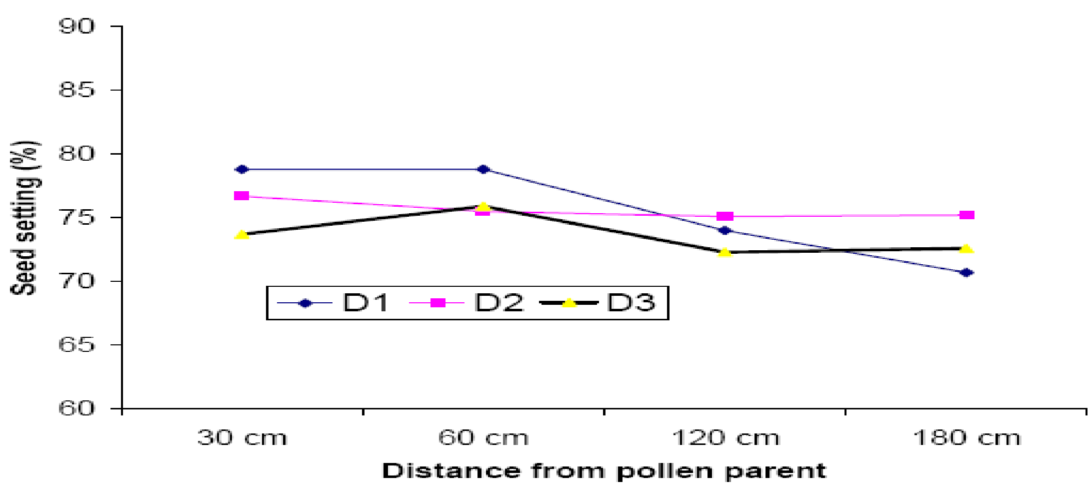


Figure: 17. ***Seed setting (%) in female parent at various distances from pollen parent***

(v) Staggered sowing

The problem of non synchrony is generally observed in sunflower hybrids. The male parent flowers later than seed parent. To avoid this problem sowing male parent early to female parent was suggested. Umesh *et al.* (2007) reported that Staggered sowing of male parent seven days early(S_2) resulted in the increase in per cent seed set and filling as a result of better synchronization in parental lines (Table 17).

Table: 17. Number of filled seeds and seed set, per capitulum as influenced by provenance, planting season and staggered sowing in seed parent of RSFH-1 sunflower hybrid

Treatments	Number of filled seeds per capitulum								
	Location (L)		Season (P)		Mean (S)	Kharif (P_1)		Rabi (P_2)	
	L_1	L_2	P_1	P_2		L_1	L_2	L_1	L_2
Female									
S_0	150.80	153.77	145.57	159.00	152.28	139.06	152.07	162.53	155.47
S_1	266.80	268.77	276.28	259.30	267.79	278.46	274.09	255.14	263.45
S_2	411.89	488.43	430.53	469.78	450.16	392.84	468.22	430.93	508.63
S_3	313.02	342.34	318.85	336.51	327.68	295.53	342.17	330.51	342.50
S_4	179.22	176.17	173.48	181.90	177.69	174.63	172.33	183.80	180.00
S_5	351.85	438.94	384.98	405.81	395.39	341.56	428.39	362.15	449.48
S_6	332.15	419.14	342.43	408.86	375.64	305.32	379.54	358.99	458.73
S_7	320.86	322.95	321.05	322.75	320.90	319.21	322.90	322.50	322.99
Mean	290.82	326.31	299.15	317.99	308.57	280.83	317.46	300.82	335.16
	L	L´S	P	P´S	S	L´P	L´P´S		
S.Em±	2.88	8.16	2.88	8.16	5.77	4.08	11.54		
CD at 5%	8.15	23.04	8.15	23.04	16.29	NS	NS		
Treatments	Seed set (%)								
S_0	28.68	29.11	27.93	29.86	28.89	27.00	28.86	30.36	29.35
S_1	44.98	45.46	46.53	43.91	45.22	46.92	46.15	43.04	44.77
S_2	65.98	76.94	68.65	74.28	71.46	63.26	74.03	68.70	79.85
S_3	51.82	56.05	52.65	55.21	53.93	49.28	56.02	54.35	56.07
S_4	32.72	32.24	31.90	33.05	32.48	32.04	31.76	33.40	32.71
S_5	57.40	69.85	62.14	65.11	63.62	55.93	68.34	58.87	71.35
S_6	55.97	68.40	57.49	66.88	62.18	52.18	62.79	59.76	74.00
S_7	52.98	53.25	53.00	53.22	53.11	52.74	53.27	53.21	53.23
Mean	48.82	53.91	50.03	52.69	51.36	47.42	52.65	50.21	55.16
	L	LxS	P	PxS	S	LxP	LxPxS		
S.Em±	0.25	0.70	0.25	0.70	0.49	0.35	0.99		
CD at 5%	0.70	1.97	0.70	1.97	1.39	NS	NS		

NS – Non Significant

Umesh *et al.*, 2007

L1 - Dharwad P1 - Kharif
L2 - Bagalkot P2 – Rabi
S0 - Simultaneous sowing of female and male parent
S1 - Sowing of male parent four days early to the female parent
S2 - Sowing of male parent seven days early to the female parent
S3 - Sowing of male parent ten days early to the female parent
S4 - S0 + Spraying of urea (2%) at button formation stage to male parent
S5 - S1 + Spraying of urea (2%) at button formation stage to male parent
S6 - S2 + Spraying of urea (2%) at button formation stage to male parent
S7 - S3 + Spraying of urea (2%) at button formation stage to male parent

(iii) Crop geometry

Suitable crop geometry and phosphorus application besides other agronomic practices are of paramount importance as sunflower has higher phosphorus requirement. Patel and Thakur (2003) reported that a crop geometry of 60 cm x 20 cm recorded significantly higher values of growth and yield attributes as compared to crop geometry 40 cm x 30 cm. Phosphorus application significantly increased the filled seed/head, seed weight/head and seed yield. Significantly higher values of yield attributes were recorded with the application of 80 kg P_2O_5/ha over 60 and 40 kg P_2O_5/ha. (Table-18).

Table: 18. Effect of crop geometry and phosphorus levels on yield attributes of sunflower

Treatment	Head diameter (cm)	Filled seeds/head	Seed weight /head (g)
Crop geometry			
40 X 30 cm	**10**	**537**	**24**
50 X 20 cm	**11**	**550**	**27**
60 X 20 cm	**11**	**590**	**28**
CD (P=0.05)	**0.6**	**33**	**2.1**
P2O5 (kg/ha)			
40	**11**	**547**	**25**
60	**11**	**559**	**26**
80	**11**	**572**	**27**
CD (P=0.05)	**NS**	**11**	**0.9**

Patel and Thakur, 2003

(iv) Fertilization

Sunflower is often considered as a soil-depleting crop, which puts heavy demands on soil and applied nutrients. Due to its high uptake of nutrients, sunflower responds very well to applied nutrients. Among the different nutrients required by sunflower, Nitrogen and Phosphorus are the primary limiting nutrients under most environments. Thavaprakash *et al*. (2002) reported that the treatment receiving N: P: K @120:75:60 kg/ha respectively and N: P: K @ 120: 120: 60 kg/ha respectively produced 21 and 27 percent higher seed yield over N: P: K @ 90: 75: 60 kg/ha respectively at UAS, Dharwad (Table 19).

Table: 19. Effect of N, P and K fertilization on yield attributes of sunflower

Quantity of nutrients ($kg\ ha^{-1}$)			Head diameter (cm)	Head weight ($g\ plant^{-1}$)	Seed weight ($g\ plant^{-1}$)	1000-seed weight (g)	Seed yield ($kg\ ha^{-1}$)
N	P_2O_5	K_2O					
0	0	60	13.04 c*	59.34 c	33.87 c	36.10 e	1949 e*
60	75	60	16.68 b	82.39 b	52.80 b	44.16 c	2800 d
60	90	60	16.93 b	82.49 b	53.67 b	47.87 b	2761 d
90	75	60	18.03 b	87.60 b	53.92 b	44.45 c	3009 cd
90	90	60	18.07 b	87.40 b	54.90 b	47.96 b	2875 d
120	60	60	20.73 a	94.11 a	62.46 a	40.98 d	3188 bc
120	75	60	20.69 a	94.80 a	62.61 a	44.61 c	3397 ab
120	90	60	20.76 a	95.44 a	62.67 a	47.88 b	3220 bc
120	120	60	20.91 a	95.84 a	66.66 a	51.56 a	3554 a
			18.43	86.60	55.95	45.06	

*In a column mean values followed by the same letter do not differ significantly at P=0.05

Boron plays a major role in membrane integrity and cell wall development and it helps in pollen tube growth. It is also known to play an important role in translocation of sugars. Hence, application of boron is beneficial in sunflower. Nanja Reddy *et al.* (2003) reported that soil application of boron (2 kg/ha) at ray floret stage increased the seed yield by 53% (Table 20)

Table: 20. Effect of boron application on seed yield of sunflower (Hybrid KBSH-1)

Treatment	Seed yield
Control	**10.0**
Borax (2kg/ha)	
At button stage	**14.3**
At ray floret opening stage	**15.3**
CD (P≤0.05)	**1.2**

Nanja Reddy *et al*., 2003

Sulphur plays vital role in the formation of chlorophyll, amino acids viz., cystine, cysteine and methionone. It increases seed yield due to more accumulation and translocation of amino acids and amide substances to the reproductive organs. Bhagat *et al* (2005) reported that seed yield was significantly increased with increasing levels of sulphur. Application of 40 kg S/ha produced highest seed yield/ha which was significantly superior over 0 and 20 kg S/ha. (Table-21)

Table: 21. Yield of sunflower as influenced by sulphur levels

Sulphur levels	Seed yield
0	**10.08**
20	**11.18**
40	**12.35**
CD (P=0.05)	**1.00**

Bhagat *et al*., 2005

(v) Irrigation

Water and fertilizer are two most important inputs in agronomic aspects of crop management. Judicious application of irrigation and nitrogen is essential to achieve higher benefits, especially under limited resource conditions. Sumathi and Rao (2007) reported that the interaction between both the components was significant where the combination of IW:CPE ratio 1.0 with the supply of entire dose of nitrogen through fertilizer was given (Table-22). Singh *et al.* (1995) reported that increasing levels of irrigation and nitrogen significantly increased the seed yield and yield attributes but irrigations applied at 25 DAS + initiation of flower buds + mid flowering + seed setting stages recorded significantly superior yield to all other irrigation treatments. In case of nitrogen 60 and 80 kg N/ha produced respectively 1.5 and 1.95 q/ha higher seed yield than 40 kg N/ha (Table-23).

Table: 22. Seed yield of sunflower as influenced by interaction of irrigation and N-management practices (mean data of 2 years) Sumathi and Rao , 2007

Treatment	N_0=control	N_1	N_2	N_3	N_4	Mean
I_1-CPE=0.6	5.7	15.3	14.6	13.2	11.7	12.1
I_2-CPE=0.8	6.3	18.7	17.6	16.6	15.8	15.0
I_3-CPE=1.0	7.8	20.0	19.4	18.6	16.9	16.5
Mean	6.6	18.0	17.2	16.1	14.8	
CD (P=0.05)	**I**		**N**		**I x N**	
	0.6		0.9		1.5	

N_1=100% fert. N; N_2=75% fert. N + 25% FYM N; N_3=50% fert. N + 50% FYM N; N_4=100% FYM N

Table: 23. Effect of different levels of irrigation and nitrogen on yield potential of rainy season sunflower

Treatment	Seed yield (q/ha) (mean of 3 years)
Irrigation level	
I_1- control	**5.24**
I_2- 2 irrigations, 25 DAS + initiation of flower buds	**7.30**
I_3- 3 irrigations, 25 DAS + initiation of flower buds + mid flowering	**9.22**
I_4- 4 irrigations, 25 DAS + initiation of flower buds + mid flowering + seed setting	**11.22**
I_5- irrigation at IW:CPE, 0.6	**9.09**
I_6- irrigation at IW:CPE, 0.8	**11.37**
CD (P=0.05)	**0.56**
N (kg/ha)	
N_1- 40	**7.76**
N_2- 60	**9.26**
N_3- 80	**9.71**
CD (P=0.05)	**0.40**

Singh *et al*., 1995

(vi) Weed control

Weeds pose serious problem in the cultivation of sunflower. If unchecked, weeds can reduce the crop yield to a greater extent. Hence, use of herbicides has become necessary to reduce weed menace during the early stages of sunflower crop. There are so many herbicides are available in the market but an efficient herbicide can only give the higher economic returns. Chittapur *et al*. (2003) studied the efficacy of herbicides in sunflower and reported that pre emergent application of alachlor @ 2.0 kg a.i./ha recorded the highest weed control efficiency (72.7%) and gave higher seed yield (Table-24).

Table: 24. Effect of herbicides on weed control in sunflower

Treatment	Dose (kg/ha)	WCE at harvest (%)	Head diameter (cm)	Filled seeds/head	1000-seed weight (g)	Yield (kg/ha)
Imazethapyr + pendimethalin	2	54.5	13	617	28.0	960
Imazethapyr + pendimethalin	2	64.6	2	54	27.0	230
acetachlor	2	57.1	13	760	30.0	850
alachlor	**2**	**72.1**	**14**	**987**	**33.4**	**1180**
trifluralin	2	63.1	14	691	29.0	910
Weed free check	-	100	15	900	36.5	1220
Unweeded control	-		9	492	29.0	620
SEm±		0.04	0.4	23	1.1	70
CD (P=0.05)		0.12	1.2	71	3.5	210

Chittapur *et al*., 2003

(vii) Insecticides uses and pollination

The use of insecticides to control pests on agricultural crops is indispensable. Often economically important non target insects such as honeybees are killed in the process of pest control. Jyothi (2004) reported that seed yield of sunflower was declined from

764.31g/head to 435.95 g/head after application of insecticide (Table 25). This decrease in yield of sunflower seeds was due to the decrease in the pollinators visit after insecticide application. Therefore it is suggested that insecticides use should be avoided at blooming stage. If the application of insecticide is so much essential, the hives may be closed for the day and the spray may preferably be taken up during evening hours.

Table: 25. Effect of Endosulfan on pollinators, pollination and seed production of sunflower

Insect/Pollinators	**Mean population of pollinators/day/hr./ capitula**		**% Pollination/day**		**Mean seed yield/head (g)**	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Apis melifera	93.3	50.8	93.00	50.00	228.12	109.60
A cerana, indica	10.4	06.2	10.00	05.00	119.10	98.06
A. dorsata	50.6	30.7	50.00	30.00	206.00	88.90
A. flora	02.5	02.0	02.05	01.9	90.09	48.40
Trigona, Iridipennis	56.4	32.4	51.00	29.6	121.01	96.99
Total *Apoidea* (A)	201.2	122.1	226.05	116.5	764.31	435.95
Other insects visitors (B)	30.5	17.2	20.09	18.10	40.08	20.98
Total (A + B)	231.7	139.3	247.4	134.6	804.39	456.93

Jyothi, 2004

(vii) Integrated nutrient management

Integration of organic manures and biofertilizers with chemical fertilizers is more emphasized not only to boost the production of sunflower from limited land resources but also for its sustainability. The results of experiments showed that the growth and yield attributes were significantly influenced by INM practices. Application of RDF (40:40:20 kg/ha) + vermicompost @ 5 t/ha + soil inoculation of Azospirillum @ 2 kg/ha + $ZnSO_4$ @ 25 kg/ha) along with foliar spray of 1% KH_2PO_4 (T_{10}) recorded the highest values for growth and yield attributes. (Kalaiyarasan and Vaiyapuri, 2007) (Table-26)

Table: 26. Effect of INM on yield attributes of sunflower

Treatment	Head diameter (cm)	Seeds/head	100 seed weight (g)	Seed yield (kg/ha)
T1=Control	15.41	418.22	4.41	432.12
T2=40:20:20 (NPK kg/ha)	17.92	521.68	4.46	501.66
T3= T2+FYM @ 12.5 t/ha	18.14	540.14	4.61	543.12
T4= T2+ Vermicompost @ 5 t/ha	18.91	572.12	4.69	574.61
T5= T3+ Azospirillum @ 2kg/ha*	19.12	610.89	4.71	662.68
T6= T4+ Azospirillum @ 2kg/ha*	20.11	673.12	4.84	793.14
T7= T5+ ZnSo4 @ 25 kg/ha	20.82	706.49	4.85	841.28
T8= T6+ ZnSo4 @ 25 kg/ha	22.96	743.31	4.86	926.12
T9= T7+ Foliar spray of 1% KH2Po4 at ray floret stage	23.11	791.21	5.92	1085.31
T10= T8+ Foliar spray of 1% KH2Po4 at ray floret stage	24.86	820.16	6.01	1243.21
CD (P=0.05)	0.18	35.21	0.12	78.56

*****Soil application

Kalaiyarasan and Vaiyapuri, 2007

(E) POLLINATION MANAGEMENT

Being entomophilous, the pollination of sunflower to large extent is determined by honeybees (*Apis* spp.). The environmental conditions prevailing during flowering period, spraying of bee attractant like Bee-Q and sugar, which attract the bees, are the deciding factors for ensuring effective bee population. The role of boron is also important in sunflower as it helps to increase the pollen viability. Prabhu *et al*. (2004) reported that hand pollination followed by Bee-Q spray (12.5 g/ha) recorded highest head diameter, filled seeds/head, seed set per cent, 100 seed weight, seed recovery percentage and seed yield but it was on par with 100% pollen and sugar spray (5%) and hand pollination 50% pollen and 50% borax (5%) and foliar spray of Bee-Q spray (12.5 g/ha). It suggests that the use of Bee-Q and sugar spray was found effective in addition to hand pollination. The net best treatment for improving the pollen use efficiency were 25% borax with 75% pollen on volume basis when combined with two sprays of Bee-Q (Table-27).

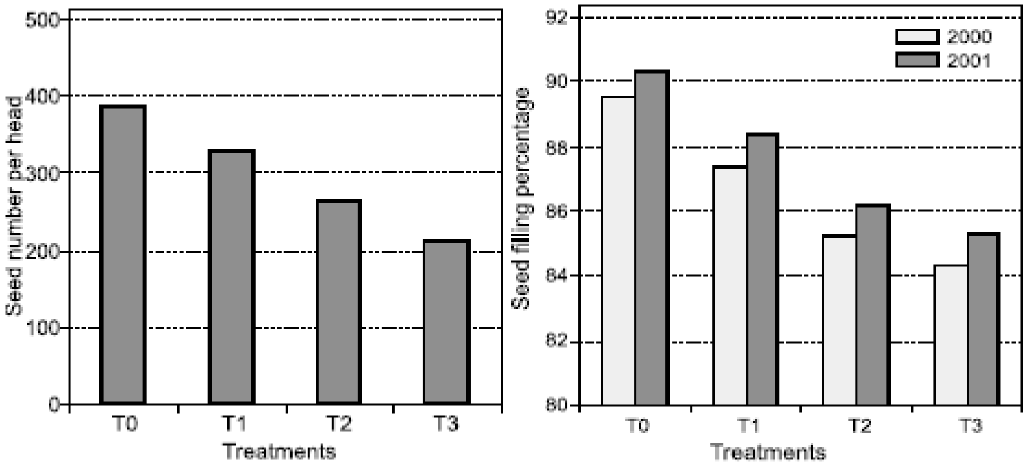
Table: 27. Effect of different treatments of pollen use efficiency on seed yield and quality parameters of sunflower hybrid DSH-1

TREATMENT	Head diameter (cm)	Seed set (%)	100 seed weight (g)	Seed yield per plant (g)
T1-hand pollination (100% pollen)	14.5	83.8	4.23	29.1
T2- hand pollination (75%pollen + 25% borax)	14.0	81.0	4.10	27.4
T3- hand pollination (50%pollen + 50% borax)	13.6	78.9	3.99	25.5
T4-T1 + sugar (5%) spray	15.0	86.2	4.68	32.5
T5- T2+ sugar (5%) spray	14.3	83.0	4.25	29.2
T6- T3+ sugar (5%) spray	14.1	80.1	4.11	26.2
T7- T1 +Bee-Q spray (12.5g/l)	15.5	88.2	5.10	33.1
T8- T2+Bee-Q spray (12.5g/l)	14.9	85.5	4.52	30.3
T9- T3+Bee-Q spray (12.5g/l)	14.2	83.4	4.25	27.3
C D (P=0.05)	0.63	4.8	0.28	3.60

Prabhu *et al*., 2004

Sumathi *et al*. (2005) also reported that use of borax as filler material helps in uniform spreading of pollen on the stigma and thus increase the seed set and filling in sunflower (Figures 18 and 19).

Figures 18 and 19. Effect of pollen and borax on mean on seed number per head and seed filling percentage in sunflower (T0=100% pollen, T1=75% pollen plus 25% borax as filler material, T2=50% pollen plus 50% borax as filler material and T3=50% pollen and 50% flour of finger millet (*Eleusine coracana* L.).



Conclusion

Based on the above-mentioned discussion it can be concluded that:

- **Low autogamy and self-incompatibility are two major genetic reasons for poor seed setting and filling in sunflower. Breeding plants for the characters directly associated with seed setting and filling, producing the self-fertile lines and growing hybrids can improve the yield in sunflower.**
- **Poor vascularization in the capitulum, high photorespiration wastage, uneven distribution of photoassimilate and source limitation are the major physiological causes for poor seed setting and filling in sunflower. Reducing the source-sink or sink-sink competition by physiological manipulation such as reduction in thalamus weight, increasing post anthesis dry matter accumulation and clipping of old leaves would help in better seed set and filling in sunflower.**
- **Directed application of TIBA to head has resulted in increased filling and test weight by way of increased translocation of photosynthates to sink hence, use of growth regulator like TIBA would be beneficial.**
- **Maintaining optimum plant stands recommended for the region is desirable. Very less plant population per unit area produced large sized flower head, which remained unnourished due to source limitation and ultimately caused poor seed setting particular in the centre of the flower head.**
- **Following only recommended fertilizer schedule for the region is beneficial. Sunflower responds profitably to the use of secondary and micronutrient boron. Boron application at ray floret opening stage improved seed set and filling percentage. Hence, application of boron at this stage is suggested.**
- **Moisture stress at bud formation, flowering and milking stages drastically reduced the growth and yield attributes. Therefore, avoiding moisture stress at these stages would be helpful in improving seed yield of sunflower.**
- **Providing supplemental pollination, either by hand pollination or through increasing pollinators (bees) activity has increased the seed set and filling percent in sunflower.**
- **Environmental factors greatly influence the seed setting and filling in sunflower by way of not only affecting crop itself but pollinators also and thus pollination. Continuous rains and cloudy weather or very high temperature affects seed set and yield. Therefore, optimum seeding period should be decided in such a way that the flowering should not coincide with extremes of temperature, heavy rainfall, fog and cloudy weather.**
- ***Rabi*/summer season recorded higher seed set percent than *kharif* season in inbreds, hybrids and populations. Hence, *rabi/*summer season is more suitable for sunflower than *kharif* for higher productivity.**

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