STUDIES ON PLANTING GEOMETRY OF MALE PARENT (R-64NB) ON POLLEN PRODUCTION AND ITS INFLUENCE ON SEED YIELD AND QUALITY IN SUNFLOWER HYBRID SEED PRODUCTION (RSFH-1)

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In

SEED SCIENCE AND TECHNOLOGY

By

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C E R T I F I C A T E

This is to certify that the thesis entitled **"STUDIES ON PLANTING GEOMETRY OF MALE PARENT (R-64NB) ON POLLEN PRODUCTION AND ITS INFLUENCE ON SEED YIELD AND QUALITY IN SUNFLOWER HYBRID SEED PRODUCTION (RSFH-I)"** submitted by **Mr. BASAVARAJ S. KOPPAD** in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SEED SCIENCE AND TECHNOLOGY** of College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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To

My Beloved Parents

Sri. Shankrappa and

Smt. Girijamma

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With soul searching memories.....

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DHARWAD

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(BASAVARAJ S. KOPPAD)

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Introduction

I. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the important members of Asteraceae family and the second most important edible oilseed crop of the world next to soybean. It is cultivated on an area of 22.71 million hectares in the world with annual production of 26.26 million metric tonnes and productivity of 1.16 metric tonnes per hectare (Anon., 2003).

Sunflower was first introduced to India as an edible oilseed crop during 1969 but did not spread to any sizeable extent in the country. However, in 1972 due to the introduction of high yielding and high oil content Russian varieties *viz.*, EC 68413, EC 68414 and EC 68415 renewed the interest on this crop in India.

Presently, in India sunflower is grown over an area of 2.01 million hectares with a production of about 1.09 million tonnes and productivity of 539 kg per hectare. Karnataka state, has an area of 0.88 million hectares with annual production of 0.41 million tonnes. The productivity of State is 463 kg per hectare (Anon., 2004). The productivity of sunflower in India at present is far lower than the world average. This is mainly because of rainfed cultivation and crop subjected to several biotic/abiotic stress factors that invariably influence the crop growth at different stages.

The crop has been well accepted by farming community because of its desirable attributes such as short duration, photoperiod insensitivity, low seed rate, high seed multiplication ratio, drought tolerance, high quality edible oil and high degree of poly unsaturated fatty acid content.

Due to intensive crop improvement programme, quite a number of hybrids have been released both at State and National level, which demands the development of seed production technology. The success of

hybrids in many crops depends upon exploitation of hybrid vigour and the feasibility of economically viable seed production. To increase the productivity level in the commercial front, supply of quality hybrid seeds assumes prime importance.

The demand for quality sunflower hybrid seed is increasing year after year because of the area under cultivation is alarmingly increasing owing to its more production stability with economic yields, suitable for input intensive agriculture and can be grown both under rainfed and irrigated conditions coupled with high remunerative market price.

The production of high quality nucleus, breeder, foundation seeds of parental lines and certified seeds of hybrid requires systematic planning, appropriate care and adoption of suitable management practices in the production plots during different seasons and situations.

At present, majority of sunflower hybrids have been developed using branching type of restorer lines. These lines are characterized by high *per se* oil content, disease resistance and ensured pollen supply over longer duration in hybrid seed production due to contribution by secondary heads. In contrast the non-branching restorers being monoheaded possess high test weight and *per se* oil content, but the pollen supply is restricted to shorter duration in seed production.

Recently RSFH-1 (Raichur Sunflower Hybrid-1) was developed at the Regional Agricultural Research Station, Raichur and released for commercial cultivation in 2002. The low pollen production in restorer line (R-64NB) is the major constraint in hybrid seed production of RSFH-1 with 3:1 female to male planting ratio.

The hybrid seed production is influenced by several factors such as planting ratio, synchrony in flowering, pollen production ability of restorer, viability period of pollen and stigma receptivity. The most important single factor, which determines the hybrid seed production is proper pollen supply by the restorer line during hybrid seed production. Pollen production is influenced by several factors like head size and duration of flowering. Since the sunflower hybrid RSFH-1 male line is monoheaded type, only alternative way to increase the pollen production is to increase the plant population of restorer line within the recommended planting proportion of 3:1 female to male lines respectively.

Keeping the above facts in view a study was initiated with the following objectives.

i. To study the influence of planting geometry of non-branching restorer line (R-64NB) on growth parameters.

ii. To study the planting geometry of non-branching restorer (R-64NB) on pollen production and its influence on seed yield and quality in hybrid seed production of RSFH-1.

Review of Literature

II. REVIEW OF LITERATURE

The available literature on the influence of plant population on pollen production, seed set, seed yield and quality of sunflower and other related crops are compiled and presented in this chapter.

2.1 INFLUENCE OF PLANTING GEOMETRY ON CROP GROWTH

2.1.1 Plant height and leaf number

i) Sunflower.

Leaf area of plant increased from 44,120 to 50,120 square meter with increase in plant population from 40,000 to 70,000 plants per ha (Tomaroga and Simota, 1977).

The height of the hybrid increased significantly from 185 to 192 cm with increase in plant population from 36,000 to 72,000 per ha (Miller and Fick, 1978).

Jadhav and Jadhav (1980) recorded significant increase in plant height from 190.6 to 199.1 cm with increase in row spacing from 30 to 60 cm.

Narasimha Rao and Narasa Reddy (1982) observed increase in leaf area index with increase in plant population from 55,555 (60 x 30 cm) to 1,11,111 (30 x 30 cm) plants per hectare.

Sankappanavar (1984) noticed significantly higher plant height (72.3 cm) at 75 cm row spacing compared to 60 cm row spacing and higher leaf area per plant (582.8 cm^2) at 60 cm compared to 75 cm (530.3 cm^2) row spacing.

Holt and Campbell (1984) observed increase in plant height from 120 to 130 cm with increase in plant population (40,000 to 85,000 plants/ha).

Solomon (1987) reported increase in plant height from 196 to 216 cm when plant population increased from 44,444 to 88,888 plants per hectare.

Gubbels and Deido (1988) noticed decrease in plant height from 169 to 160 cm with row spacing of 90 to 45 cm. Karami (1980) also recorded decrease in plant height at 1,11,111 plants per hectare (154 cm) over 55,555 plants per hectare (177 cm).

Gubbels and Deido (1989) recorded increased plant height (150 to 163 cm) from plant population 30,000 to 60,000 per hectare.

Significant differences in leaf area index were observed due to variation in row spacing at all the stages. Plants under narrow row spacing (45 cm) recorded significantly higher (15 %) leaf area index compared to wider row spacing of 60 cm (Deshpande, 1990).

Gubbels and Dedio (1990) observed increase in plant height from 111 to 126 cm at 30 cm row spacing and 109 to 125 cm at 60 cm row spacing for low to high plant densities respectively.

Seenappa *et al.* (1992) reported reduction in plant population from 0 to 40 per cent decreased the plant height from 124 to 119 cm. A plant population of 67,000 to 1,00,000 had no significant effect on plant height (Gajendra, 1996).

Increase in plant height and number of leaves with increase in plant population has been reported by Majid and Schneiter (1988) and Hegde and Havanagi (1998).

Kumar and Mohammad (2001) observed increase in plant height from 74.2 to 83.6 cm and 77 to 80 cm with decrease in inter-row spacing from 90 to 30 cm and 30 to 10 cm intra-row spacing respectively. Whereas, number of leaves per plant was increased from 15.20 to 23.20 in inter row spacing only.

ii) Niger.

Singh *et al.* (1973 and 1982) observed significant difference in plant height due to variation in row spacing. Closer row spacing of 20 cm produced taller plants (195.9 cm) than the wider row spacing of 30 (152.3 cm) and 40 cm (146.8 cm).

Singh and Verma (1975) reported that differences in spacing caused considerable effect on plant height. A row spacing of 20 cm produced significantly more plant height (101.17 cm) than 40 cm row spacing (93.42 cm).

Plant density significantly influenced plant height, the maximum plant height was observed in plants sown at a spacing of 15 x 10 cm compared to spacing of 22.5 x 10.00 cm (Paikaray *et al.*, 1997).

2.1.2 Capitulum diameter

Capitulum diameter was increased by 16.8 per cent with increase in row spacing from 30 to 60 cm (Chidanand, 1973). Singh and Kaushal (1975) observed 18.3 per cent bigger heads at 60 cm over 45 cm row spacing.

Miller and Fick (1978) observed decrease in head size from 18.7 to 16.3 cm with increase in plant population from 36 to 72 thousand plants per hectare.

Sankappanavar (1984) observed inverse relationship between head diameter and plant density. Holt and Campbell (1984) recorded decrease in capitulum diameter (15.2 to 12.4 cm) with increase in plant population (40 to 85 thousand/ha).

Capitulum diameter decreased from 20 to 18 cm with increase in plant population from 44 to 88 thousand per hectare (Solomon, 1987). Plant population above 32,123 plants per hectare decreased the head diameter (Majid and Schneiter, 1988).

Kameswara Rao and Gangasaran (1991) reported that capitulum diameter increased from 10.9 to 11.4 cm with decrease in plant population from 1.67 to 1.11 lakh plants per hectare. Plant stand losses from 0 to 40 per cent increased the head diameter from 14.69 to 16.81 cm (Seenappa *et al.*, 1992).

Increase in plant population from 67,000 to 1,00,000 per hectare significantly decreased capitulum diameter from 12.8 to 12 cm (Gajendra, 1996).

The largest head diameter (16.6 cm) was produced under low plant density, whereas the smallest (14.9 cm) was observed at the highest plant density (Ortegon and Diaz, 1997).

Kumar and Mohammad (2001) recorded decrease in head diameter from 20.0 to 12.3 cm with decrease in inter-row spacing from 90 to 30 cm and 16.6 to 15.4 cm with decrease in intra-row spacing from 30 to 10 cm.

A plant spacing of 40 x 15, 50 x 15, 60 x 20 and 70 x 20 cm produced an increased head diameter from 8 to 10 cm (Sen *et al.*, 2002).

2.2 FLOWERING IN SUNFLOWER

With respect to pollen viability studies, Leolopez (1972) observed non-viability of pollen grains when anthesis phase of sunflower coincided with hot weather and scorching sun.

Seetharam and Kusumakumari (1974) reported that, the pollen viability is restricted only to morning hours of the day. Pollen viability varied from 4 to 80 per cent in different months and was controlled mainly by temperature and humidity at the time of dehiscence.

Alessi *et al.* (1977) did not observe significant differences in days to 50 per cent flowering due to variation in row spacing from 30 to 90 cm.

Yu (1981) reported that the flowers in the head opened regularly from periphery to the center. Flowering period lasted for 7-12 days with most of the flowers opened between three to five days after flowering, which began each day at 5.30 to 6.00 hours. Pollen shedding began between 6.00 to 6.30 hours and was rapid until 10.00 hours and then decreased gradually.

Opening of all florets on a single head is usually completed in 5 to 10 days, but individual florets are not quickly pollinated, they can remain receptive for 14 days with a greatly reduced possibility of being fertilized. Introduction of the reproductive phase is related to day length and although the relationship appears complex, it is considered that short days favour floral initiation. As a field guide, floral initiation occurs at the eight leaf stage of development (Weiss, 1983).

Holt and Campbell (1984) observed that with increase in plant density days to 50 per cent flowering increased in sunflower. Sankappanavar (1984) reported non-significant difference in days to 50 per cent flowering between 60 and 75 cm row spacing in sunflower.

Deshpande (1990) observed more number of days to 50 per cent flowering with 45 cm row spacing (62.67) compared to 60 cm (61.22) sunflower. Kempegowda (1992) reported that the stigma remain receptive upto 3 days.

Days taken to 50 per cent flowering was found to increase with increased population density (Majid and Schneiter, 1988 and Hulagur, 1992).

In parental lines of RSFH-1, female (CMS-103A) took 57 and 64 days, male (R-64NB) took 66 and 72 days for first ray floret opening and days to 50 per cent flowering respectively during rabi-summer season (Umesh, 2004).

2.3 POLLEN PRODUCTION IN SUNFLOWER AS INFLUENCED BY PLANT POPULATION

Simidchev and Simidchiev (1977) reported that the total pollen production per ha was found to be 223.9 to 838 kg per ha. .

A single disc floret of the main capitulum of RHA-274 produce on an average 88,271 pollen grains while, those of secondaries produce on an average 83,015 pollen grains. A single plant of RHA-274 produces 193.42 million pollen grains over a period of 17 days (Satyanarayana, 1979). This is very high when compared to many other crops. Whereas, in maize 18 million pollen grains are produced per tassel (De Vries, 1971).

Vermeulen (1985) reported that single headed plants had larger pollen producing surface (PPS), much shorter flowering period than branching restorer. Further he observed that, wide spacing increased the secondary head diameter and lengthened the period of peak pollen production. Total and primary head PPS per square meter decreased with increased spacing.

Frank *et al.* (1985) recorded pollen grain number per floret in 7 inbreds of sunflower, which ranged from 32,266 to 40,938 among the four single headed lines, and from 52,250 to 56,459 among the three branched restorer lines.

The number of pollen grains per floret ranged from 28,194 in GV x RHA-274 to 42,087 in B11A3 x RHA-274 hybrid sunflower (Tourvieille *et al.*, 1988).

The pollen production in the main head is always high when compared with the secondaries. The increased main head size might have provided sufficient space for the development of individual disc florets (Kannababu *et al.*, 1993).

Suresh (1994) reported that the total pollen production in branching restorer line of 6D-1 was 158.67 mg per plant when compared to continuously nipped plant, which recorded lowest pollen production per plant (77.88 mg) due to its larger main head size.

Among the restorer lines, pollen production was highest in RHA-274 both in case of main head (0.580 g) and secondary head (0.361 g) over a period of 16 days compared to RLC-2 wherein pollen production was low in both main head (0.363 g) and secondary head (0.318 g). Among non-branching restorer lines, X-13NB recorded highest pollen production

(0.619 g) than VI-78 NB (0.387 g) and the highest pollen production was reached on 4th and 5th day during flowering (Easwar, 1996).

2.4 SEED SET AND SEED YIELD

i) Sunflower

In a study of planting design in sunflower a planting ratio of 1:3 (male: female) recorded highest number of filled seeds, per cent seed set and seed yield (g) per plant (326, 35.6 and 17.93, respectively) when compared to 1:4 and 1:5 planting ratios (Kempegowda, 1992).

Among branching and non-branching restorer lines, RHA-274 had highest pollen production and seed set (96.76%) with CMS-234A parent of BSH-1 sunflower hybrid when compared to other restorers (Easwar, 1996).

Seed filling per cent decreased steadily from 83.5 to 74.19 as the proportion of male to female rows increased from 1:2 to 1:5 and the reduction in seed filling was more pronounced in 1:5 ratio in sunflower hybrid seed production (Balamurugan and Angamuthu, 1999).

Rajashekhar (2000) reported that use of 100 per cent pollen resulted in significantly more number of filled seeds, seed set and yield when compared to 50 per cent pollen with 50 per cent filler mixture. He opined that this increase in seed yield was mainly due to increased number of pollen grains available for successful pollination and increased filled seeds and decreased wilted and empty achenes.

Kantha Raju (2003) studied the pollen use efficiency in sunflower and noticed more number of filled seeds, higher seed set (61.98%) with 100 per cent pollen when compared to 75 per cent and 50 per cent pollen

(remaining filler material, 25% and 50%, respectively in which seed setting was 60.85 and 56.24 per cent respectively.

Salmana Sultana and Rajendra Prasad (2005) recorded highest seed yield in hybrid KBSH-1 when pollination was carried with 100 per cent pollen compared to pollination carried with 75 parts of pollen mixed with 25 parts of filler material.

ii) Other crops

Pederson and Barnes (1973) observed a significant correlation between pollen production index (PPI), seed set and seed yield per plant in alfalfa and in *Taxus canadensis* by Allison (1990).

Shashi and Chaudhary (1985) in rice, reported that seed set per cent and seed yield (g) per plant was higher in A- line when R-line was space planted at 10 x 10 over 15 x 10 cm (31.2, 62 and 24.2, 60, respectively). Further they opined that increase in seed yield could be due to increase in pollen production per unit area and homogenous distribution of pollen.

Schlichtin *et al.* (1987) and Quesada *et al.* (1996) observed lower seed number in squash fruits due to lower pollen quantity compared to the use of high pollen amount.

Vara Prasad *et al.* (1999) observed in groundnut an increase in pollen grains per flower (2,000 to 8,000) increased the fruit set from 0 to 48 per cent.

Niesenbaum (1999) recorded increase in fruit set with large pollen load when compared to small pollen loads in *Mirabilis jalapa* (Nyctaginaceae).

Highbush blueberry (*Vaccinium carymbosum* ; Ericaceae) selfing and crossing with small and high pollen loads increased the fruit set from 40 to 64 per cent and 40 to 80 per cent respectively (Dogterom *et al.*, 2000).

Hand pollination with large amount of pollen load resulted in highest number of seeds per fruit (200.5) and per hectare when compared to small pollen load (165.1) in *Cucurbita foetidissima* (Winsor and Stephenson, 2000)

In maize, kernel set was reduced at a rate of 0.4 per cent when pollen grain availability reached less than 227 pollen grains per square centimeter per day. A threshold of about two pollen grains per exposed silk was estimated as lowest limit for obtaining 95 per cent kernel set (Uribelarrea *et al.*, 2002).

Lima *et al.* (2003) observed in squash that by using 50 per cent of anther on stigma of female flower resulted in significant lower values of seed weight per plant and seed yield per hectare when compared to total anther.

In maize, harvested female kernels per ha increased asymptotically with pollen amount. Increasing pollen production per tassel from 1.5 million grains to 2.0 million grains increased harvest to about 19.0 million seeds per hectare. Thus, a 37 per cent increase in pollen production has improved potential kernel production by 8 per cent. The limiting of pollen production to 0.5 million grains per tassel only 10.9 million (33.6%) of the silks would set kernel. This reduction in pollen availability by 66 per cent resulted in 39 per cent reduction in potential kernel set (Fonseca *et al.*, 2004).

Colling *et al.* (2004) observed decrease in seed set when pollen quantity was limited and increase in seed set when pollination was carried with additional pollen quantity in *Scorzonera humilis* (Asteraceae).

2.5.1 Seed dormancy in sunflower

Dormancy is usually not a significant effect in the production of major annual crop plants as the seeds pass through this phase during storage between harvesting and sowing. However, it is important with seeds of sunflower where the period between harvest and planting is very short. Wallace and Haber (1958) reported that post harvest dormancy is absent in sunflower. Contrary to this Udaya Kumar and Shastry (1975) reported a dormancy period of 45-50 days in seeds of two varieties *viz.*, EC68414 and EC 69874.

The period of dormancy varies in different species and is influenced by the position of the seed in the fruit (Ketring and Morgan, 1970). Main reason for the seed dormancy in many crop species is due to the balance in promoter-inhibitor is more towards inhibitors component at the time of seed maturity (Amen, 1968; Wareing and Saunders, 1971).

Marappan *et al.* (1974) reported a dormancy period of 8-10 weeks in summer and *kharif* grown seeds of sunflower. Two cultivars *viz.*, Vniimk and Armaverts showed a dormancy period of 14-18 days after maturity (Mehrotra *et al.*, 1978). Seed harvested later in growing season had a shorter dormant period than that harvested earlier in sunflower (Zimmerman and Zimmer, 1978)

Zoia (1979) reported a mean dormancy period of 26-30 days in sunflower hybrids and their parents. Dighe and Patil (1980) recorded a dormancy period of 45 days in EC-68414 and 15 days in PKV-suf-72-37.

Several workers have reported a dormancy period of 35-40 days in different cultivars of sunflower (Mohammad *et al.*, 1984; Singh *et al.*, 1990)

The dormancy duration from physiological maturity was 30 days in Morden and 40 days in EC68414, APSH-11 and A, B and R-lines of APSH-11 from harvest (Rao *et al.*, 1993).

Rama *et al.* (2002) observed less than 30 days of seed dormancy in 57 genotypes of sunflower, while 28 genotypes had dormancy between 31-65 days. The genotypes 89-B, IB-24 and 852-B recorded more than 50 days of seed dormancy.

2.5.2 Seed quality of hybrid as influenced by restorer population

Seed quality parameters like germination percentage, shoot and root length, seedling dry weight, vigour index, speed of germination, electrical conductivity, field emergence were not significantly affected by male plant population in hybrid seed production of sunflower (Satyanarayana and Seetharam, 1983).

Kempegowda (1992), Rajashekhar (1994) and Somashekhar (1997) observed non-significant differences in seed quality parameters among various planting ratios.

Salmana Sultana and Rajendra Prasad (2005) reported non-significant differences in germination and vigour index by varied quantity of pollen in sunflower.

Material and Methods

III. MATERIAL AND METHODS

The field and laboratory experiments were conducted to study the effect of planting geometry of non-branching male parent (R-64NB) on pollen production and its influence on seed set, seed yield and quality in sunflower hybrid seed production of RSFH-1. The details of material used and techniques adopted during the course of investigation are furnished in this chapter.

3.1 LOCATION OF THE EXPERIMENTAL SITE

The experiment was conducted on deep black soils at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *rabi* season 2004. Dharwad is situated on a latitude of 15^0 26' North and 75^0 07' East longitude and at an altitude of 678 meters above mean sea level.

3.2 CLIMATE

The monthly meteorological data with respect to rainfall, air temperature and relative humidity for the period from January 2004 to February 2005 and average rainfall, temperature, relative humidity for the past 54 years are furnished in Table 1.

Main Agricultural Research Station of Agricultural College, Dharwad is situated in the North transitional tract of Karnataka state where the mean annual rainfall is 750.43 mm which is fairly distributed from April-May to October. The mean maximum temperature ranges from 22.02 ^{0}C (August) to 37.00 ^{0}C (April) mean minimum temperature ranges from 13.44 ^{0}C (December) to 21.48 ^{0}C (May). The mean monthly maximum relative humidity is 87.43 per cent (July) while the mean monthly

Table 1. Mean monthly meteorological data for experimental year (*kharif* 2004) and the mean of past 54 years (1950-2004) of Main Agricultural Research Station, UAS, Dharwad

Months	Rain fall (mm)		Temperature (°C)				Relative humidity (%)	
			Mean maximum		Mean minimum			
	2004-05	Mean*	2004-05	Mean*	2004-05	Mean*	2004-05	Mean*
January	0	0.086	29.6	29.15	14.7	19.23	54	63.34
February	0	1.161	32.5	34.52	16.4	16.02	53	51.18
March	0	0.147	36.5	35.73	19.6	18.81	49	56.47
April	24.4	48.45	37.4	37.00	19.8	21.32	51	76.98
May	61.1	81.40	33.6	36.52	21.4	21.48	66	66.71
June	43.8	148.70	28.8	29.50	21.5	21.21	80	81.69
July	24.8	15.77	29.2	22.06	21.0	20.95	79	87.43
August	160.7	95.30	27.0	22.02	20.3	20.62	83	86.51
September	222.1	100.54	28.6	28.75	19.9	20.16	77	82.40
October	64.6	130.99	30.1	30.12	18.4	19.30	65	76.44
November	0.6	32.04	30.2	29.46	15.9	15.50	52	68.13
December	0.0	54.50	29.4	29.18	12.5	13.44	59	63.81
January	48.0	-	30.7	-	15.0	-	67	-
February	0	-	33.2	-	16.3	-	62	-

minimum relative humidity was 51.18 per cent (February). The entire cropping period (October to February) received 113.2 mm rainfall from September to February. The highest maximum temperature recorded was 37.4 ^{0}C (April) while the highest minimum temperature was 21.5 ^{0}C (June). The lowest maximum and minimum temperatures recorded during the cropping period were 29.4 ^{0}C (December) and 12.5 ^{0}C (December) respectively and maximum and minimum relative humidity were 67 per cent (January) and 52 per cent (November) respectively.

3.3 SOIL TYPE OF THE EXPERIMENTAL SITE

The experimental site consisted of black clayey textured soil neutral in reaction. The soil physical and chemical composition are presented in Table 2.

3.4 PREVIOUS CROP

In the experimental site soybean was raised during *kharif* season of 2004.

3.5 DESCRIPTION OF PARENTAL LINES OF SUNFLOWER HYBRID RSFH-1

The description of the parental lines of sunflower hybrid RSFH-1 are presented in Table 3 (Plate 3 and 4).

3.6 EXPERIMENTAL DETAILS

3.6.1 Design and layout

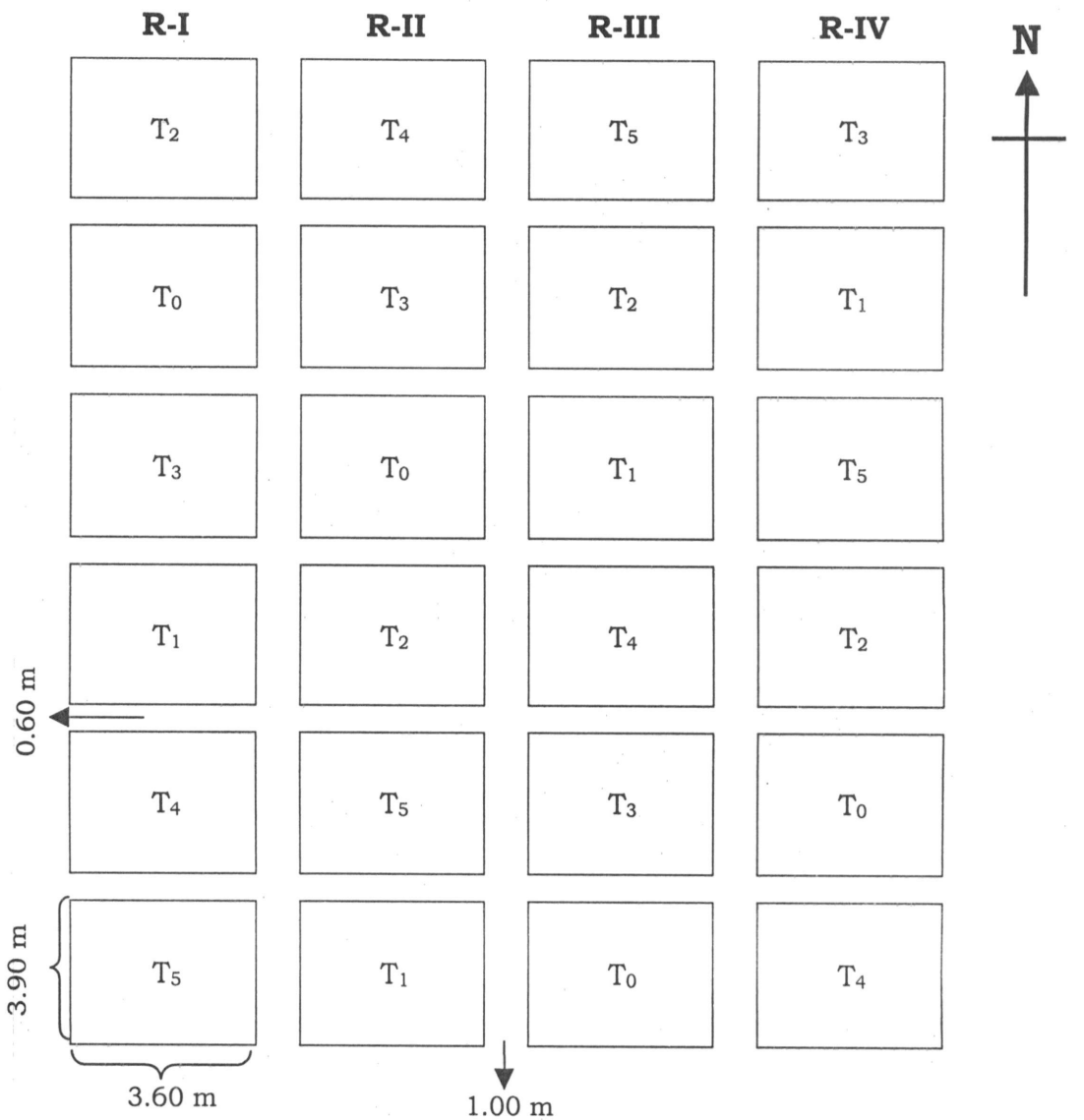
The experiments were laid out in a simple randomised block design with four replications. Plan of layout of the experiment is given in Figure 1.

Table 2. Soil physical and chemical properties of the experimental site

Particulars	Values
A. Physical properties	
Clay (%)	32.70
Silt (%)	9.50
Fine sand (%)	31.24
Coarse sand (%)	26.56
B. Chemical properties	
Total N (kg/ha)	265.0
Available P_2O_5 (kg/ha)	10.8
Available K_2O (kg/ha)	245.0
pH	6.7
Available Fe (ppm)	6.0
Available Zn (ppm)	0.6
Available Cu (ppm)	1.2
Available S (ppm)	25
Available Ca (C mol(+)kg)	25
(Exchangeable)	

Table 3. Description of the parental lines of sunflower hybrid RSFH-1

Sl. No.	Characters	Female parent (CMS-103A)	Male parent (R-64NB)
Morphological characters			
1.	Plant height (cm)	150-160 cm	100-130 cm
2.	Plant type	Non-branching	Non-branching
3.	Leaf colour	Dark green	Light green
4.	Leaf shape	Cardate and broad	Cordate and broad
5.	Leaf margin	Slightly serrate	Serrate
6.	Leaf apex	Slightly acute	Slightly acute
7.	Head shape	Flat to convex	Flat
8.	Head size (cm)	15-25	15-25
Flower and seed character			
9.	Inflorescence	Mono head	Mono head
10.	Ray florets	Yellow and round type	Yellow and round type
11.	Disc florets	Male sterile and stigma slightly pigmented	Male fertile
12.	Days to 50% flowering	58-62	62-66
13.	Seed size and colour	Bold and black	Medium bold and brown
Reaction to pest and diseases			
14.	Diseases	Resistant to rust, tolerant to *Alternaria* and moderately tolerant to necrosis	Resistant to rust and tolerant to *Alternaria*
15.	Pests	No major damage	No major damage



LEGEND

T0 - 60 x 30 cm single row, 55,555 plants per ha of male parent (R-64NB)

T1 - 60 x 30 cm paired row, 1,11,110 plants per ha of male parent (R-64NB)

T2 - 60 x 20 cm single row, 83,333 plants per ha of male parent (R-64NB)

T3 - 60 x 20 cm paired row, 1,66,666 plants per ha of male parent (R-64NB)

T4 - 45 x 30 cm single row, 74,074 plants per ha of male parent (R-64NB)

T5 - 45 x 30 cm paired row, 1,48,148 plants per ha of male parent (R-64NB)

Fig. 1: Plan of lay out of the experiment

3.6.2 Treatment details

Totally there were six treatments comprising of different spacing or plant populations for the non-branching male parent (R-64NB).

T_0 - 60 x 30 cm single row , 55,555 plants per ha

T_1 - 60 x 30 cm paired row, 1,11,110 plants per ha

T_2 - 60 x 20 cm single row, 83,333 plants per ha

T_3 - 60 x 20 cm paired row, 1,66,666 plants per ha

T_4 - 45 x 30 cm single row , 74,074 plants per ha

T_5 - 45 x 30 cm paired row, 1,48,148 plants per ha

Seed parent (CMS-103A) was spaced at 60 x 30 cm single row with 55,555 plants per ha.

3.6.3 Plot size

Pollen parent (R-64 NB)

Gross plot size : 3.90 x 3.60 m

Seed parent (CMS-103A)

Gross plot size : 6.40 x 6.60 m

Net plot size : 5.80 x 4.80 m

3.7 CULTURAL PRACTICES

3.7.1 Seed material

The seeds of CMS-103A (seed parent) and R-64NB (pollen parent) were obtained from the Senior Scientist (Breeding), Regional Agricultural Research Station, Raichur.

3.7.2 Land preparation

The land was ploughed with mould board plough and harrowed twice. Stubbles and weeds were collected from the experimental area. The land was brought to fine tilth by passing wooden plank and plots were laid out a week before sowing.

3.7.3 Fertilizer application

The fertilizers were applied in the form of urea, single super phosphate and muriate of potash to supply recommended levels of 60:90:60 kg NPK per ha. Half of the nitrogen and entire quantity of phosphorus and potash were applied at the time of sowing. The fertilizers were applied in furrows opened ten centimeter away from the seed row. Remaining half of the nitrogen (30 kg/ha) was applied at 30 days after sowing.

3.7.4 Sowing

The seeds were soaked in water for 6 hours and then treated with imidachloprid at the rate of 7.5 ml per kg of seeds. Treated seeds were dried in shade for 2-4 hours. The seeds were hand dibbled by giving spacing mentioned in the treatments. At each hill two to three seeds were dibbled to ensure optimum plant population. The seeds of male parent were sown in four staggered dates as follows.

First sowing (30% male) - 29-10-2004

Second sowing (30% male) - 31-10-2004

Third sowing (30% male) - 02-11-2004

Fourth sowing (10% male + entire female) - 04-11-2004

3.7.5 After care

Seedlings were thinned at 15 days after sowing and only one vigorous seedling was left per hill. Hand weeding was carried out at 30 days after sowing, earthing up was done between 30-35 days after sowing followed by (DAS) followed by top dressing with remaining half dose of nitrogenous fertilizer. The crop was protected from defoliators and leaf spot by spraying endosulfan (2 ml/litre) and Dithane M-45 (4 g/litre) during vegetative stage of the crop. The crop was irrigated once in 10-12 days interval to maintain optimum moisture content in soil for proper crop growth.

3.7.6 Roguing

Female plots were thoroughly checked for off-types and they were rogued out in order to maintain genetic purity.

3.7.7 Pollination

Hand pollination was carried out every day between 8-11 am from the day of commencement of flowering till the completion by collecting the pollen in petridishes and smeared on to the female flowers with the help of brush. The male heads were covered with cloth bags in order to avoid pollen theft by bees.

3.7.8 Harvesting and threshing

The crop was harvested when the back of the head turned lemon yellow colour indicating the harvest maturity. The heads in all the treatments collected separately and dried. Seeds were seperated by manual threshing of the heads.

The heads of ten randomly selected plants from each plot were cut and threshed separately to determine the yield and yield components.

General view of experimental plots are presented in Plate 1 and 2.

3.8 COLLECTION OF EXPERIMENTAL DATA

3.8.1 Sampling

Ten plants were tagged at random in each treatment for recording detailed biometric observations on the following characters.

3.8.2 Growth parameters

3.8.2.1 Plant height (cm)

Height of ten randomly selected plants was measured from the ground level to the base of the capitulum at ray floret opening stage. The average height of the plant in centimeter was worked out.

3.8.2.2 Number of leaves

The total number of leaves per plant were counted at ray floret opening stage in each plot and mean was worked out and expressed as number of green leaves per plant.

3.8.2.3 Days to first ray floret opening

The number of days taken for first ray floret opening of ten randomly selected plants in each plot was taken. The average number of days taken for opening of first ray floret was worked out and expressed in days.

3.8.2.4 Days to 50 per cent flowering

Number of days taken from sowing to first ray floret opening in 50 per cent of the plants in each treatment was recorded.

3.8.2.5 Pollen [illegible]

Plate 1. A bird view of the male parent (R-64NB) plot of sunflower hybrid RSFH-1

Plate 2. A bird view of the female parent (CMS-103A) plot of sunflower hybrid RSFH-1

Plate 3. A single plant of restorer line (R-64NB) of sunflower hybrid RSFH-1

Plate 4. A single plant of seed parent (CMS-103A) of sunflower hybrid RSFH-1

3.8.2.5 Pollen production

Ten random plants were tagged in each treatment of restorer line. From the day of ray floret opening, every day pollen produced in the head of each plant was collected and weighed separately. The total pollen production per plant was worked out upto flowering. The total pollen production per hectare was worked out using the total plant population in each plot.

3.8.2.6 Capitulum diameter (cm)

The distance between two diagonally opposite edges of the capitulum was measured as capitulum diameter in ten randomly selected plants from each plot after completion of flowering.

3.8.3 Yield parameters

3.8.3.1 Number of filled seeds

The seeds obtained from ten randomly selected plants were cleaned and filled seeds were separated manually and counted. The average number of filled seeds was worked out and expressed in number.

3.8.3.2 Per cent seed set

Heads from selected ten plants were threshed separately and number of filled and unfilled seeds were counted and per cent seed set was worked out by using the following formula.

$$\text{Seed set (\%)} = \frac{\text{Number of filled seeds per head}}{\text{Total number of seeds (filled + unfilled) per head}} \times 100$$

3.8.3.3 Seed yield per plant (g)

The heads of ten randomly selected plants were harvested, dried and threshed separately. The mean was worked out and recorded as yield per plant.

3.8.3.4 Test weight (g)

Hundred seeds were counted in four replications from the samples drawn from each plot. The mean was worked out and recorded.

3.8.3.5 Seed yield per hectare (kg)

The heads from net plot area in each treatment were harvested and threshed. After thorough cleaning, the seeds were dried upto 9 per cent moisture. The seed weight was recorded for each treatment. Based on net plot yield, the seed yield was computed in kilograms per hectare.

3.8.3.6 Seed recovery percentage

The recommended sieve size of 2.8 mm (S) was used to process the known bulk quantity of seed and quantity of good seed retained on the sieve was weighed and recovery percentage was worked out by using following formula. The portion of sample that passed through a sieve was considered as rejected seed.

$$\text{Seed recovery (\%)} = \frac{\text{Weight of seed retained over sieve (g)}}{\text{Total weight of seeds used for processing (g)}} \times 100$$

3.8.3.7 Processed seed yield per hectare (kg)

The processed seed yield per hectare in kilograms was computed by multiplying the total seed yield in kilograms per hectare with seed recovery percentage.

Processed seed yield (kg/ha)= Total seed yield (kg/ha) x seed recovery (%)

3.8.3.8 Achene oil content (%)

Samples were drawn from each treatment of hybrid seed and the oil content in the seeds was estimated by Nuclear Magnetic Resonanee Spectrometre installed at Regional Agricultural Research Station, Raichur.

3.8.3.9 Oil yield (kg/ha)

Oil yield was calculated by multiplying the seed yield per hectare with their respective oil percentage.

3.8.4 Seed quality parameters of sunflower hybrid RSFH-1

3.8.4.1 Seed dormancy

The standard germination test was conducted immediately after harvesting in order to determine the period of seed dormancy as per the ISTA procedure (ISTA, 1999). The rolled paper towels were placed at slanting position in a cabinet seed germinator at a constant temperature of 25 $\pm$ 1^{0}C and 95 $\pm$ 1 per cent RH.

The seeds were put for germination every week and germination count was taken on 7th day and expressed in percentage. The germination test was continued until constant values were obtained and period of dormancy was worked out.

3.8.4.2 Seed germination (%)

Germination test was conducted as per ISTA rules (ISTA, 1999). The number of normal seedlings were counted at the end of 4th and 10th day as first and final count of germination respectively and expressed in percentage.

3.8.4.3 Root length (cm)

Ten normal seedlings were randomly selected from each of the replication of the germination test on 10th day (final count) and used for measuring root length. The root length was measured between collar region and tip of root with the help of a scale. The mean values were calculated and expressed in centimeters.

3.8.4.4 Shoot length (cm)

Ten seedlings used for measuring root length were used for measuring shoot length. The shoot length was measured from collar region to the point of attachment of cotyledons. The mean values were computed and expressed in centimeters.

3.8.4.5 Seedling length (cm)

The seedling length of ten randomly selected seedlings was worked out by adding the root and shoot length of the seedling and expressed in centimeters.

3.8.4.6 Seedling vigour index

The seedling vigour index was computed by adopting the method suggested by Abdul-Baki and Anderson (1973) and expressed as an index number.

SVI = Seedling length x Germination (%)

3.8.4.7 Speed of germination

The seedlings with minimum of 3 cm root were taken as germinated for computing the speed of germination. Every day counts were taken and speed of germination was calculated using following formula as suggested by Maguire (1962).

$$\text{Speed of germination} = \frac{G_1}{T_1} + \frac{G_2}{T_2} + \text{- - - - -} + \frac{Gn}{Tn}$$

Where,

G_1 = Number of seed germinated on first day (T_1)

G_2 = Number of seed germinated on second day (T_2)

Gn = Number of seed germinated on final day (Tn)

3.8.4.8 Seedling dry weight (g)

The ten normal seedlings selected for shoot and root length measurement were put in butter paper packet and kept in an oven maintained at 85 $\pm$ 1^{0}C for 24 hours. After drying, the seedlings were kept in a desiccator for cooling. The weight of dry seedlings was recorded and mean weight was calculated and expressed in milligrams (Anon., 1996).

3.8.4.9 Electrical conductivity (dSm^{-1})

The ten gram seeds from each treatment in four replications were weighed and surface sterilized by using 0.1 per cent mercury chloride solution and then rinsed with water for three times. These seeds were soaked in 25 ml distilled water in a beaker and kept in an incubator maintained at 25$\pm$1^{0}C temperature. After 24 hours of soaking, the solution

was decanted and volume was made upto 25 ml by adding distilled water. The electrical conductivity was recorded using the digital conductivity metre and expressed in desi Simons per metre (dSm^{-1}).

3.9 B:C RATIO

The B:C ratio was calculated by using the following formula,

$$\text{B:C ratio} = \frac{\text{Total returns (Rs.)}}{\text{Total cost of cultivation (Rs.)}}$$

3.10 STATISTICAL ANALYSIS

The data collected from the experiment were analysed statistically as per by procedure given by Panse and Sukhatme (1967) and Sundararajan *et al.* (1972). Critical differences were calculated at 5 per cent level. The percentage data was to transformed into arcsine values and utilised for statistical analysis (Snedecor and Cochron, 1967 and Fisher and Yates, 1963).

Correlation coefficients were calculated between pollen production, seed yield and yield characters following the method of Panse and Sukhatme (1967).

Experimental Results

IV. EXPERIMENTAL RESULTS

The investigation involved field and laboratory experiment to study the effect of planting geometry of non-branching male parent (R-64NB) on pollen production and its influence on seed set, seed yield and quality of sunflower hybrid seed production of RSFH-1.

Field experiment was conducted at Main Agricultural Research Station, Dharwad during *rabi* season of 2004-05. The results of the experiment are presented hereunder.

4.1 EFFECT OF PLANTING GEOMETRY OF MALE PARENT (R-64NB) ON GROWTH, POLLEN PRODUCTION AND ITS INFLUENCE ON SEED YIELD AND QUALITY OF SUNFLOWER HYBRID SEED PRODUCTION OF RSFH-1

4.1.1 Growth parameters in non-branching male parent (R-64NB)

4.1.1.1 Plant height (cm) at ray floret opening

The results on plant height of male parent (R-64NB) as influenced by planting geometry of restorer line are presented in Table 4.

The effect of plant population on plant height at ray floret opening was found significant. The highest plant height of male plant (134.63 cm) was noticed in plant population of 1.66 lakh per ha (60 x 20 cm paired row) followed by 45 x 30 cm paired row (128.60), 60 x 30 paired row (128.30 cm) and 60 x 20 cm single row (125.50 cm). Significantly lowest plant height (116.00 cm) was recorded in plant population of 0.55 lakh plants per hectare (60 x 30 cm single row).

Table 4. Influence of planting geometry on plant height and number of leaves at ray floret opening in male parent (R-64NB) of sunflower hybrid RSFH-1

Treatments	Plant height (cm)	Number of leaves
T_0 - 60 x 30 cm single row (55,555 plants/ha)	116.00	17.65
T_1 - 60 x 30 cm paired row (1,11,110 plants/ha)	128.30	18.83
T_2 - 60 x 20 cm single row (83,333 plants/ha)	125.50	18.96
T_3 - 60 x 20 cm paired row (1,66,666 plants/ha)	134.63	20.28
T_4 - 45 x 30 cm single row (74,074 plants/ha)	122.30	18.38
T_5 - 45 x 30 cm paired row (1,48,148 plants/ha)	128.60	19.43
Mean	**125.89**	**18.92**
S.Em±	3.28	0.51
CD at 5%	9.88	1.54

4.1.1.2 Number of leaves per plant at ray floret opening

The results on number of leaves per plant at ray floret opening as influenced by planting geometry of restorer line are presented in Table 4.

Significantly more number of leaves per plant (20.28) was recorded in T_3 (1,66,666 plants/ha) followed by T_5 (1,48,148 plants/ha) (19.43). Significantly lowest number of leaves per plant (17.65) was recorded in T_0 (55,555 plants/ha) treatment.

4.1.2 Flowering duration in male parent (R-64NB)

4.1.2.1 Days to ray floret opening

The results on days taken for opening of ray floret in male parent (R-64NB) as influenced by planting geometry are presented in Table 5.

Influence of plant densities on days to ray floret opening was non-significant. However, maximum number of days (68.20) to ray floret opening was observed in T_3 (1,66,666 plants/ha) and minimum (66.20) in T_1 (1,11,110 plants/ha) treatment.

4.1.2.2 Days to 50 per cent flowering

The results on days to 50 per cent flowering of male parent (R-64NB) as influenced by planting geometry are presented in Table 5.

Influence of plant density showed non-significant effect on days to 50 per cent flowering in R-64NB. However, numerically more number of days (73.50) to 50 per cent flowering was recorded in T_3 (1,66,666 plants/ha) while minimum number of days (72.19) in T_0 (55,555 plants/ha) treatment.

Table 5. Influence of planting geometry on days to ray floret opening and 50 per cent flowering in male parent (R-64 NB) of sunflower hybrid RSFH-1

Treatments	Days to	
	Ray floret opening	**50 per cent flowering**
T_0 - 60 x 30 cm single row (55,555 plants/ha)	66.95	72.19
T_1 - 60 x 30 cm paired row (1,11,110 plants/ha)	66.20	72.88
T_2 - 60 x 20 cm single row (83,333 plants/ha)	66.30	72.44
T_3 - 60 x 20 cm paired row (1,66,666 plants/ha)	68.20	73.50
T_4 - 45 x 30 cm single row (74,074 plants/ha)	66.40	72.38
T_5 - 45 x 30 cm paired row (1,48,148 plants/ha)	67.80	73.19
Mean	**66.98**	**72.26**
S.Em±	0.56	0.53
CD at 5%	NS	NS

NS – Non-significant

4.1.3 Flowering duration in female parent (CMS-103A)

The results on days to ray floret opening, 50 per cent flowering in female parent (CMS-103A) are presented in Table 6.

The mean number of days taken by the female (CMS-103A) line for ray floret opening and 50 per cent flowering were 58.00 and 64.63 respectively.

4.1.4 Capitulum diameter (cm)

The results on capitulum diameter of restorer line R-64NB as influenced by planting geometry are presented in Table 7.

Among the different treatments, significantly lowest capitulum diameter (11.93 cm) was found in T_3 (60 x 20 cm paired row) followed by T_5 (45 x 20 cm paired row), T_1 (60 x 30 cm paired row), T_2 (60 x 20 cm single row) and T_4 spaced at 45 x 30 cm single row (12.15, 12.50, 12.93 and 13.68 cm, respectively). The maximum capitulum diameter of 14.25 was recorded in T_0 (60 x 30 cm single row).

4.1.5 Pollen production in restorer line (mg/plant)

The results on total pollen production per plant during entire flowering period as influenced by planting geometry of restorer line are presented in Table 7.

Among the different plant densities significantly highest pollen production (712.75 mg) was recorded in T_0 (55,555 plants/ha) treatment. Significantly lowest pollen production (571.25 mg) was recorded in T_3 (1,66,666 plants/ha) treatment.

Table 6. Number of days taken by the female parent (CMS-103A) of sunflower hybrid RSFH-1 for ray floret opening and 50 per cent flowering.

Replications	Days to	
	Ray floret opening	50 per cent flowering
R_1	58.00	64.67
R_2	58.17	64.67
R_3	57.67	65.17
R_4	58.17	64.00
Mean	**58.00**	**64.63**

Table 7. Influence of planting geometry of male parent (R-64 NB) on capitulum diameter and pollen production

Treatments	Capitulum diameter (cm)	Production (mg/plant)	Production (kg/ha)
T_0 - 60 x 30 cm single row (55,555 plants/ha)	14.25	712.75	39.59
T_1 - 60 x 30 cm paired row (1,11,110 plants/ha)	12.50	610.75	67.85
T_2 - 60 x 20 cm single row (83,333 plants/ha)	12.93	633.50	52.79
T_3 - 60 x 20 cm paired row (1,66,666 plants/ha)	11.93	571.25	95.20
T_4 - 45 x 30 cm single row (74,074 plants/ha)	13.68	685.00	50.74
T_5 - 45 x 30 cm paired row (1,48,148 plants/ha)	12.15	598.75	88.70
Mean	**12.91**	**635.33**	**65.81**
S.Em±	0.38	9.58	1.83
CD at 5%	1.13	28.87	5.51

4.1.5.1 Mean daily pollen production (mg/plant/day)

The mean daily pollen production per plant as influenced by planting geometry of restorer line is presented in Table 8.

Among the different plant densities significantly highest pollen production per day (59.40 mg) was recorded in T_0 (60 x 30 cm single row with 55,555 plants/ha) followed by T_4 (74,074 plants/ha), T_2 (83,333 plants/ha), T_1 (1,11,110 plants/ha) and T_5 (1,48,148 plants/ha), in these treatments the mean pollen production per plant per day was 58.08, 52.79, 50.90 and 49.90 mg respectively and lowest (47.61 mg) was recorded in T_3 (1,66,666 plants/ha) treatment.

The pollen production was distributed up to 11-12 days during the entire flowering period. It reached maximum on 4th (85.96 mg) and 5th (86.29 mg) day after anthesis in all the treatments. Thereafter, pollen production declined and lowest pollen production was recorded on 12th (5.5 mg) day in all the treatments.

4.1.5.2 Pollen production per ha (kg)

The results of pollen production per hectare as influenced by planting geometry of restorer line are presented in Table 7.

The pollen production per ha found to differ significantly among plant densities. Significantly higher pollen production (95.20 kg/ha) was recorded in highest plant population (1,66,666 plants/ha) followed by 1,48,148 plants per hectare (88.70 kg/ha) treatment. Significantly lowest pollen production (39.59 kg/ha) was recorded in T_0 (55,555 plants/ha) followed by plant population of 74,074 per hectare in T_4 (50.74 kg/ha) treatment.

Table 8. Influence of planting geometry on pollen production in male parent (R-64 NB) of RSFH-1 hybrid sunflower

Treatments	Pollen production per plant (mg) from first whorl of flower opening to last whorl of flower opening (1-12 days)													
	1	2	3	4	5	6	7	8	9	10	11	12	Total	Mean
T_0	47.50	77.75	87.75	96.00	96.00	82.00	75.00	60.00	42.00	25.50	15.70	7.50	**712.75**	**59.40**
T_1	35.25	63.50	73.75	82.25	84.00	70.00	61.00	51.75	42.00	23.75	15.50	8.00	**610.75**	**50.90**
T_2	41.50	67.75	78.00	85.50	86.75	73.75	65.25	49.75	39.50	22.75	15.25	7.75	**633.50**	**52.79**
T_3	31.50	64.00	72.00	80.50	78.50	65.75	56.25	46.25	40.50	19.75	14.00	2.25	**571.25**	**47.61**
T_4	49.50	73.75	84.50	90.50	91.25	80.00	69.50	58.50	39.00	25.50	15.50	6.50	**685.00**	**58.08**
T_5	40.00	64.00	76.50	81.00	81.25	68.25	61.25	48.50	41.25	21.25	14.50	1.00	**598.75**	**49.90**
Mean	39.99	68.46	78.75	85.96	86.29	73.29	64.71	52.46	40.71	23.08	15.08	5.5	**635.33**	**33.31**
S.Em±													**9.58**	**1.66**
CD at 5%													**28.87**	**4.99**

T_0- 60 x 30 cm single row
T_1- 60 x 30 cm paired row
T_2- 60 x 20 cm single row
T_3- 60 x 20 cm paired row
T_4-45 x 30 cm single row
T_5- 45 x 30 cm paired row

4.1.6 Yield and yield components in female parent (CMS-103A) of sunflower hybrid RSFH-1

4.1.6.1 Number of filled seeds per capitulum

The results on number of filled seeds per head as influenced by planting geometry of restorer line are presented in Table 9.

The number of filled seeds per capitulum was found to differ significantly among different treatments. The number of filled seeds per head was significantly higher (480) in T_3 followed by T_5 (467) and T_1 (451). In these treatments the total male plant population per hectare was 1,66,666, 1,48,148 and 1,11,110 respectively. Significantly lowest number of filled seeds (413) was recorded in T_0 (55,555 plants/ha) treatment.

4.1.6.2 Number of unfilled seeds per capitulum

The data on number of unfilled seeds per capitulum as influenced by planting geometry of restorer line are presented in Table 9.

Number of unfilled seeds per capitulum differed significantly among different treatments. Significantly highest number of unfilled seeds (205) was recorded in T_0 (55,555 plants/ha) followed by T_4 (199) with 74,074 plants per hectare. Significantly lowest number of unfilled seeds (173) was observed in T_3 (1,66,666 plants/ha) followed by T_5 (175) with 1,48,148 plants per hectare.

4.1.6.3 Total number of seeds per capitulum

The results on total number of seeds as influenced by planting geometry of restorer line are presented in Table 9.

Planting geometry of male parent on total number of filled seeds in female parent has recorded non-significant differences. However,

Table 9. Effect of pollen availability due to planting geometry of male parent (R-64 NB) on filled, unfilled and total number of seeds per capitulum in female parent (CMS-103A) of sunflower hybrid RSFH-1

Treatments	No. of filled seeds	No. of unfilled seeds	Total number of seeds
1. Quantity of pollen available (39.59 kg/ha) in T_0 60 x 30 cm single row (55,555 plants/ha)	413	205	618
2. Quantity of pollen available (67.85 kg/ha) in T_1 60 x 30 cm paired row (1,11,110 plants/ha)	451	184	635
3. Quantity of pollen available (52.79 kg/ha) in T_2 60 x 20 cm single row (83,333 plants/ha)	424	186	610
4. Quantity of pollen available (95.20 kg/ha) in T_3 60 x 20 cm paired row (1,66,666 plants/ha)	480	173	653
5. Quantity of pollen available (50.74 kg/ha) in T_4 45 x 30 cm single row (74,074 plants/ha)	429	199	628
6. Quantity of pollen available (88.70 kg/ha) in T_5 45 x 30 cm paired row (1,48,148 plants/ha)	467	175	643
Mean	**444.00**	**187.00**	**631.16**
S.Em±	12.27	5.61	13.16
CD at 5%	36.97	16.90	NS

NS – Non significant

maximum number of seeds (653) was recorded in T_3 (1,66,666 plants/ha) and minimum of 610 was recorded in T_2 (83,333 plants/ha).

4.1.6.4 Seed set per cent

The results on seed set per cent as influenced by planting geometry of restorer line are presented in Table 10.

The seed set per cent in female parent was found to differ significantly among the plant densities of restorer line. Significantly higher seed set (73.44%) was recorded in T_3 (1,66,666 plants/ha) followed by T_5 (72.73%) and T_1 (71.01%) with male population of 1,48,148 and 1,11,110 plants per hectare respectively. Significantly lowest seed set per cent (66.87%) was recorded in T_0 (55,555 plants/ha) treatment.

4.1.6.5 Seed yield per plant (g)

The results on seed yield per plant as influenced by planting geometry of restorer line are presented in Table 10.

The seed yield per plant were found to differ significantly in different treatments. Highest seed yield (19.56 g) was recorded in T_3 (1,66,666 plants/ha) followed by T_5 (19.18 g) with 1,48,148 plants per hectare. While significantly lowest seed yield (17.24 g) was recorded in T_0 (55,555/ha).

4.1.6.6 Seed yield per ha (kg)

The results on seed yield per hectare as influenced by planting geometry of restorer line are presented in Table 11.

The seed yield was found to differ significantly among different treatments. Significantly highest seed yield of 808.63, 794.78 and 758.37 kg per hectare was recorded in T_3 (1,66,666 plants/ha), T_5 (1,48,148

Table 10. Effect of pollen availability due to planting geometry of male parent (R-64 NB) on seed set and seed yield in female parent (CMS-103A) of sunflower hybrid RSFH-1

Treatments	Seed set percentage	Seed yield (g/plant)
1. Quantity of pollen available (39.59 kg/ha) in T_0 60 x 30 cm single row (55,555 plants/ha)	66.87	17.24
2. Quantity of pollen available (67.85 kg/ha) in T_1 60 x 30 cm paired row (1,11,110 plants/ha)	71.01	18.65
3. Quantity of pollen available (52.79 kg/ha) in T_2 60 x 20 cm single row (83,333 plants/ha)	69.44	17.60
4. Quantity of pollen available (95.20 kg/ha) in T_3 60 x 20 cm paired row (1,66,666 plants/ha)	73.44	19.56
5. Quantity of pollen available (50.74 kg/ha) in T_4 45 x 30 cm single row (74,074 plants/ha)	68.27	17.88
6. Quantity of pollen available (88.70 kg/ha) in T_5 45 x 30 cm paired row (1,48,148 plants/ha)	72.73	19.18
Mean	**70.29**	**17.96**
S.Em±	1.07	0.49
CD at 5%	3.23	1.50

NS – Non significant

Table 11. Effect of pollen availability due to planting geometry of male parent (R-64 NB) on seed yield and test weight in female parent (CMS-103A) of sunflower hybrid RSFH-1

Treatments	Seed yield (kg/ha)	Test weight (g)
1. Quantity of pollen available (39.59 kg/ha) in T_0 60 x 30 cm single row (55,555 plants/ha)	700.19	4.17
2. Quantity of pollen available (67.85 kg/ha) in T_1 60 x 30 cm paired row (1,11,110 plants/ha)	758.37	4.13
3. Quantity of pollen available (52.79 kg/ha) in T_2 60 x 20 cm single row (83,333 plants/ha)	720.50	4.15
4. Quantity of pollen available (95.20 kg/ha) in T_3 60 x 20 cm paired row (1,66,666 plants/ha)	808.63	4.07
5. Quantity of pollen available (50.74 kg/ha) in T_4 45 x 30 cm single row (74,074 plants/ha)	720.32	4.16
6. Quantity of pollen available (88.70 kg/ha) in T_5 45 x 30 cm paired row (1,48,148 plants/ha)	794.78	4.10
Mean	**750.47**	**4.13**
S.Em±	19.03	0.04
CD at 5%	57.35	NS

NS – Non significant

plants/ha) and T_1 (1,11,110 plants/ha) respectively. The lowest (700.19 kg/ha) was observed in T_0 (55,555 plants/ha) treatment.

4.1.6.7 Seed recovery (%)

The results on seed recovery percentage as influenced by planting geometry of restorer line are presented in Table 12.

Seed recovery percentage among different treatments was found non-significant. However, numerically more seed recovery of 88.00 per cent was recorded in T_0 (55,555 plants/ha) and lowest seed recovery (85.00%) observed in T_3 (1,66,666 plants/ha) treatment.

4.1.6.8 Processed seed yield (kg/ha)

The data on processed seed yield per hectare as influenced by planting geometry of restorer line are presented in Table 12.

Among different treatments, the processed seed yield differed significantly. Maximum processed seed yield was recorded in T_3 (687.33 kg/ha) followed by T_5 and T_1 (678.34 and 656.00 kg/ha, respectively). All these treatments were on par with each other. The minimum processed seed yield was recorded in T_0 (616.17 kg/ha).

4.1.6.9 Test weight (g)

The results on test weight as influenced by planting geometry of restorer line are presented in Table 11.

The test weight among different treatments was found non-significant. However, test weight varied from 4.07 g in T_3 (1,66,666 plants/ha) to 4.17 g (55,555 plants/ha) in T_0.

Table 12. Effect of pollen availability due to planting geometry of male parent (R-64 NB) on seed recovery and processed seed yield in female parent (CMS-103A) of sunflower hybrid RSFH-1

Treatments	Seed recovery (%)	Processed seed yield (kg /ha)
1. Quantity of pollen available (39.59 kg/ha) in T_0 60 x 30 cm single row (55,555 plants/ha)	88.00	616.17
2. Quantity of pollen available (67.85 kg/ha) in T_1 60 x 30 cm paired row (1,11,110 plants/ha)	86.50	656.00
3. Quantity of pollen available (52.79 kg/ha) in T_2 60 x 20 cm single row (83,333 plants/ha)	87.00	626.83
4. Quantity of pollen available (95.20 kg/ha) in T_3 60 x 20 cm paired row (1,66,666 plants/ha)	85.00	687.33
5. Quantity of pollen available (50.74 kg/ha) in T_4 45 x 30 cm single row (74,074 plants/ha)	87.50	630.28
6. Quantity of pollen available (88.70 kg/ha) in T_5 45 x 30 cm paired row (1,48,148 plants/ha)	85.35	678.34
Mean	**86.56**	**649.16**
S.Em±	1.27	17.64
CD at 5%	NS	53.14

4.1.6.10 Oil content (%)

The data on oil content as influenced by planting geometry of restorer are presented in Table 13.

The oil content among different treatments was found non-significant. However, highest oil content (40.70%) was recorded in T_0 (55,555 plants/ha) and lowest (39.40 %) in T_3 (1,66,666 plants/ha) treatment.

4.1.6.11 Oil yield (kg/ha)

The results on oil yield as influenced by planting geometry of restorer line are presented in Table 13.

The oil yield differed significantly among different treatments. Significantly higher oil yield was recorded in T_3 (318.60 kg/ha) followed by T_5 (314.70) and T_1 (304.86 kg/ha) where as lower oil yield was recorded in T_0 (285.00 kg/ha) treatment.

4.1.7 Seed quality parameters of sunflower hybrid RSFH-1

4.1.7.1 Seed dormancy

The data on dormancy as ascertained by seed germination percentage at weekly intervals are presented in Table 14.

The period of dormancy as ascertained by per cent germination did not differ significantly among the treatments in different weeks. A mean initial germination of 12.88 was observed immediately after harvesting of hybrid seed.

Table 13. Effect of pollen availability due to planting geometry of male parent (R-64 NB) on oil content and oil yield in female parent (CMS-103A) of sunflower hybrid RSFH-1

Treatments	Oil content (%)	Oil yield (kg/ha)
1. Quantity of pollen available (39.59 kg/ha) in T_0 60 x 30 cm single row (55,555 plants/ha)	40.70	285.00
2. Quantity of pollen available (67.85 kg/ha in T_1 60 x 30 cm paired row (1,11,110 plants/ha)	40.20	304.86
3. Quantity of pollen available (52.79 kg/ha) in T_2 60 x 20 cm single row (83,333 plants/ha)	40.55	292.16
4. Quantity of pollen available (95.20 kg/ha) in T_3 60 x 20 cm paired row (1,66,666 plants/ha)	39.40	318.60
5. Quantity of pollen available (50.74 kg/ha) in T_4 45 x 30 cm single row (74,074 plants/ha)	40.60	292.44
6. Quantity of pollen available (88.70 kg/ha) in T_5 45 x 30 cm paired row (1,48,148 plants/ha)	39.60	314.70
Mean	**40.18**	**301.30**
S.Em±	1.21	9.30
CD at 5%	NS	28.03

Table 14. Influence of planting geometry of male parent (R-64 NB) on hybrid seed dormancy

Weeks after harvesting	0	1	2	3	4	5	6
Treatments	**Germination (%)**						
T_0 - 60 x 30 cm single row (55,555 plants/ha)	12.50 (20.70)*	30.75 (33.68)	45.75 (42.55)	65.25 (53.90)	73.50 (59.02)	86.00 (68.03)	92.60 (74.21)
T_1 - 60 x 30 cm paired row (1,11,110 plants/ha)	13.00 (21.13)	31.00 (33.03)	46.00 (42.71)	64.50 (54.43)	72.75 (58.52)	85.50 (66.82)	92.25 (73.80)
T_2 - 60 x 20 cm single row (83,333 plants/ha)	13.25 (21.30)	31.50 (34.14)	46.50 (42.99)	65.00 (53.73)	74.00 (59.34)	86.25 (68.23)	92.36 (73.94)
T_3 - 60 x 20 cm paired row (1,66,666 plants/ha)	12.75 (20.92)	31.25 (33.98)	45.75 (42.55)	64.75 (53.58)	73.75 (59.18)	85.00 (67.21)	92.00 (73.57)
T_4 - 45 x 30 cm single row (74,074 plants/ha)	13.50 (21.56)	32.00 (34.44)	46.00 (42.71)	65.75 (54.18)	74.25 (59.47)	86.50 (68.44)	92.48 (74.11)
T_5 - 45 x 30 cm paired row (1,48,148 plants/ha)	12.25 (20.46)	30.50 (26.92)	46.25 (42.84)	65.50 (54.03)	74.50 (59.67)	85.75 (67.82)	92.15 (73.70)
Mean	**12.88**	**31.17**	**46.04**	**65.13**	**73.79**	**85.83**	**92.31**
S.Em±	0.28	1.19	0.99	0.91	0.97	1.05	1.05
CD at 5%	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

* Values in parenthesis are arcsine transformed values

The germination was above the Minimum Seed Certification Standards (70%) after fourth week of harvesting and a maximum mean germination (92.31) was recorded after sixth week of harvesting.

4.1.7.2 Germination percentage

The results of germination percentage as influenced by planting geometry of restorer line are presented in Table 15.

Germination percentage did not differ significantly among different plant densities of restorer line. Germination percentage was found to be higher (92.60%) in T_0 (55,555 plants/ha) and lower in T_3 (92.00%) treatment.

4.1.7.3 Shoot length (cm)

The results of shoot length as influenced by planting geometry of restorer line are presented in Table 15.

The shoot length among different plant populations did not differ significantly. However, maximum shoot length (16.60 cm) was recorded in T_0 (55,555 plants/ha) and the minimum (16.40 cm) was recorded in T_3 (1,66,666 plants/ha).

4.1.7.4 Root length (cm)

The results of root length as influenced by planting geometry of restorer line are presented in Table 15.

The root length was non-significant among different plant densities. However, highest root length (19.62 cm) was recorded in T_0 (55,555 plants/ha) and lowest (19.40 cm) in T_3 (1,66,666 plants/ha).

Table 15. Influence of planting geometry of male parent (R-64 NB) on germination, shoot length and root length in sunflower hybrid RSFH-1

Treatments	Germination (%)	Shoot length (cm)	Root length (cm)
T_0 - 60 x 30 cm single row (55,555 plants/ha)	92.60 (74.21)*	16.60	19.62
T_1 – 60 x 30 cm paired row (1,11,110 plants/ha)	92.25 (73.80)	16.46	19.48
T_2 - 60 x 20 cm single row (83,333 plants/ha)	92.36 (73.94)	16.50	19.52
T_3 - 60 x 20 cm paired row (1,66,666 plants/ha)	92.00 (73.57)	16.40	19.40
T_4 - 45 x 30 cm single row (74,074 plants/ha)	92.48 (74.11)	16.56	19.57
T_5 - 45 x 30 cm paired row (1,48,148 plants/ha)	92.15 (73.70)	16.43	19.44
Mean	**92.31**	**16.49**	**19.51**
S.Em±	1.05	0.22	0.44
CD at 5%	NS	NS	NS

NS – Non significant

* Values in parenthesis are arcsine transformed values

4.1.7.5 Seedling length (cm)

The results of seedling length as influenced by planting geometry of restorer line are presented in Table 16.

Seedling length did not differ significantly among different plant density treatments. However, maximum seedling length (36.22) was obtained in T_0 (55,555 plants/ha) and minimum (35.80) in T_3 (1,66,666 plants/ha).

4.1.7.6 Seedling vigour index

The data on seedling vigour index as influenced by planting geometry of restorer line are presented in Table 16.

The vigour index did not differ significantly among different plant densities. Highest vigour index (3354) was noticed in T_0 (55,555 plants/ha) and lowest (3294) was in T_3 (1,66,666 plants/ha) treatment.

4.1.7.7 Seedling dry weight (mg)

The results on seedling dry weight as influenced by planting geometry of restorer line are presented in Table 17.

Seedling dry weight did not differ significantly due to different treatments. The maximum seedling dry weight (53.70 mg) was recorded in T_0 (55,555 plants/ha) and minimum (51.67 mg) in T_3 (1,66,666 plants/ha).

4.1.7.8 Speed of germination

The results on speed of germination as influenced by planting geometry of restorer line are presented in Table 17.

Table 16. Influence of planting geometry of male parent (R-64NB) on seedling length and seedling vigour index in sunflower hybrid RSFH-1

Treatments	Seedling length (cm)	Seedling vigour index
T_0 - 60 x 30 cm single row (55,555 plants/ha)	36.22	3354
T_1 - 60 x 30 cm paired row (1,11,110 plants/ha)	35.94	3315
T_2 - 60 x 20 cm single row (83,333 plants/ha)	36.02	3327
T_3 - 60 x 20 cm paired row (1,66,666 plants/ha)	35.80	3294
T_4 - 45 x 30 cm single row (74,074 plants/ha)	36.13	3341
T_5 - 45 x 30 cm paired row (1,48,148 plants/ha)	35.87	3305
Mean	**36.00**	**3323**
S.Em±	0.66	40.75
CD at 5%	NS	NS

NS – Non significant

Table 17. Influence of planting geometry of male parent (R-64 NB) on seedling dry weight and speed of germination in sunflower hybrid RSFH-1

Treatments	Seedling dry weight (mg)	Speed of germination
T_0 - 60 x 30 cm single row (55,555 plants/ha)	53.70	22.70
T_1 – 60 x 30 cm paired row (1,11,110 plants/ha)	52.60	22.19
T_2 – 60 x 20 cm single row (83,333 plants/ha)	53.15	22.50
T_3 - 60 x 20 cm paired row (1,66,666 plants/ha)	51.67	21.75
T_4 - 45 x 30 cm single row (74,074 plants/ha)	53.33	22.60
T_5 - 45 x 30 cm paired row (1,48,148 plants/ha)	51.90	21.83
Mean	**52.73**	**22.26**
S.Em±	0.83	0.33
CD at 5%	NS	NS

NS – Non significant

Among different plant densities, speed of germination did not differ significantly. However, highest speed of germination (22.70) was obtained in T_0 (55,555 plants/ha) and lowest (21.75) in T_3 (1,66,666 plants/ha).

4.1.7.9 Field emergence (%)

The results on field emergence as influenced by planting geometry of restorer line are presented in Table 18.

Per cent field emergence was non-significant among different plant density treatments. The maximum field emergence (83.50) was noticed in T_0 (55,555 plants/ha) and minimum (82.00) in T_3 (1,66,666 plants/ha).

4.1.7.10 Electrical conductivity of seed leachate (dS m^{-1})

The results on electrical conductivity as influenced by planting geometry of restorer line are presented in Table 18.

Electrical conductivity did not differ significantly among different treatments. However, lowest (0.691 dSm^{-1}) electrical conductivity was recorded in T_0 (55,555 plants/ha) and highest (0.742 dSm^{-1}) in T_3 (1,66,666 plants/ha).

4.1.8 Economics of sunflower hybrid seed production of RSFH-1 per hectare

The results on economics of hybrid seed production of RSFH-1 are presented in Table 19.

Among different treatments, the highest gross returns (Rs. 55,592.90), net returns (Rs. 27,111.42) and B:C ratio (1.95) was recorded in T_3 (1,66,666 plants/ha) followed by T_5 (Rs. 54,849.40, Rs. 26,367.92 and 1.93, respectively) and T_1 (Rs. 52,991.85, Rs. 24,510.37

Table 18. Influence of planting geometry of male parent (R-64NB) on field emergence and electrical conductivity in sunflower hybrid RSFH-1

Treatments	Field emergence (%)	Electrical conductivity (dSm^{-1})
T_0 - 60 x 30 cm single row (55,555 plants/ha)	83.50 (66.03)*	0.691
T_1 – 60 x 30 cm paired row (1,11,110 plants/ha)	82.35 (65.16)	0.714
T_2 – 60 x 20 cm single row (83,333 plants/ha)	82.62 (65.35)	0.722
T_3 – 60 x 20 cm paired row (1,66,666 plants/ha)	82.00 (64.93)	0.742
T_4 - 45 x 30 cm single row (74,074 plants/ha)	82.86 (65.55)	0.701
T_5 - 45 x 30 cm paired row (1,48,148 plants/ha)	82.15 (65.00)	0.735
Mean	**82.58**	**0.472**
S.Em±	0.71	0.02
CD at 5%	NS	NS

NS – Non significant

* Values in parenthesis are arcsine transformed values

Table 19. Economics of sunflower hybrid (RSFH-1) seed production per hectare

Treatments	Cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	B:C ratio
T_0 - 60 x 30 cm single row (55,555 plants/ha)	28,481.48	49,713.70	21,232.22	1.75
T_1 - 60 x 30 cm paired row (1,11,110 plants/ha)	28,481.48	52,991.85	24,510.37	1.86
T_2 - 60 x 20 cm single row (83,333 plants/ha)	28,481.48	50,614.75	22,133.27	1.78
T_3 - 60 x 20 cm paired row (1,66,666 plants/ha)	28,481.48	55,592.90	27,111.42	1.95
T_4 - 45 x 30 cm single row (74,074 plants/ha)	28,481.48	50,872.60	22,391.12	1.79
T_5 - 45 x 30 cm paired row (1,48,148 plants/ha)	28,481.48	54,849.40	26,367.92	1.93

and 1.86, respectively) whereas, lowest observed in T_0 (Rs. 49,713.70, Rs. 21,232.22 and 1.75, respectively).

4.1.9 Correlation studies for yield and yield components in female line (CMS-103A) of sunflower hybrid RSFH-1 as influenced by planting geometry in male line (R-64NB)

The data on simple correlation studies for yield and yield components are presented in Table 20.

Pollen yield per hectare had positive and significant correlation coefficients with all yield and yield components *viz.,* filled seeds (0.990), seed set per cent (0.985), seed yield per plant (0.985), seed yield per hectare (0.998) and processed seed yield per hectare (0.998) except number of unfilled (-0.936) seeds and seed recovery per cent (-0.994) which recorded negative correlation.

The yield components like number of filled seeds (0.995), seed set per cent (0.981), seed yield per plant (0.992) and oil yield per hectare (0.999) are positively correlated to seed yield per hectare. The number of unfilled seeds (-0.923) and oil content (-0.990) recorded negative correlation with seed yield per hectare.

Test weight has recorded positive correlation with per cent oil content (0.987) and negative with number of filled seeds (-0.978).

Table 20. Correlation studies for yield and yield components in sunflower hybrid RSFH-1

	Pollen production (kg/ha)	No. of filled seeds	No. of unfilled seeds	Seed set (%)	Seed yield (g/plant)	Seed yield (kg/ha)	Test weight (g)	Seed recovery (%)	Processed seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
Pollen production/ha	1	0.990**	-0.936**	0.985**	0.985**	0.998**	-0.984**	-0.994**	0.994**	-0.991**	-0.996**
No. of filled seeds		1	-0.903**	0.972**	0.999**	0.995**	-0.976**	-0.973**	0.997**	-0.978**	0.996**
No. of unfilled seeds			1	-0.978**	-0.892*	-0.923**	0.919**	0.965**	-0.908**	0.901**	-0.927**
Seed set (%)				1	0.966**	0.981**	-0.966**	-0.992**	0.974**	-0.959**	0.984**
Seed yield (g/plant)					1	0.992**	-0.963**	-0.964**	0.996**	-0.969**	0.995**
Seed yield (kg/ha)						1	-0.981**	-0.987**	0.999**	-0.990**	0.999**
Test weight (g)							1	0.983**	-0.975**	0.987**	-0.974**
Seed recovery (%)								1	-0.978**	0.982**	-0.984**
Processed seed yield (kg/ha)									1	-0.986**	0.998**
Oil content (%)										1	-0.981**
Oil yield (kg/ha)											1

* = Significant at 0.05 per cent
** = Significant at both 0.01 and 0.05 per cent

Discussion

V. DISCUSSION

The discussion on the results generated from the studies on the effect of planting geometry of non-branching restorer line (R-64NB) on growth, pollen production and its influence on seed yield and quality of sunflower hybrid seed production of RSFH-1 are discussed in this chapter in the light of available literature.

5.1 INFLUENCE OF PLANTING GEOMETRY OF NON-BRANCHING RESTORER LINE (R-64NB)

5.1.1 Growth parameters

In the CGMS system of hybrid seed production, the sufficient pollen production in restorers to supply adequate pollen for pollinating the seed parent is most essential to get maximum seed set and hybrid seed yield. Pollen production is influenced by several factors like head size and duration of flowering.

The restorer line (R-64NB) of sunflower hybrid RSFH-1 is a monoheaded type, hence, the main constraint in hybrid seed production of RSFH-1 is low pollen production and the supply of pollen is restricted to shorter duration as a result seed set percentage in female parent is comparatively less. Therefore the only alternative to maximize seed yield in female line (CMS-103A) of sunflower hybrid RSFH-1 in a given environment is by increasing the plant density of restorer line within the recommended planting proportion of 3:1 female to male parent.

In this context the male line (R-64NB) of RSFH-1 hybrid was planted at different spacings *viz.*, 60 x 30 cm single row (55,555 plants/ha), 60 x 30 cm paired row (1,11,110 plants/ha), 60 x 20 single

row (83,333 plants/ha), 60 x 20 cm paired row (1,66,666 plants/ha), 45 x 30 cm single row (74,074 plants/ha), 45 x 30 cm paired row (1,48,148 plants/ha).

The plant height of restorer (R-64NB) decreased significantly with decrease in plant density (1,66,666 to 55,555 plants/ha). The plants spaced at 60 x 20 cm paired row (1,66,666 plants per/ha) recorded significantly more plant height (134.63 cm) at ray floret opening followed by 45 x 30 cm paired row (128.60 cm) compared to plants spaced at 60 x 30 cm single row (116.00 cm) which might be due to greater interplant competition for light or solar energy which activated the cell division of apical meristem towards light resulting in elongation of meristem. These results are in conformity with the findings of Singh *et al.* (1973 and 1982), Singh and Verma (1975) and Paikary *et al.* (1997) in niger, Suraj Bhan (1977), Miller and Fick (1978), Jadhav and Jadhav (1980), Holt and Campbell (1984), Sankappanavar (1984), Solomon (1987), Majid and Schneiter (1988), Gubbels and Deido (1989 and 1990), Seenappa *et al.* (1992), Gajendra (1996), Hegde and Havanagi (1998), Kumar and Mohammad (2001) and Sen *et al.* (2002) in sunflower.

The number of leaves per plant increased significantly with increase in plant density. Significantly more number of leaves (20.28) at ray floret opening was recorded in plants spaced at 60 x 20 cm paired row (1,66,666 plants/ha) followed by plant population of 1,48,148 plants per hectare spaced at 45 x 30 cm paired row (19.43) over 60 x 30 cm single row with plant population of 55,555 plants per hectare (17.65). The increased number of leaves was mainly due to increase in number of nodes with increase in plant height. Increased leaf area index (LAI) and leaf area per hectare due to increase in leaf number was also reported by

Narasimha Rao and Narasa Reddy (1982), Sankappanavar (1984), Deshpande (1990), Kumar and Mohammad (2001) in sunflower.

Variation in the plant population did not influence significantly the days taken for ray floret opening and 50 per cent flowering (Fig. 2) in restorer line (R-64NB). However, marginally higher number of days to ray floret opening (68.20) and 50 per cent flowering (73.50) was recorded in the male parent spaced at 60 x 20 cm paired row (1,66,666 plants/ha).

This delay in days taken for ray floret opening and 50 per cent flowering may be attributed to more plant density, which favoured the more vegetative growth competing for sunlight or solar energy. This is in conformity with the findings of Alessi *et al.* (1977) and Sankappanavar (1984) who observed no variation in days to 50 per cent flowering with decreased row spacing. However, contrasting results were reported by Majid and Schneiter (1988), Deshpande (1990) and Hulagur (1992) in sunflower.

The seed parent (CMS-103A) of hybrid in question took a mean of 58.00 and 64.63 days for ray floret opening and 50 per cent flowering respectively.

Capitulum diameter of restorer (R-64NB) increased significantly with decrease in plant population. The plants spaced at 60 x 30 cm single row (55,555 plants/ha) recorded more capitulum diameter (14.25 cm) when compared to increased plant population. This increase in capitulum diameter at low plant population is attributed to less interplant competition which permitted better development of individual plants owing to adequate availability of moisture, nutrients and light resulting in bigger heads. Similar results were also reported by Chidanand (1973),

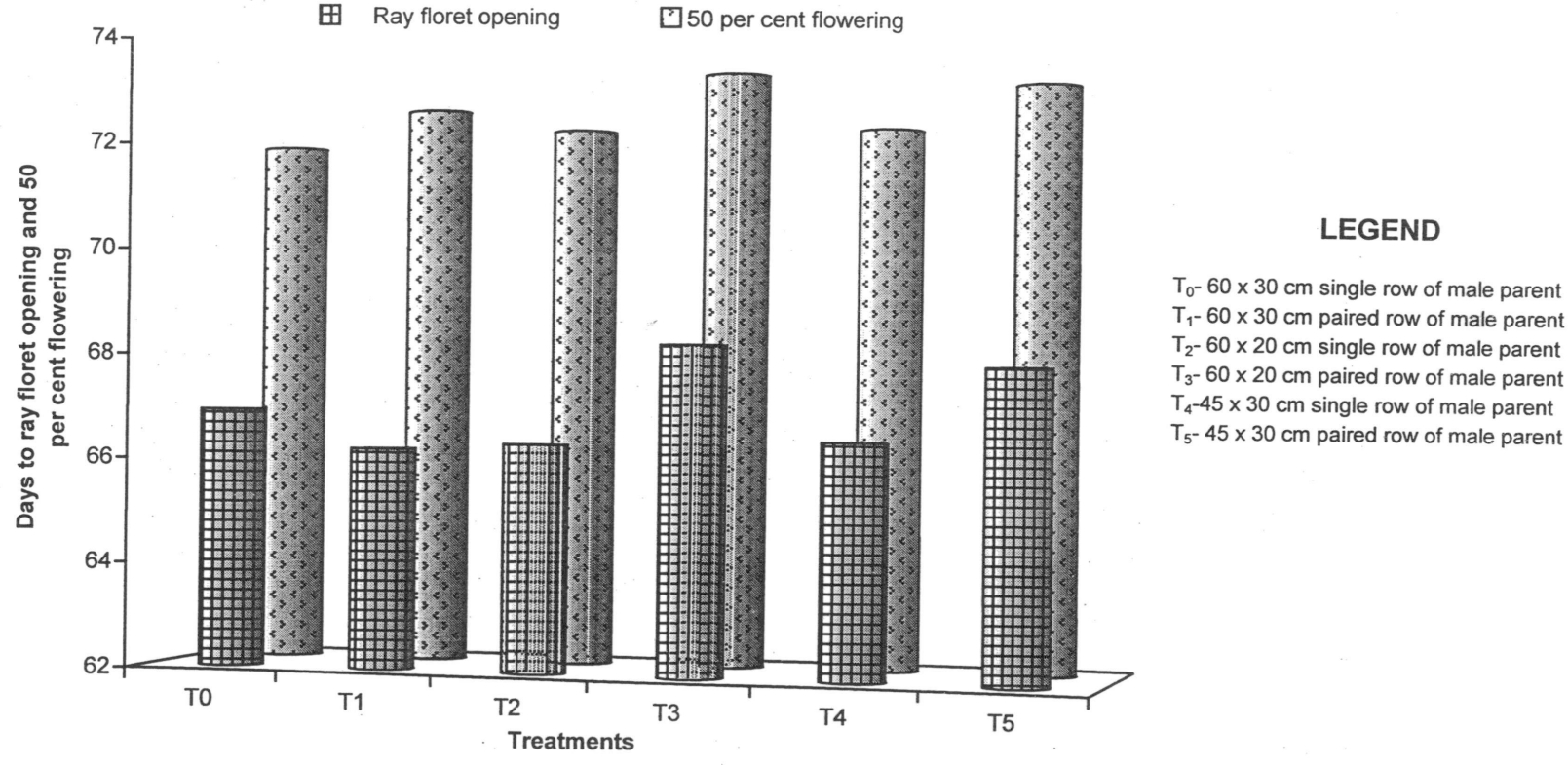


Fig. 2 : Days to ray floret opening and 50 per cent flowering in non-branching male parent (R-64NB) of sunflower hybrid RSFH-1

Singh and Kaushal (1975), Miller and Fick (1978), Holt and Campbell (1984), Sankappanavar (1984), Solomon (1987), Kameshwara Rao and Gangasaran (1991), Seenappa *et al.* (1992), Gajendra (1996), Ortegon and Diaz (1997) and Kumar and Mohammad (2001) in sunflower.

5.1.2 Pollen production

The pollen production in male parent was distributed over 12 days during the flowering period. The pollen production reached its maximum level on 4th and 5th day and there after it declined (Fig. 4). Similar findings were also reported by Easwar (1996).

Total pollen production per plant decreased with increasing plant population. Significantly more pollen production of 712.75 mg was recorded in lowest plant population of 55,555 plants per hectare planted at 60 x 30 cm single row (Fig. 3). This might be attributed to larger head size (14.25 cm) in case of lower plant density owing to less interplant competition for light, nutrients and moisture resulting in larger head size. The increased head size provide sufficient space for the development of individual disc florets leading to more pollen production (Kannababu *et al.,* 1993). The results of the present study are in conformity with the findings of Vermeulen (1985), Suresh (1994) and Easwar (1996) in sunflower who observed that wider spacing provided more pollen producing surface (head size) and also by Shashi and Chaudhary (1985) in rice. The minimum total amount of pollen production of 571.25 mg per plant was recorded in highest plant population (1,66,666 plants/ha) with 60 x 20 cm paired row planting due to smaller head size (11.93 cm).

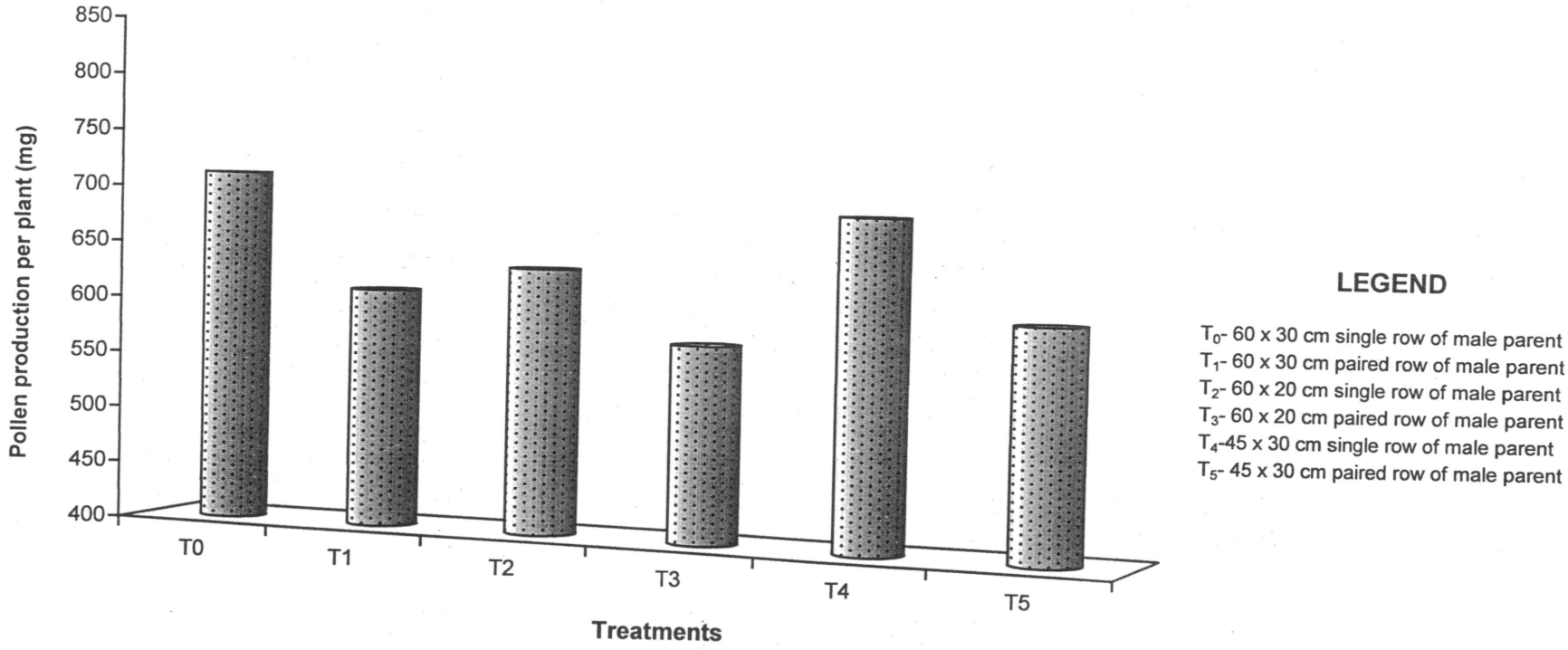


Fig. 3 : Influence of planting geometry of non-branching male parent (R-64NB) on pollen production per plant

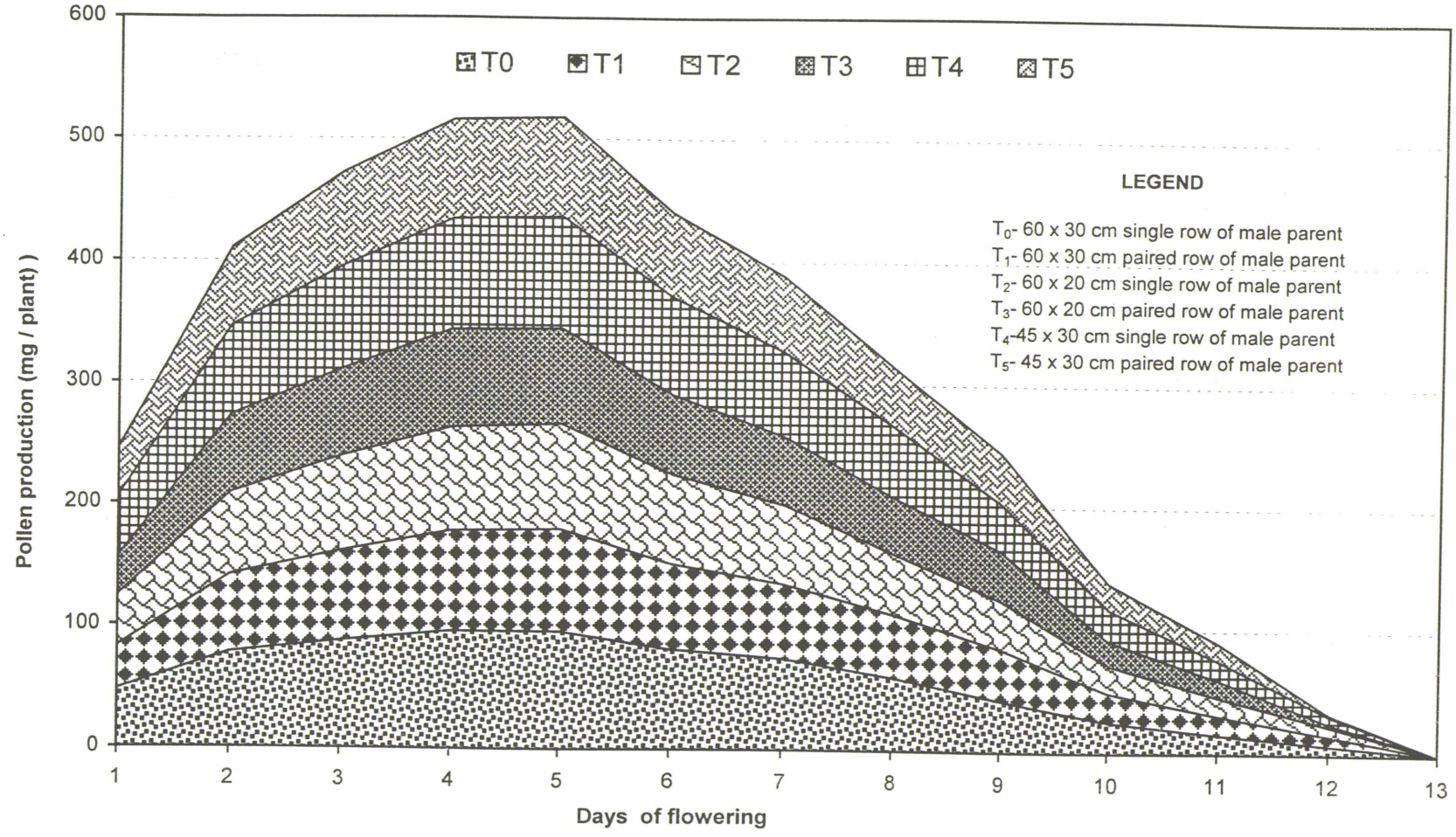


Fig. 4 : Influence of planting geometry of male parent (R-64NB) on daily pollen production

The mean daily pollen production per plant decreased with increase in plant population. Significantly more mean daily pollen production of 59.40 mg was recorded in 60 x 30 cm single row sowing (55,555 plants/ha) compared to 47.61 mg in plants spaced at 60 x 20 paired row (1,66,666 plants/ha) which may be due to more amount of total pollen production per plant on account of bigger size capitulum noticed with plant recorded in lower plant population.

The total pollen production is a function of size of capitulum and number of plants per unit area. In the present study the total pollen production per hectare increased with increase in plant population (Fig. 5). The highest amount of 95.20 kg pollen was produced in plants spaced 60 x 20 cm paired row (1,66,666 plants/ha) followed by (88.70 kg) 45 x 30 cm paired row planting (1,48,148 plants/ha). Although the total pollen production per plant was low but the total pollen production per hectare was significantly more due to more number of plants which contributed for total pollen production per hectare. The lowest pollen production of 39.59 kg per hectare was recorded in lower plant population (55,555 plants/ha).

5.1.3 Effect of planting geometry of restorer line (R-64NB) on pollen production and its influence on seed yield and components of female line (CMS-103A) of sunflower hybrid RSFH-1

More number of filled seeds per plant (480) was observed in female parent which received pollen from male plants spaced at 60 x 20 cm paired row (1,66,666/ha) followed by 45 x 30 cm paired row (467) with restorer population of 1,48,148 plants per hectare (Fig. 6). The per cent increase was 16.22 and 13.05 respectively over the lower plant population (55,555 plants/ha) spaced at 60 x 30 cm single row respectively (Fig. 6).

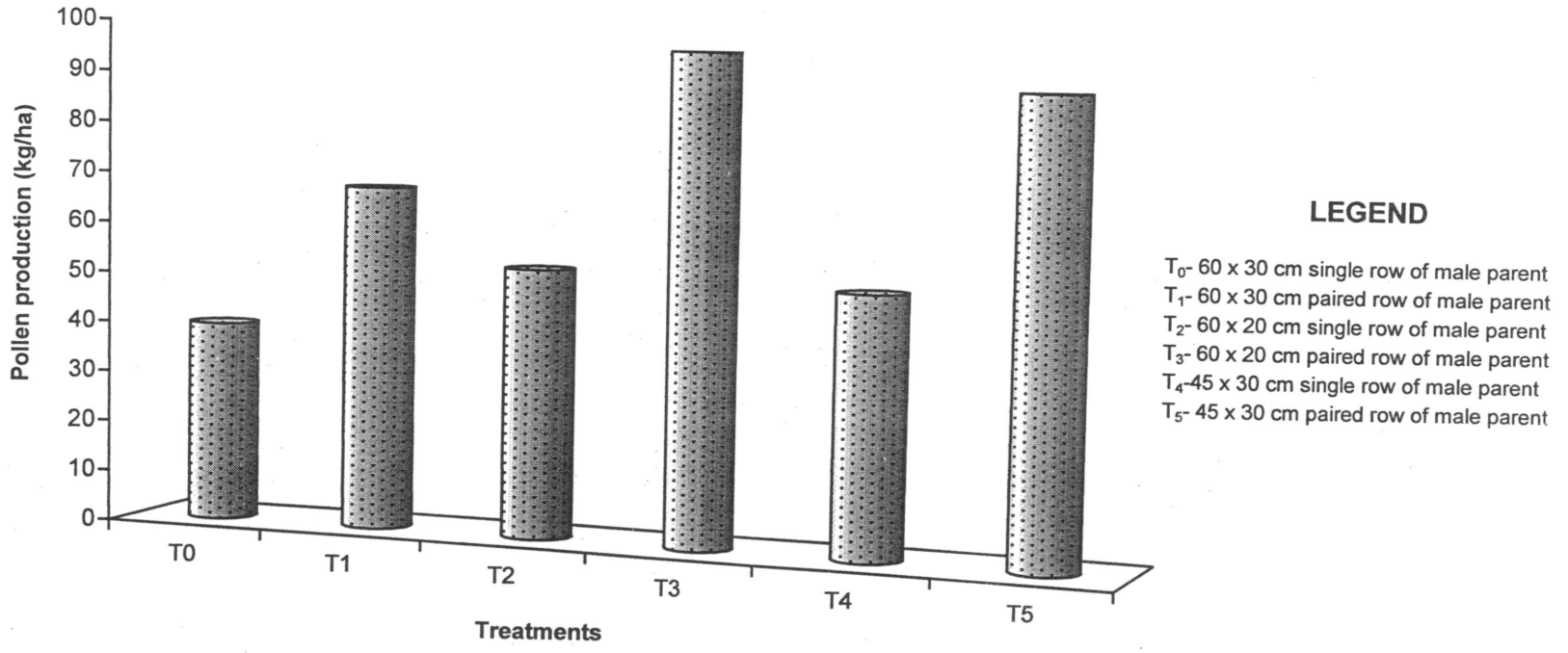


Fig. 5 : Influence of planting geometry of non-branching male parent (R-64NB) on pollen production per hectare

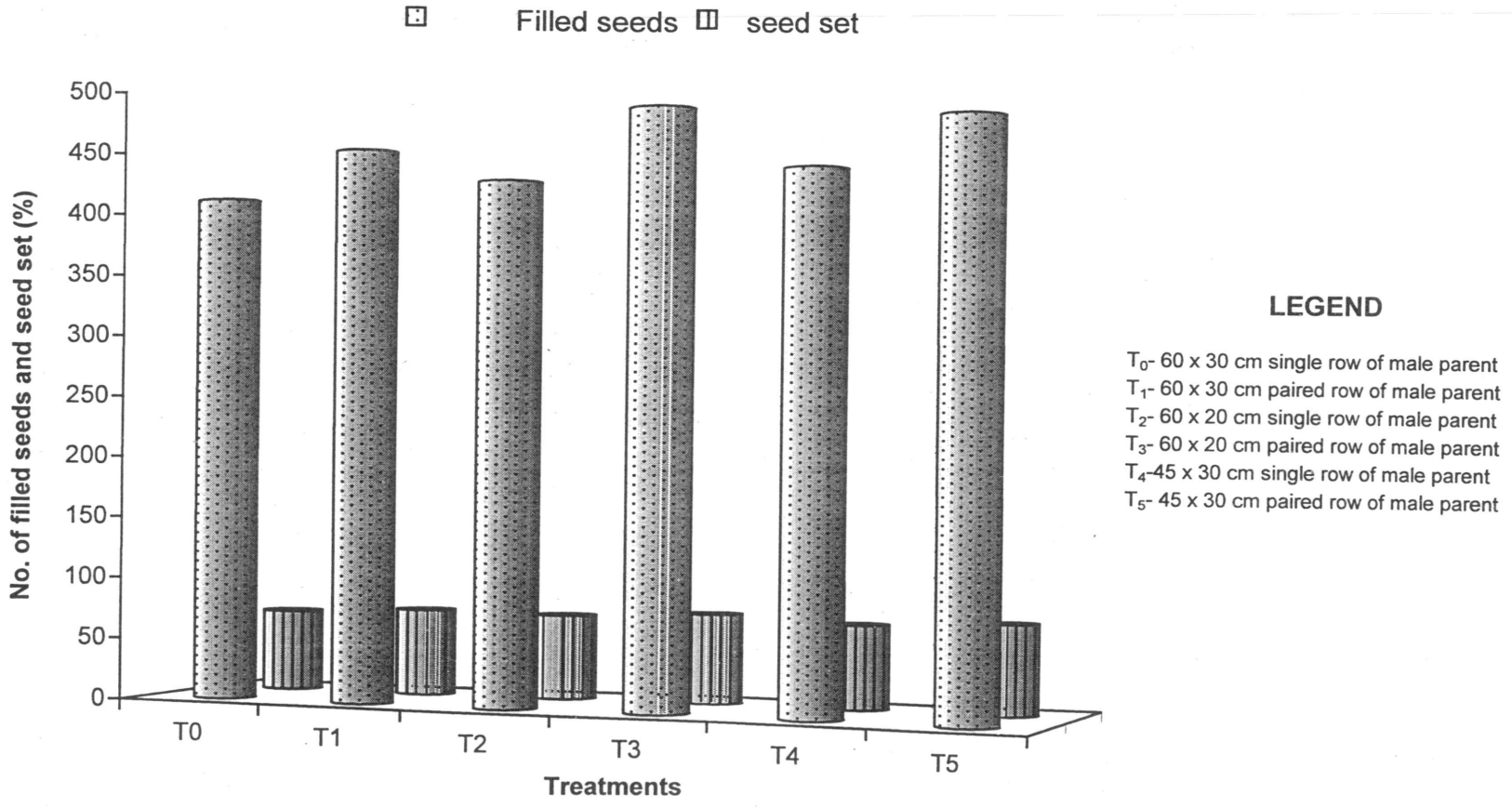


Fig. 6 : Influence of planting geometry of male parent (R-64NB) on number of filled seeds and seed set per cent in seed parent (CMS-103A) of sunflower hybrid RSFH-1

The higher number of filled seeds are attributed to sufficient amount of pollen grains available for pollination in highest plant density, which is due to increased number of pollen grains available for successful pollination, there by decreased the wilted achenes and empty achenes in female line (Kempegowda, 1992; Rajashekhar, 2000 and Kantha Raju, 2003 in sunflower). Similar findings were also reported in other crops by Schlichtin *et al.* (1987) in Squash, Winsor and Stephenson (2000) in *Cucurbita foetidissim,* Uribelarrea *et al.* (2002) and Fonseca *et al.,* (2004) in maize.

More number of unfilled seeds (205) were recorded in female plants which were pollinated with the pollen obtained from male plants spaced widely (60 x 30 cm single row). This increase in unfilled seeds per plant may be due to less availability of pollen grains per unit area. The total number of seeds per plant did not differ significantly among plant populations. However, marginally more number of seeds per plant (653) was observed in the female line which received pollen from high plant density of male line.

The per cent seed set in female line increased with increase in population of restorer line. Significantly higher seed set (73.44%) was recorded in female plants which were pollinated with the pollen grains obtained from the restorer planted at 60 x 20 cm paired row (1,66,666 plants/ha) followed by (72.73%) plant spaced at 45 x 30 cm paired row (1,48,148 plants/ha). The per cent increase in seed set in female over control in these treatments were 10.83 and 8.76 respectively (Fig. 6). This can be ascribed to more number of filled seeds and more quantity of pollen available for pollination due to increased number of restorer plants per unit area. Kempegowda (1992), Balamuragan and Angamuthu (1999)

also have reported lower row proportion (female to male) increased the per cent seed set in sunflower due to sufficient supply of pollen. Pederson and Barnes (1973) observed a significant correlation between pollen production index and seed set in alfalfa, Allison (1990) in *Taxus canadensis*, Vara Prasad *et al.* (1999) in groundnut, Niesenbaum (1999) in *Mirabilis jalapa,* Dogterom *et al.* (2000) in highbush blue berry, Colling *et al.* (2004) in *Scorzonera humilis* (Asteraceae).

The seed yield per plant and per hectare increased with increase in plant population of restorer (Fig. 7). The highest seed yield of 19.56 g per plant and 808.63 kg per hectare was recorded in female parent which received pollen from T_3 (60 x 20 cm paired row, with 1,66,666 plants/ha) followed by 19.18 g per plant and 794.78 kg per hectare in T_5 (45 x 30 cm paired row with 1,48,148 plants/ha). In these treatments the per cent increase over control (60 x 30 cm single row, with 55,555 plants/ha) is 13.45 and 11.25 per plant, 15.49 and 13.51 per hectare respectively. Increase in seed yield is attributed to more number of filled seeds, seed set per cent and seed yield per plant as noticed in present study. Shashi and Chaudhary (1985) reported that seed yield per plant was more in A line when restorer was space planted at 10 cm row than at 15 cm due to increased and homogenous pollen supply in rice hybrid. Vara Prasad *et al.* (1999) observed increase in seed yield per plant with increase in pollen production per flower in groundnut. Lima *et al.* (2003) reported in squash that use of full anther increased the seed yield per plant and per hectare than half anther. So also in sunflower Rajashekhar (2000), Kantha Raju (2003) and Salmana Sultana and Rajendra Prasad (2005) have reported that use of 100 per cent pollen resulted in significantly highest seed

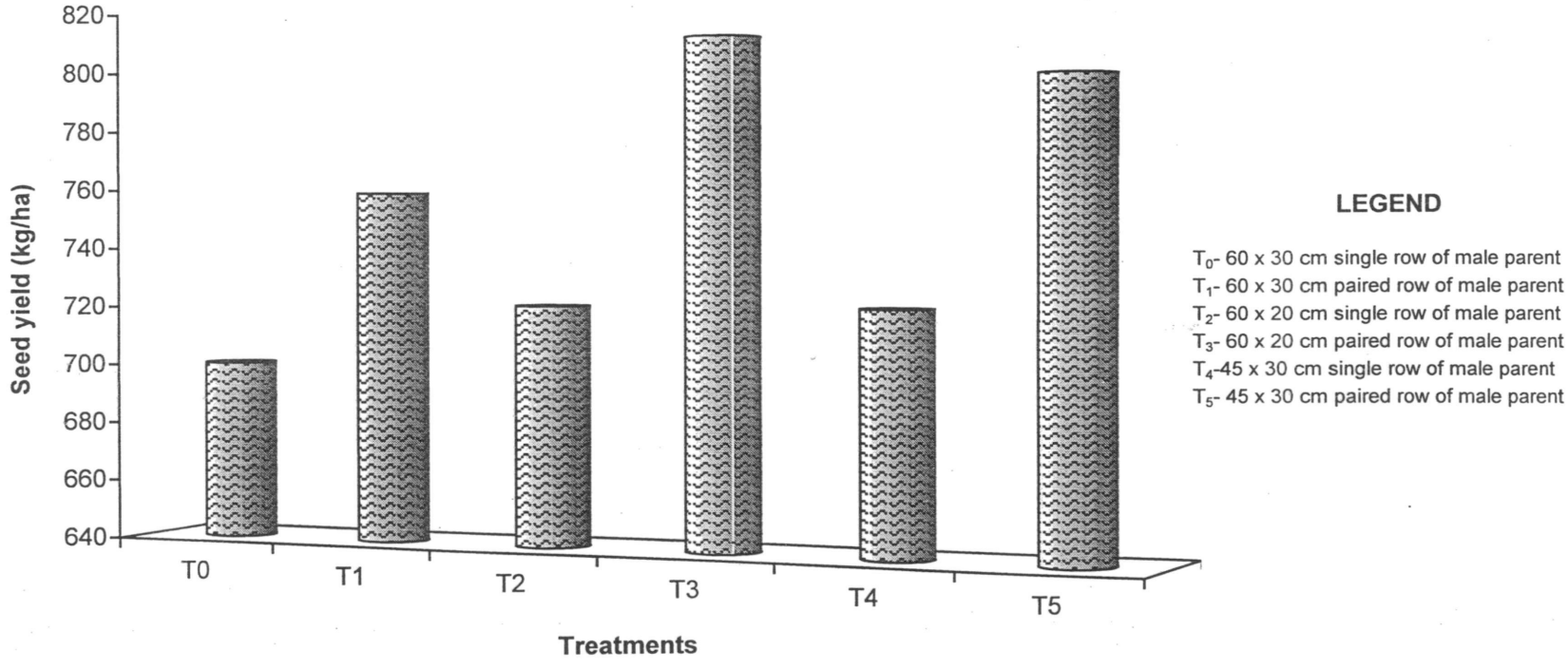


Fig. 7: Influence of planting geometry of male parent (R-64 NB) on seed yield in seed parent (CMS-103A) of sunflower hybrid RSFH-1

yield per plant and per hectare over pollen mixed with filler material (25 to 50 %).

The highest seed set, seed yield per plant and per hectare (73.44%, 19.56 g and 808.63 kg, respectively) were noticed in female which crossed with pollen collected from 60 x 20 cm paired row of restorer (1,66,666 plants/ha) followed by 45 x 30 cm paired row with 1,48,480 plants per hectare (72.73%, 19.18 g and 794.78 kg, respectively) and were on par with each other. So it can inferred that, increase in plant population of restorer from 55,555 to 1,66,666 plants per ha increased the seed yield in female line significantly mainly due to increase in pollen production per unit area, *vis-a-vis* adequate availability of pollen required to pollinate all the receptive female florets every day.

Increased plant population of male parent has resulted non-significant difference in hundred seed weight of female parent. Seed recovery per cent in female line increased with increase in plant population of restorer. Numerically more seed recovery of 88.00 per cent was recorded in T_0 (60 x 30 cm single row, 55,555 plants/ha) compared to 85.00 per cent at higher male population of 1,66,666 plants per hectare (60 x 20 cm paired row). This was mainly due to decreased number of unfilled seeds recorded in T_0 treatment. So also processed seed yield was more (687.33 kg/ha) in 60 x 20 cm paired row (1,66,666 plants/ha) which may be due to higher seed yield obtained in this treatment.

Oil yield per hectare increased with increased plant population of restorer. Significantly more oil yield of 318.60 kg per hectare was recorded in T_3 (1,66,666 plants/ha) planted at 60 x 20 cm paired row) which is 11.79 per cent increase over control. This can be attributed to higher seed yield in the respective treatment.

5.1.4 Influence of planting geometry of restorer (R-64NB) on seed dormancy in sunflower hybrid RSFH-1

Seed dormancy as ascertained by germination percentage showed no variation among the different plant densities of male line. The mean initial germination of 12.88 per cent recorded immediately after harvest in the hybrid seed of RSFH-1. Germination reached above minimum seed Certification Standards (70%) on fourth week onwards. Dormancy period in RSFH-1 seed remained up to sixth week (40-42 days) after harvest.

Seed dormancy can be attributed to the imbalance in promoter-inhibitor ratio, if the ratio is more towards inhibitors compounds then it leads to seed dormancy (Amen, 1968 and Wareing and Saunders, 1971). Similar results on seed dormancy in sunflower were also reported by Marappan *et al.* (1974), Mehrotra *et al.* (1978), Zoia (1979), Dighe and Patil (1980), Mohammad *et al.* (1984), Rao *et al.* (1993) and Rama *et al.* (2002).

5.1.5 Influence of planting geometry of restorer (R-64NB) on seed quality of sunflower hybrid RSFH-1

The variation in plant density of restorer has recorded non-significant influence on seed germination percentage, shoot length, root length, seedling length, seedling vigour index, seedling dry weight, speed of germination, field emergence and electrical conductivity of the hybrid seeds. However, marginally more germination (92.60%), shoot length (16.60 cm), root length (19.62 cm), seedling vigour index (3354), seedling dry weight (53.70 mg), speed of germination (22.70), field emergence (83.50%) and lower electrical conductivity (0.691 dSm^{-1}) was recorded in T_0 (60 x 30 cm single row with 55,555 male plants/ha). This could be attributed to higher hundred seed weight obtained in this

treatment compared to other plant populations. These results are in conformity with the findings of Satyanarayana and Seetharam (1983), Kempegowda (1992), Rajashekhar (1994) and Somashekhar (1997) in sunflower.

Numerically more oil content of 40.70 per cent recorded in T_0 (55,555 male plants/ha) treatment. Increase in oil content may be attributed to more hundred seed weight and such seeds contain larger endosperm rich in oil content.

5.1.6 Correlation studies for yield and components in female line (CMS-103A) of sunflower hybrid RSFH-1 as influenced by planting geometry of male line

Pollen yield per hectare had positive and significant correlation coefficients with all yield and yield components *viz.,* filled seeds (0.990), seed set per cent (0.985), seed yield per plant (0.985), seed yield per hectare (0.998) and processed seed yield per hectare (0.998) except number of unfilled (-0.936) seeds and seed recovery per cent (-0.994) which recorded negative correlation.

The yield components like number of filled seeds (0.995), seed set per cent (0.981), seed yield per plant (0.992) and oil yield per hectare (0.999) are positively correlated to seed yield per hectare. The number of unfilled seeds (-0.923) and oil content (-0.990) recorded negative correlation with seed yield per hectare.

Test weight has recorded positive correlation with per cent oil content (0.987) and negative with number of filled seeds (-0.978).

5.1.7 Economics of sunflower hybrid seed production of RSFH-1

The gross returns, net returns and B:C ratio was more (Rs. 55,592.90, Rs. 27,111.40 and 1.95, respectively) in T_3 (60 x 20 cm paired row with 1,66,666 plants/ha) treatment which supplied more pollen to female line followed by T_5 (45 x 30 cm paired row, with 1,48,148 plants/ha) treatment (Rs. 54,849.40, Rs. 26,367.92 and 1.93,respectively).

This reveal that sufficient amount of pollen if made available to the female parent during the entire flowering period, it is possible to recover more processed seed yield per hectare there by hybrid seed production in sunflower can be made more economical and profitable. This is evident from the present study that by increasing the plant population of non-branching restorer line (R-64NB) within the recommended planting ratio of 3:1 of female to male lines, maximum hybrid seed yield can be realized.

PRACTICAL APPLICATIONS OF RESULTS

1. During the hybrid seed production of RSFH-1, it is necessary to increase the plant population of monohead restorer (R-64NB) by sowing in paired row at 60 x 20 cm to increase sufficient amount of pollen production per unit area.

2. It is possible to increase seed yield in female parent (CMS-103A) of the sunflower hybrid RSFH-1, without increasing the area under restorer line and within the recommended planting ratio of 3:1 female to male line.

FUTURE LINE OF WORK

1. Studies on influence of growth regulators on pollen production in non-branching restorer (R-64NB) during hybrid seed production of RSFH-1 may be initiated.

2. Role of micro and macro nutrients on pollen production in non-branching restorer may be studied.

Summary

VI. SUMMARY

The present investigation was undertaken at Main Agricultural Research Station, College of Agriculture, Dharwad during rabi season of 2004 to study the effect of planting geometry of non-branching restorer line (R-64NB) on growth, pollen production and its influence on seed yield and quality of hybrid seed production of RSFH-1. The inference drawn from the results obtained are summarised below.

1. The plant height of restorer line was increased significantly from 116.00 to 134.63 cm at ray floret opening stage due to increase in the plant population from 55,555 (60 x 30 cm single row) to 1,66,666 (60 x 20 cm paired row) per hectare.

2. The number of leaves were also increased from 17.65 to 20.28 at ray floret opening in different planting geometry of restorer line. More number of leaves were observed at higher plant population (1,66,666 plants/ha) compared to lower plant population (55,555 plants/ha).

3. Days taken to ray floret opening and 50 per cent flowering did not differ significantly with variation in plant population of pollen parent (R-64NB). However more number of days to ray floret opening (68.20) and 50 per cent flowering (73.50) was taken by the plants spaced at 60 x 20 cm with plant population of 1,66,666 plants per hectare.

4. Highest capitulum diameter (14.25 cm) was recorded at lower plant population of 55,555 plants per hectare (60 x 30 cm single row) as compared to higher plant population of 1,66,666 plants per hectare

(60 x 20 cm paired row) wherein the capitulum diameter was 11.93 cm.

5. Pollen production per plant (712.75 mg) and mean pollen production (59.40 mg) per day was significantly more in male parent planted at 60 x 30 cm single row (55,555 plants/ha) compared to plants spaced at 60 x 20 cm paired row (1,66,666 plants/ha). In this treatment the pollen production was 571.25 and 47.61 mg per plant and mean pollen production per day respectively. However, pollen production per hectare was significantly more (95.20 kg/ha) at higher plant population (1,66,666 plants/ha) compared to 39.59 kg per hectare recorded in lower plant population of 55,555 plants per hectare.

6. The yield components like number of filled seeds (480), seed set (73.44%), seed yield per plant (19.56 g) and seed yield per hectare (808.63 kg) were higher in female line which received pollen from male line sown at 60 x 20 cm paired row with 1,66,666 plants per hectare. Conversely total number of seeds, 100 seed weight did not differ significantly with variation in plant population of restorer line.

7. Seed recovery per cent was more in female parent which received pollen from restorer planted at 60 x 30 cm single row (88 %) as compared to plant population of 1,66,666 plants per hectare (85 %). Processed seed yield per hectare was more in female parent which received sufficient pollen from restorer planted at 60 x 20 cm paired row (687.33 kg/ha) as compared to lower plant population of 55,555 plants per hectare (616.17 kg/ha).

8. The higher bulk and processed hybrid seed yield was recorded from the female line which were crossed with pollen obtained from the male parent planted at 60 x 20 cm paired row 1,66,666 plants per hectare (808.63 and 687.33, respectively).

9. The oil yield per hectare in female line increased from 285.00 to 318.60 kg per hectare due to increase in the non-branching male parent population from 55,555 to 1,66,666 plants per hectare.

10. The seed dormancy in sunflower hybrid RSFH-1 was noticed upto 40-42 days after harvesting.

11. Seed quality parameters in sunflower hybrid RSFH-1 did not vary significantly due to increased plant population of male line. However, oil content was more in hybrid seed harvested from female line which received sufficient pollen from restorer line spaced at 60 x 30 cm single row with 55,555 plants per hectare.

12 The gross returns (Rs. 55,592.90), net returns (Rs. 27,111.42) and B:C ratio (1.95) was more in male plant population 1,66,666 plants per hectare spaced at 60 x 20 cm paired row.

13 Pollen production per hectare recorded significant positive correlation with seed yield components and yield per hectare. Also, all the yield components had positive correlation with the seed yield per hectare. Oil content had positive correlation with test weight and negative correlation with number of filled seeds.

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Appendix

APPENDIX – I

ECONOMICS OF SUNFLOWER HYBRID SEED PRODUCTION

Sl. No.	Name of operation	No of labour	Bullock pair	Tractor (hrs)	Rate Rs./ labour	Rate Rs./ BP	Rate Rs./ tractor hrs.	Total Am. (Rs.)
I	**Cost of cultivation**							
A	**Labour cost**							
1.	Land preparations							
	a) Ploughing	-	-	1	-	-	250	250=00
	b) Harrowing	-	-	0.5	-	-	125	125=00
	c) Levelling	-	-	0.5	-	-	125	125=00
2.	Sowing	2	-	-	40=00	-	-	80=00
3.	Thinning /gap filling	1	-	-	40=00	-	-	40=00
4.	Fertilizer application (basal)	2	-	-	40=00	-	-	80=00
5.	Intercultivation – 2 times	1	1	-	40=00	125=00	-	125=00
6.	Weeding	2	-	-	40=00	-	-	80=00
7.	Top dressing of fertilizer	1	-	-	40=00	-	-	40=00
8.	Irrigation	3	-	-	40=00	-	-	120=00
9.	Spraying –3 times	3	-	-	40=00	-	-	120=00
10.	Crossing	20	-	-	40=00	-	-	800=00
11.	Harvesting	4	-	-	40=00	-	-	160=00
12.	Cleaning, processing and packing	2	-	-	40=00	-	-	80=00
	Total cost (A)							2,225=00
B	**Cost of inputs**							
1.	Seeds	-	-	-	-	-	-	500=00
2.	Fertilizers	-	-	-	-	-	-	570=00
3.	Chemicals	-	-	-	-	-	-	500=00
4.	Irrigation and power	-	-	-	-	-	-	50=00
	Total cost (B)	-	-	-	-	-	-	1,620=00
	Total cost (A+B)/0.135 ha	-	-	-	-	-	-	3845=00
	for 1.0 ha	-	-	-	-	-	-	28481=48

II Returns

Treatments	Processed seed		Rejected seed		Total returns (Rs.)	B:C ratio
	Quantity (kg)	Rate (Rs./kg)	Quantity (kg)	Rate (Rs./kg)		
T_0	616.17	80.00	84.02	5.00	49,713.70	1.75
T_1	656.00	-do-	102.37	-do-	52,991.85	1.86
T_2	626.83	-do-	93.67	-do-	50,614.75	1.78
T_3	687.33	-do-	121.30	-do-	55,592.90	1.95
T_4	630.28	-do-	90.40	-do-	50,872.60	1.79
T_5	678.34	-do-	116.44	-do-	54,849.40	1.93