

## ALLOMETRY, AGRONOMIC TRAITS AND YIELD OF AUTUMN PLANTED SUNFLOWER HYBRIDS UNDER VARYING ROW SPACING

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Studies were conducted to assess the agronomic kg ha<sup>-1</sup> and physiological basis of variation in yield among three sunflower hybrids of varying maturity groups, sow at row spacing of 45, 60 and 75 cm during the autumn seasons of 2006 and 2007. In both years of experimentation, the hybrid Hysun-33, a long season hybrid, stood out not only for maximum leaf area index, but also for its crop growth rate, plant height, number of achenes and achene yield. Hysun-33 produced significantly higher achene yield (3033 kg/ha), planted at the 60 cm apart rows, followed by SF-187 (2783 kg/ha), when sown at 45 cm apart rows. The minimum yield was recorded, when FH-331 was sown at 75 cm apart rows. Although, head diameter, number of achenes per head, 1000 achene weight increased with increasing row spacing from 45-75 cm, but the increase in yield with narrow rows was largely related to increased achene number, higher leaf area index and maximum crop growth rate.

**Keywords:** Sunflower, growth, yield, row spacing, hybrids.

### INTRODUCTION

Local availability of edible oilseeds in Pakistan hardly meets the demand and this is the scenario since decades. Escalating population and continuous rise in urbanization has further widened the gap between local supply and demand. Total domestic requirements of edible oil stood at about 3.07 million tons, of which 27.2% (0.83 million tons) came from local production (Govt. of Pakistan, 2009). Demand for edible oil is met through imports, ranking Pakistan as the third largest importer of edible oil in the world. The country, at present, is constrained to import edible oil in large quantities (72.8% of total requirement). Spending on import of edible oil accounts largest drain on national exchequer that is second to only mineral oil. Pakistan spent Rs. 84000 million for 1290 thousand tons of edible oil and Rs. 13756.83 million for 723.96 thousand tons of oilseeds (Govt. of Pakistan, 2009) during 2008-2009. A developing country like ours cannot afford such a mounting export bill indeed. The situation thus warrants for enhancing the indigenous oilseed production to save the country from a major catastrophe in future.

Sunflower as a non conventional oilseed crop offers promising results for enhancing local oilseeds production. Agro-climatic conditions in the country allow successful sunflower cultivation as spring and autumn crop, without causing displacement of any major crop. Presently, in Pakistan, sunflower is grown on an area of 506 thousand hectares with the total production of 755 thousand tons and an average seed

yield of 1492 kg ha<sup>-1</sup>, which is far below its potential yield (Govt. of Pakistan, 2009). In fact, many of the site-specific production aspects still need to be standardized for an array of sunflower hybrids available in the country for general cultivation.

Hybrids with contrasting morphological, and possibly, physiological characters in particular are available under different sets of macroclimatic conditions. Such hybrids of different morpho-physiological characteristics show beneficial, neutral or counter productive response at reduced distance between rows (Villalobos *et al.*, 1994). Potential areas for future progress include planting density effects on leaf area, growth and seed production of diverse sunflower hybrids. Sunflower cultivars have considerable genetic variation in time of maturity and stature length. Yield responses to inter-row distance are variable. For sunflower, reduced distance between rows could be beneficial (Andrade *et al.*, 2002), or neutral in terms of yield (Zaffaroni and Schneiter, 1991). Successful sunflower production in some areas depends on early maturity to ensure successful harvesting and allows timely planting of subsequent crops. Longer maturing cultivars usually produce the highest yields due to having more growing degree days and using sunlight for their photosynthetic activities for longer duration.

The achene yield increases to a maximum with increasing plant density and remains constant at even higher plant densities under favourable conditions. Under less favourable conditions, however, the achene yield may decline at very high plant density (Wade and Foreman, 1988). The behaviour of yield components

reveals the great compensation capacity of sunflower with regard to different plant densities. The number of seeds per head and the mean seed weight decrease significantly with an increasing plant density (Barros *et al.*, 2004). Higher plant populations produce lighter seeds, thinner stems, taller plants and more yield than lesser plant density (Beg *et al.*, 2007). Diepenbrock *et al.* (2001) reported that achene yield increased with increasing row spacing while 1000 achene weight increased with increasing row spacing and decreased with increasing plant population. This suggests that among the agronomic practices, optimum plant population plays an important role in improving productivity of sunflower. Present studies were conducted to determine optimum row spacing/planting density for sunflower hybrids of diverse maturity.

## MATERIALS AND METHODS

Experiments were conducted to study the agro-physiological response of sunflower hybrids of different maturity groups to varying plant population for two consecutive years during autumn, i.e. 2006 and 2007 at the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan. The climate of the region was subtropical to semi-arid. The experimental area was located at 73° East longitude, 31° North latitude and at an altitude of 135 m above mean sea level.

The experimental area was quite uniform and a composite and representative soil sample was taken from a depth of 30 cm prior to initiate the trials in the field. Experimental soil was sandy loam. The physico-chemical analysis of experimental soil showed 0.045 % nitrogen (N), 8.00 ppm available phosphorus (P) and 175 ppm available potassium (K). The crop was sown in third week of August. Sowing was done manually with the help of dibbler and 2-3 seeds per hole were placed. Three sunflower hybrids (FH-331, SF-187 and Hysun-33) owing to different maturity groups were sown in different planting densities. Six rows of each hybrid were sown at row spacing of 45 cm (98765 plants ha<sup>-1</sup>), 60 cm (74074 plants ha<sup>-1</sup>) and 75 cm (59259 plants ha<sup>-1</sup>) with plant to plant distance of 22.5 cm in each case. The experiments were laid out in randomized complete block design (RCBD) with split plot arrangement and replicated three times. Seedbed was prepared by cultivating the soil for 3-4 times with tractor mounted cultivator each followed by planking. Fertilizer dose of NPK at the rate of 140, 100, 50 kg ha<sup>-1</sup> respectively was applied in the form of urea, diammonium phosphate and potassium sulphate. Half of the N and full phosphorus and potash was applied at

sowing, while remaining nitrogen was applied with 2<sup>nd</sup> irrigation.

Standard procedures were followed to record data on different agronomic and yield traits and yield. Leaf area was measured at a regular interval of fifteen days by a leaf area meter (DT Area Meter, model MK2). Leaf area index (LAI) was calculated by dividing leaf area with land area (Watson, 1947). Dry matter (DM) accumulation was determined at fortnight intervals by selecting five plants randomly from each subplot. Samples were placed in oven at 70±5°C to dry the plant material to their constant dry weight. Dry weight m<sup>-2</sup> was calculated and used to estimate crop growth rate (Hunt, 1978) as  $CGR = (W_2 - W_1) / (t_2 - t_1)$ , where  $w_1$  and  $w_2$  are dry weights of plant samples at corresponding times  $t_1$  and  $t_2$ , respectively.

## Statistical Analysis

Data collected were statistically analysed using Fisher's analysis of variance techniques and LSD test ( $P=0.05$ ) was used to compare the difference/s among treatments' means (Steel *et al.*, 1997).

## RESULTS AND DISCUSSION

### Leaf area index

Periodic data (Fig. 1) showed that during both the years the hybrids showed progressive increase in LAI and the greatest value being reached at flowering stage and then declined toward harvest. The differences among the hybrids were non-significant at 30, 45 and 60 days after sowing (DAS). At 75 DAS there was significant difference among the hybrids. Long season hybrid Hysun-33 exhibited highest LAI (5.10), followed by SF-187 (4.49), which was statistically at par with FH-331 (4.32). During both the years, the differences in LAI of hybrids planted at different row spacing were significant throughout the growing season (Fig. 2). During 2006, highest LAI (5.20) was recorded for the crop sown at 60 cm apart rows that declined to 4.50 and 4.32 for 45 and 75 cm apart rows, respectively. During 2007, maximum LAI (5.01) was observed when the crop was sown at 45 cm apart row spacing and was statistically at par with that of the plants planted at 60 cm apart rows, while the lowest (4.46) was recorded at 75 cm apart rows. Similar patterns of LAI for these hybrids were recorded during the second year. Time of achieving maximum leaf area indices corresponded to their flowering times. Miralles *et al.* (1997) reported that a longer season hybrid (SH-222) stood out for its maximum LAI and crop growth rate (CGR) and dry matter than the other hybrids. Differential leaf area indices of hybrids have also been reported by Saleem and Malik (2004) and

Khaliq (2004). Patterns of leaf area indices for sunflower planted with increasing population were quite opposite to that for leaf area per plant so that LAI was always greater in plots with higher population than that of lower planting densities (Ferreira and Abreu, 2001). This suggests that the high ground cover stability of sunflower, with variation in plant density, results from variation in leaf size (Frande, 1995).

### **Crop growth rate**

Periodic data at fortnight interval (Fig. 3) revealed that crop growth rate (CGR) progressively increased up to 60 DAS and then after this the hybrids under study showed varying response up to the time of maturity. Long maturity hybrid Hysun-33 recorded maximum CGR ( $21.21 \text{ g m}^{-2} \text{ d}^{-1}$ ) at 75 DAS and then started declining and reached  $6.63 \text{ g m}^{-2} \text{ d}^{-1}$  at 90 DAS during 2006 and depicting same trend during 2007. Early maturing hybrid FH-331 recorded maximum CGR ( $19.30 \text{ g m}^{-2} \text{ d}^{-1}$ ) at 60 DAS that declined slightly ( $16.75 \text{ g m}^{-2} \text{ d}^{-1}$ ) at 75 DAS and reached lower level ( $1.85 \text{ g m}^{-2} \text{ d}^{-1}$ ) at 90 DAS. Almost the same trend was exhibited by SF-187 and the maximum ( $20.45 \text{ g m}^{-2} \text{ d}^{-1}$ ) and the minimum ( $3.81 \text{ g m}^{-2} \text{ d}^{-1}$ ) CGRs were recorded at 60 and 90 DAS, respectively. During 2007, SF-187 showed slight increase (19.89 to 20.10) in CGR from 60 to 75 DAS and then reached to its minimum ( $2.47 \text{ g m}^{-2} \text{ d}^{-1}$ ) level at 90 DAS, while FH-331 recorded the similar trend during both years. Regarding row spacing, crop planted at 45 cm apart rows showed maximum CGR throughout the growing season as compared to plants grown at 60 and 75 cm apart rows for both the years. Variation in CGR of different hybrids is attributed to their different maturity periods. The highest CGR in Hysun-33 was due to its higher leaf area index. Miralles *et al.*, (1997) also reported that a longer season hybrid (SH-222) had the highest CGR which was the consequence of its higher leaf area index. Contrary to this, Zaffaroni and Schneiter (1991) reported that relative growth rate, net assimilation rate, crop growth rate and leaf area index were similar for semi dwarf and standard height sunflower hybrids grown at different row arrangements.

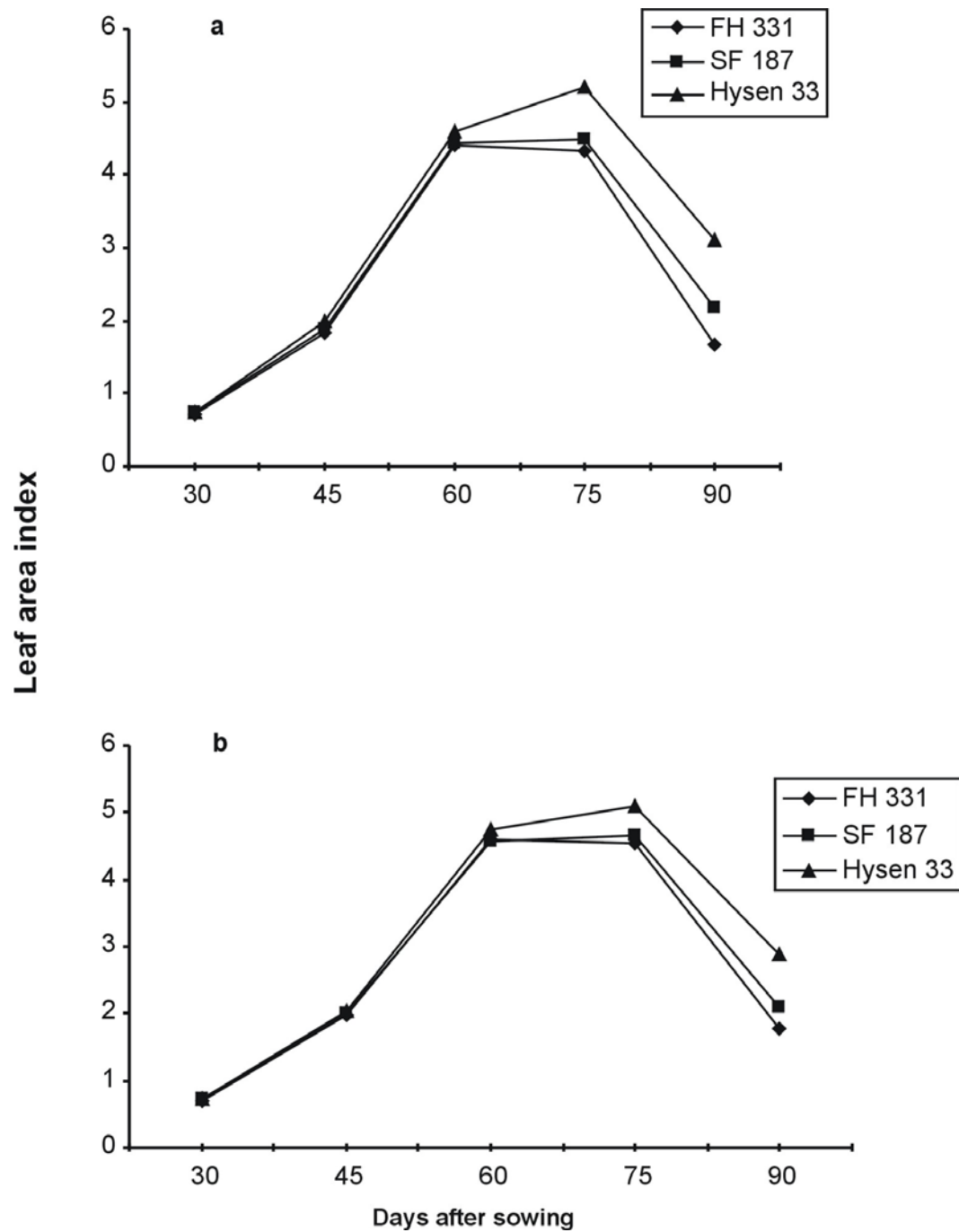
### **Head diameter**

Different sunflower hybrids produced heads that varied significantly in diameter (Table 1). During 2006 SF-87 recorded maximum (18.57 cm) head diameter and was followed by Hysun-33 (16.86 cm) and FH-331 (16.10 cm). Similar trend was observed during 2007. Row spacing also significantly affected head diameter for first year. Maximum head diameter (18.22 cm) was recorded for sunflower planted on 75 cm apart rows. Narrowing the row spacing from 75 to 45 cm resulted

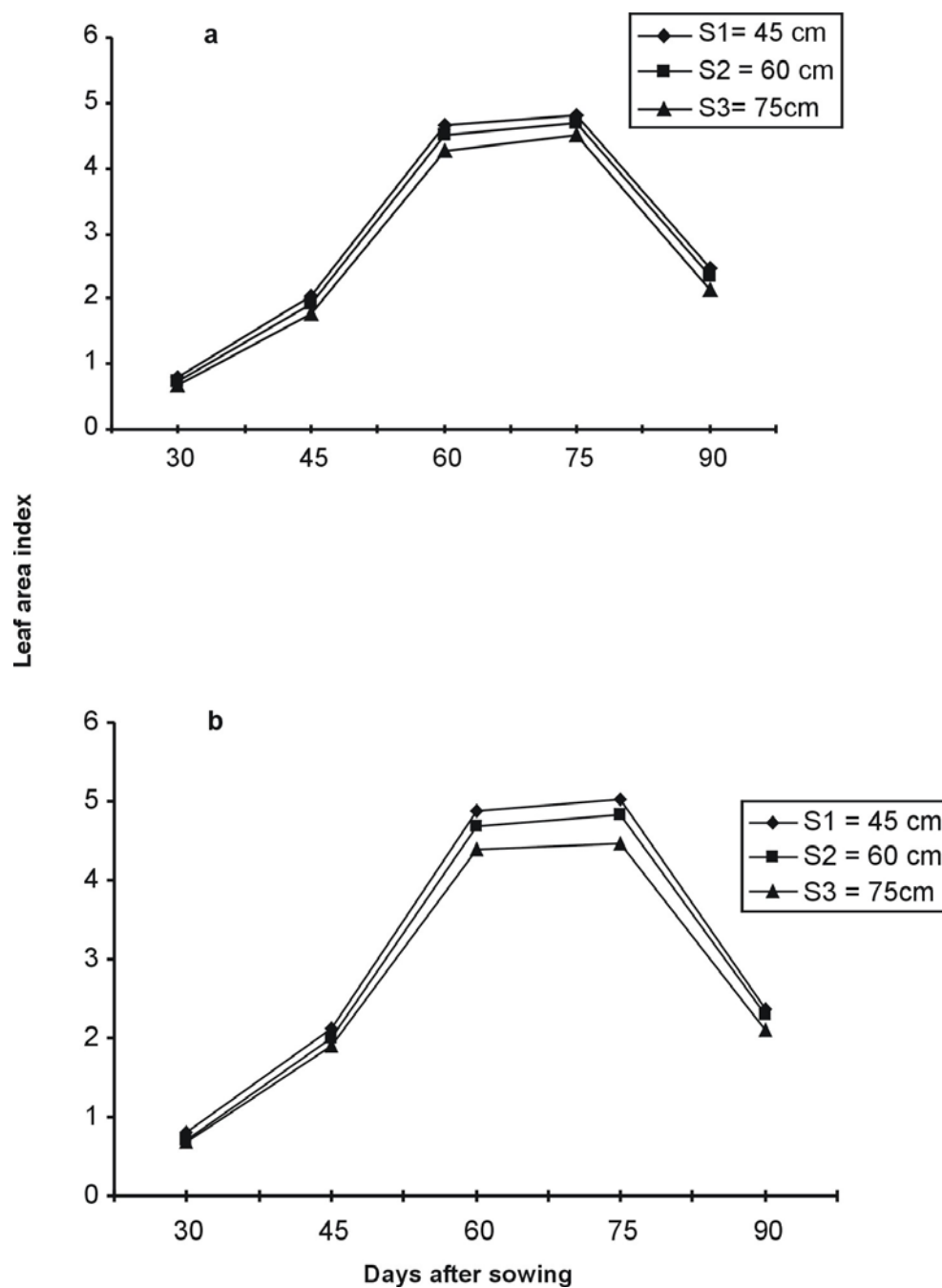
in decrease of 2.39 % in head diameter. For the second year, pattern of increasing head diameter with increasing row spacing was also recorded. Interactive effect of hybrids and row spacing on head diameter was significant during both the years. Maximum head diameter (19.55 cm) during 2006 was attained when SF-87 was sown at 75 cm apart rows while minimum was obtained when FH-331 was planted at 45 cm row spacing. Hybrid SF-87 produced maximum head size on all row spacing. Similar results were recorded during 2007. This significant difference among the hybrids may be attributed to inherent character of specific hybrids. The variation in head size of hybrids of different maturity groups was also reported by Khaliq (2004), Tunio *et al.* (1999) and Reddy *et al.* (2002). Negative influence of increasing plant density on head diameter was also reported by Ahmad and Qurush (2000) and Al-Thabat (2006).

### **Number of achenes per head**

Number of achenes per head differed significantly among the three hybrids during both years of experimentation (Table 1). During first year of the trials, maximum number of achenes per head (793.80) was recorded for Hysun-33 that was 17.80% higher than that (673.80) recorded for SF-87 and 21.06% higher more than FH-331. Results of second year showed similar behaviour of hybrids and number of achenes per head were within the range of 657.70-783.30. Row spacing had a significant bearing upon number of achenes per head. Increasing row spacing from 45 cm to 60 cm and 75 cm resulted in about 8.14% and 3.20 % enhancement in this trait. During 2007, maximum number of achenes were recorded when the crop was planted at 75 cm apart rows. Narrowing row spacing had a suppressive influence on the number of achenes per head so that it decreased by 6.18% and 13.02% when row spacing was decreased to 60 and 45 cm, respectively. The interactive effect of hybrids and row spacing was found to be non significant during both years of studies. These results suggested that number of achenes per head increased with increasing head size. These findings are in agreement to those of Ahmad *et al.* (1997) and Saleem and Malik (2004). Diepenbrock *et al.* (2001) and Nawaz *et al.* (2001) reported that number of achenes per head was reduced with decreasing row spacing from 50 to 75 cm apart rows, but the quantity of achenes  $\text{m}^{-2}$  increased significantly with decreasing row spacing. Andrade *et al.* (1993) reported that mutual shading at narrow row spacing might cause grain abortion and hereby reduce number of grains.



**Fig. 1.** Leaf area index of different sunflower hybrids during year a) 2006 and b) 2007



**Fig. 2.** Leaf area index as affected by different row spacing in sunflower hybrids during year (a) 2006 and (b) 2007

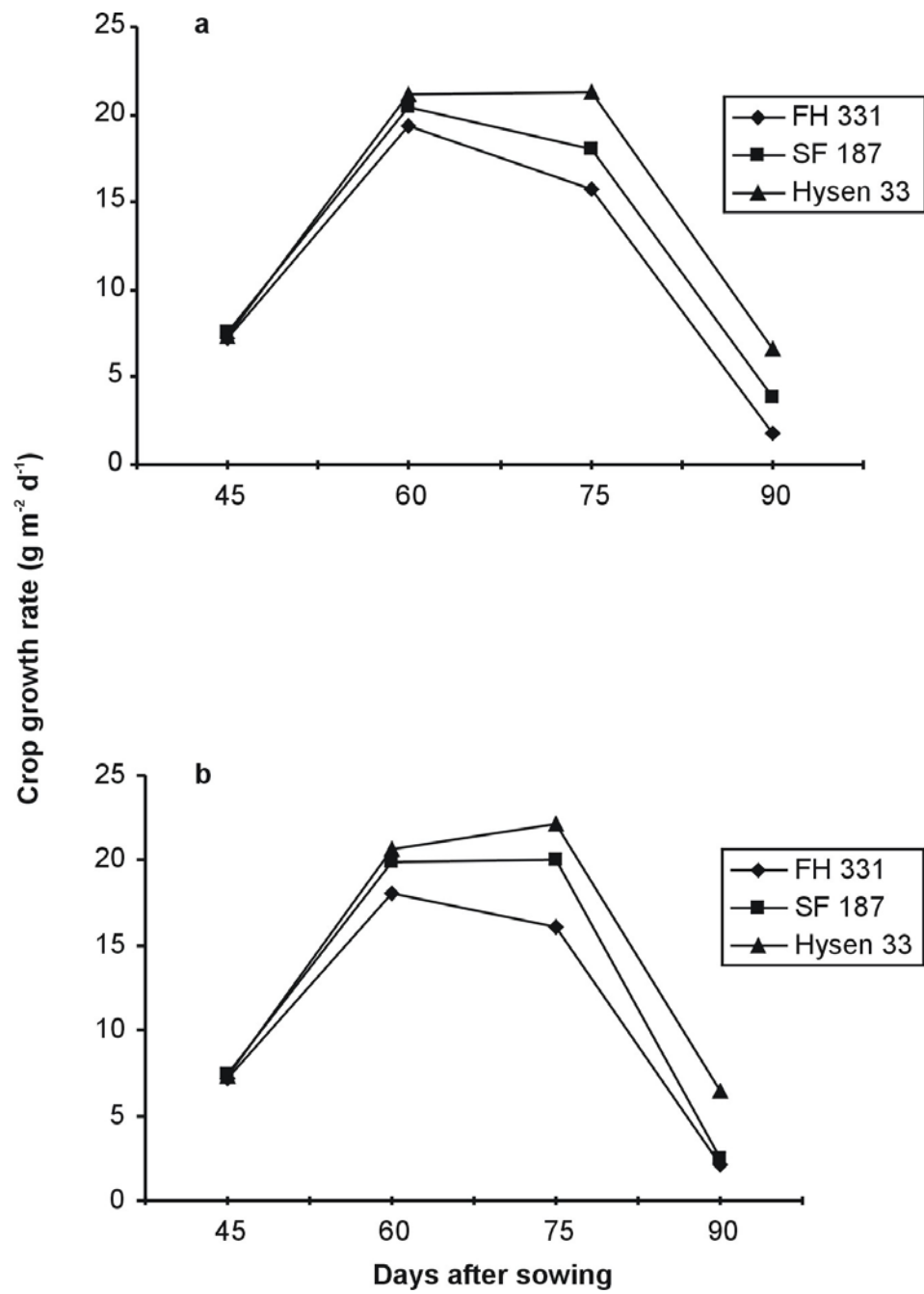
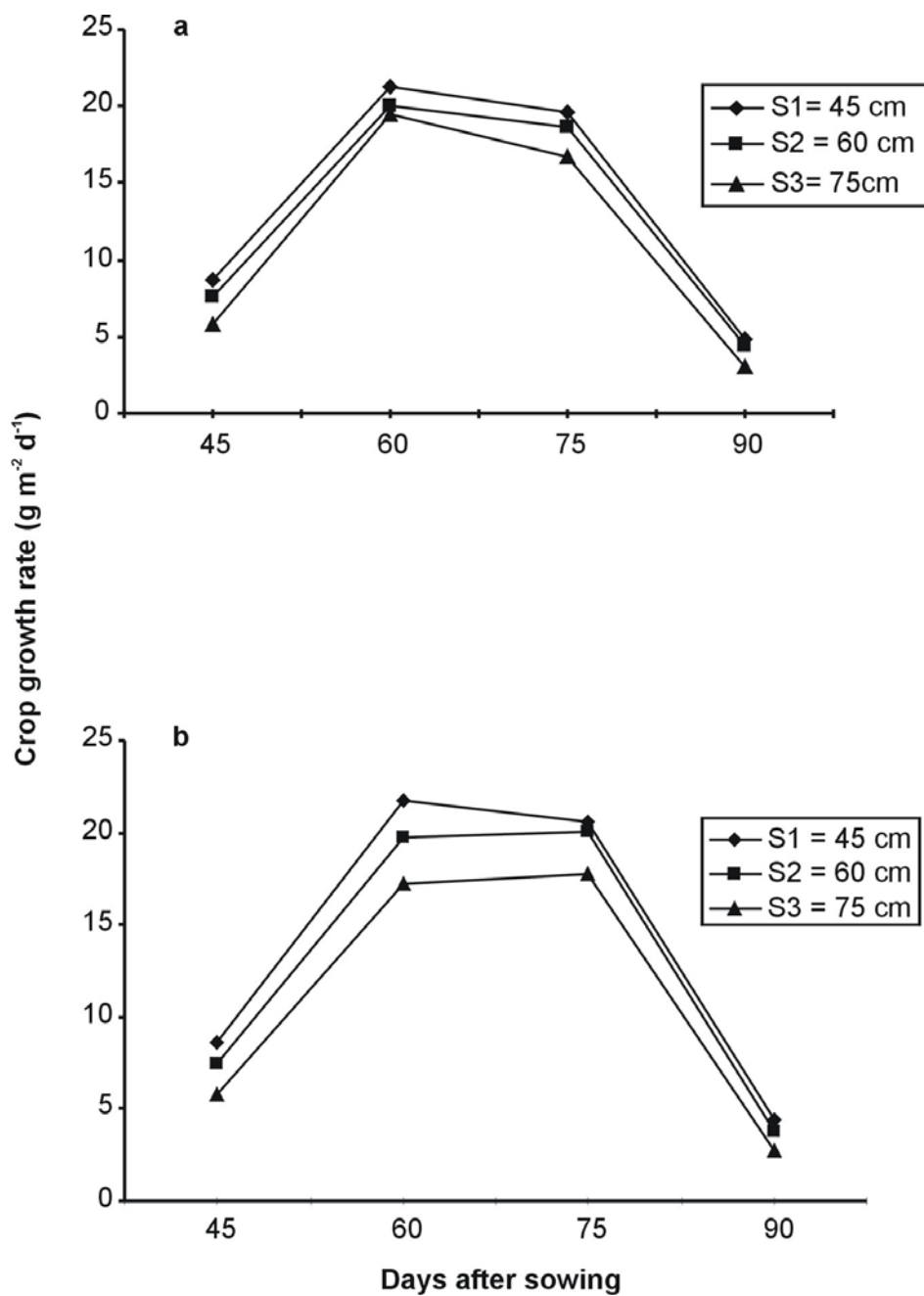


Fig. 3. Crop growth rate of different sunflower hybrids during year a) 2006 and b) 2007



**Fig. 4.** Crop growth rate as affected by different row spacing in sunflower hybrids during year  
a) 2006 and b) 2007

**Table 1. Effect of different row spacing on plant height, head diameter, number of achenes per head, 1000-achenes weight and achene yield in sunflower hybrids**

Treatments	Head diameter (cm)		Number of achenes head <sup>-1</sup>		Number of achenes m <sup>-2</sup>		1000-achene weight (g)		Achene yield (kg ha <sup>-1</sup> )	
Hybrids (H)	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
H <sub>1</sub> = FH 331	16.10 c	15.87 c	655.70 b	657.70 b	4934 b	4935 c	47.86 c	46.82 c	2311 b	2256 c
H <sub>2</sub> = SF187	18.57 a	18.14 a	673.80 b	682.72 b	5074 b	5126 b	54.06 a	52.57 a	2588 a	2519 b
H <sub>2</sub> = Hysun 33	16.86 b	16.65 b	793.80 a	783.30 a	5914 a	5849 a	50.06 b	48.67 b	2856 a	2741 a
LSD= 0.05	0.55	0.60	28.54	26.63	205.20	173.7	1.23	1.08	272	217
Row spacing (S)										
S <sub>1</sub> = 45 cm	15.83 c	15.76 c	664.1 b	667.90 c	6390 a	6338 a	42.76 c	42.18 c	2722 a	2630 a
S <sub>2</sub> = 60 cm	17.49 b	17.08 b	718.20 a	710.90 b	5209 b	5144 b	51.95 b	49.88 b	2628 a	2524 ab
S <sub>3</sub> = 75 cm	18.22 a	17.82 a	741.00 a	754.9 a	4323 c	4427 c	57.28 a	55.99 a	2405 b	2361 b
LSD= 0.05	0.69	0.46	28.90	27.02	215.4	227	1.72	3.30	187	166
Interaction										
H <sub>1</sub> S <sub>1</sub>	15.13 ef	15.00 f	646.20	647.33	6226.33	6241	42.62 ef	41.60	2633 bc	2533 bcd
H <sub>1</sub> S <sub>2</sub>	16.27 de	15.80 e	675	687.67	4900.67	4982.33	48.35 d	47.30	2267 de	2233 de
H <sub>1</sub> S <sub>3</sub>	16.90 cd	16.80 d	700	713.00	4084.67	4153.33	52.61 c	51.57	2033 e	2000 e
H <sub>2</sub> S <sub>1</sub>	17.77 bc	17.43 bcd	727	706.67	6966.33	6813	44.45 de	44.03	2783 ab	2740 ab
H <sub>2</sub> S <sub>2</sub>	18.40 ab	18.20 ab	819	786.66	5920.67	5667	54.50 bc	51.85	2583 bcd	2450 bcd
H <sub>2</sub> S <sub>3</sub>	19.55 a	18.78 a	835.2	856.68	4854.67	5065.67	62.23 a	61.82	2398 cd	2367 cd
H <sub>3</sub> S <sub>1</sub>	14.58 f	14.83 f	618.88	619.67	5968	5959.67	40.19 f	40.90	2750 ab	2617 abc
H <sub>3</sub> S <sub>2</sub>	17.80 bc	17.25 cd	660.60	658.33	4806.67	4781.67	53.00 c	50.50	3033 a	2888 a
H <sub>3</sub> S <sub>3</sub>	18.20 b	17.87 bc	687.6	695.00	4029	4063.33	57.00 b	54.58	2783 ab	2717 ab
LSD= 0.05	0.39	0.80	NS	NS	NS	NS	2.98	NS	324	287

Means sharing the same letters in a column do not differ significantly at  $P \leq 0.05$ ; NS=Non significant

### 1000-achene weight

Different hybrids recorded different achene-weight during both years (Table 1). During 2006, maximum 1000-achene weight (54.06 g) was recorded for SF-187, which was 8% higher than Hysun-33 (50.06 g) and 12.95% more than FH-331 (47.86 g). Although lighter achenes were produced during 2007, the trend was similar to that for 2006. Difference between two years was attributable to more rainfall during growth period of 2006 and the higher temperature at the time of grain formation for the same year than that during 2007. Differential response of sunflower hybrids to 1000-achene weight was also reported by Behrooznia *et al.* (1999) and Ekin *et al.* (2005). Maximum 1000-achene weight (57.28 g) was recorded when the crop were sown at 75 cm apart row spacing., which was 10.92 % more than (51.95 g) crop sown at 60 cm apart row spacing and the minimum (42.18 g) was observed in case, when sunflower was sown at 45 cm row spacing. During both the years, 1000-achene weight linearly decreased with each 15 cm decrease in row spacing from 75 cm to 45 cm. This suppressive effect of narrowing the row spacing has been reported earlier by Johnson (2003). Interactive effect of

sunflower hybrid on row spacing was significant during 2006; however a non-significant interaction was observed during 2007. Both SF-187 and Hysun-33 produced heavier achenes when planted at 75 cm row spacing while SF-187 did so when planted at 60 cm apart rows.

### Number of achenes m<sup>-2</sup>

During both years of experimentation, significantly different number of achenes per unit area (m<sup>-2</sup>) was recorded for the hybrids under study (Table 1). During 2006, Hysun-33 produced highest (5914) number of achenes as compared to SF-187 (5074) and FH-331 (4934). Narrowing row spacing had a positive bearing on the number of achenes m<sup>-2</sup>. Maximum number of achenes m<sup>-2</sup> was observed with 45 cm row spacing. Narrowing the row spacing from 75 to 60 and then 45 cm, resulted an increment of achene number by 20.49% and 22.67%, respectively. Similar trend for hybrids and row spacing was observed during 2007. Interactive effect of hybrids and varying row spacing was found to be non-significant for both the years of studies. The reason for increase in number of achenes m<sup>-2</sup> in narrow rows is the higher number of plants per unit area in case of sunflower sown at comparatively



narrow row spacing. Increased grain number for sunflower hybrid in case of narrow row spacing was also reported by Calvino *et al.* (2004).

### **Achene yield**

Hysun-33 recorded highest achene yield (2856-2741 kg ha<sup>-1</sup>) during both the years that was statistically at par with SF-187 (2588 kg ha<sup>-1</sup>). It was 10.35% and 23.58% higher than the achene yield recorded in SF-187 and FH-331 (2311 kg ha<sup>-1</sup>), respectively. Similar trend was noted during 2007. Row spacing significantly influenced achene yield of sunflower hybrid during both the years. During 2006, maximum achene yield (2722 kg ha<sup>-1</sup>) was observed when crop was planted at 45 cm apart row spacing followed by 60 cm row spacing where yield was (2628 kg ha<sup>-1</sup>) and the lowest yield (2405 kg ha<sup>-1</sup>) was obtained when 75 cm apart rows were maintained. Narrowing the row spacing from 75 cm to 60 cm resulted in 9.27% increase in yield and further 3.5 % more yield was obtained at 45 cm rows spacing. Similar results were recorded for the year 2007. A significant interaction was recorded amongst different combinations of sunflower hybrids and their respective row spacing during both the years. An increase in achene yield with narrowing the row spacing, but all the hybrids behaved differently at varying row spacing. Highest achene yield (3033 kg ha<sup>-1</sup>) was recorded with the hybrid Hysun-33 planted at 60 cm apart rows, followed by (2783 kg ha<sup>-1</sup>), when SH-187 was sown at 45 cm row spacing that was exactly at par with Hysun-33 planted at 75 cm apart rows. The lowest yield (2000 kg ha<sup>-1</sup>) was recorded when FH-331 was sown at the row spacing (75 cm). The more achene yield with narrow rows may be attributed to more number of plants per unit area, higher LAI, more number of grains per unit area, higher light interception by the plants and more crop growth rate of the plants sown at narrow spacing (Calvino *et al.*, 2004). In contrast, the studies by Zaffaroni and Schneiter (1989) gave inconsistent results by increasing row spacing. The results obtained by Jose *et al.* (2004) also suggested that both the number of achenes per head and the 1000 achene weight decreased significantly with increment in plant density, but the number of achenes m<sup>-2</sup> and higher mean seed weight were sufficient to compensate this decrease. Diepenbrock *et al.* (2001) had contradictory findings that the yield was consistently higher at 75 cm rather than at 50 cm row spacing. Andrade *et al.* (2002) also reported the response to grain yield in Zenit (short season) and Ramcull (long season) hybrids and showed positive response to narrow rows in terms of percentage increase in radiation interception (RI) and grain yield.

Maximum RI at flowering in wide rows was achieved with the long season hybrid, and no positive grain yield response to narrow rows was observed which is contrary to findings of Zaffaroni and Schneiter (1991). This study concluded that where the cropping patterns permit the long season hybrid (Hysun-33) may be more beneficial in terms of higher yield. This hybrid need to be planted at 60 cm apart rows as compared to conventional planting at 75 cm row spacing. For areas with intensive cultivation, the short season hybrids like FH-331 perform better and gave higher yield at even narrow row spacing (45 cm) as compared with wider row spacing (75 and 60 cm).

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