The Pharma Innovation Journal 2022; 11(8): 167-178

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(8): 167-178

www.thepharmajournal.com
Received: 20-06-2022
Accepted: 30-07-2022

Sneha MA
Department of Agronomy, UAS, Raichur, Karnataka, India

BK Desai
Director of Research and Professor, Department of Agronomy, UAS, Raichur, Karnataka, India

MR Umesh
Scientist, AICRP on Sunflower, UAS, Raichur, Karnataka, India

BG Koppalkar
Professor and Head, Department of Agronomy, UAS, Raichur, Karnataka, India

PH Kuchanur
Professor and Head, Genetics and Plant Breeding, AC, Bheemarayanagudi, Karnataka, India

Corresponding Author:
Sneha MA
Department of Agronomy, UAS, Raichur, Karnataka, India

Effect of planting density and fertilizer rate on performance of newly developed sunflower hybrids (*Helianthus annuus* L.)

Sneha MA, BK Desai, MR Umesh, BG Koppalkar and PH Kuchanur

Abstract
A field experiment was conducted to study the effect of planting density and fertilizer rate on performance of newly developed sunflower hybrids. The objective of the study was to find out optimum row spacing and fertilizer rate for new sunflower hybrids of UAS Raichur. Experiment was laid out in split-split plot design with three replications. The treatments consisted of sunflower hybrids RSFH-12-700, RSFH-12-705 and RSFH 1887 as main plots, row spacings at 60 cm and 75 cm as sub plots and fertilizer rate at 100, 125 and 150% RDF as sub-sub plots. The results revealed that sunflower hybrid RSFH-12-700 has recorded 7.98 and 15.58 percent higher seed yield (2144 kg ha^{-1}) compared to RSFH-12-705 and RSFH 1887, respectively. The growth and yield attributes *viz*., plant height, number of leaves, leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), stalk yield, harvest index (HI), oil content and oil yield were also higher in RSFH-12-700. Narrow row spacing at 60 cm had significant effect on growth attributes *viz.*, plant height, leaf area index, LAD, CGR and HI. Whereas, application of 150% RDF has produced significantly higher seed yield (2104 kg ha^{-1}), growth and yield parameters but on par with 125% RDF and superior over 100 percent RDF. It was concluded that the new sunflower hybrid RSFH-12-700 showed greater growth and yield at optimum plant spacing of 60 cm and 150% recommended dose of fertilizers.

Keywords: Hybrids, planting density, RDF, seed yield, growth

Introduction
Sunflower (*Helianthus annuus* L.) is an important oilseed crop and is native to southern parts of USA and Mexico. Sunflower ranks fourth next to soybean, groundnut and rape seed in total production of oilseeds of the world. Seeds of sunflower contain high concentration of oil together with an appropriate proportion of unsaturated fatty acids with non-cholesterol and anti-cholesterol properties. It is cultivated for domestic and industrial purpose for its excellent quality and high oil content. The seeds contain 42-49% of oil and the cake contains 25-35% of protein. India is the largest producer of oilseeds in the world. In India, sunflower is grown over an area of about 0.23 m ha with a production of 0.22 m t and a productivity of 1011 kg ha^{-1} (Anon., 2020) [5]. The cultivation of sunflower is largely confined to southern parts of the country comprising the states of Karnataka, Maharashtra, Tamil Nadu and Andhra Pradesh. These four states contribute about 90 percent of total acreage and 78 percent of total production. Karnataka is the leading sunflower producing state in the country and contributes nearly 63 percent of total area and 54 percent of the total production in the country.

The productivity of sunflower in India is low (886 kg ha^{-1}) as compared to other sunflower growing nations and one of the major reason for low productivity is due to its cultivation mainly under rainfed conditions with sub optimal crop stand, imbalanced nutrition and lack of soil moisture conservation techniques, thus leading to poor seed set and high percent of chaffy seed, low oil content and yield. To achieve highest yield potential of a sunflower hybrid, providing ideal or optimum geometry is through best planting density. Plant spacing effects are highly pronounced in sunflower because there is no possibility of covering gaps between plants by branching or tillering. Thus, an optimum plant stand helps in harnessing the renewable resources in efficient manner towards achieving high crop yields. Inadequate or imbalance use of fertilizer has been one of the critical constraints in sunflower production. Application of nitrogenous, phosphatic and potassic fertilizer at sub optimal level adversely affects the growth and yield (Reddy *et al*., 2007) [33]. Hence, balanced fertilizer application is important for high crop yield and consequently more oil yield.

Fertilizer application represents an important measure to correct nutrient deficiencies and to replace elements removed in the products harvested and has been shown to be particularly effective with respect to yield formation.

The exploitation of new genotypes of sunflower has opened up new horizons in production. However, development and identification of local specific production technology is of prime importance in relevance to enhancing hybrids productivity. Higher productivity of sunflower can be achieved with the identification of high yielding genotypes as well as suitable agronomic practices like maintenance of suitable optimum plant density and use of optimum fertilizer rate. Keeping in view the above facts, the present investigation was carried out with the following objectives to evaluate the performance of new sunflower hybrids under varied planting density and fertilizer levels.

Materials and Methods

The field experiment was carried out at Main Agricultural Research Station, UAS, Raichur to study the "Effect of planting density and fertilizer rate on performance of newly developed sunflower hybrids (*Helianthus annuus* L.)". Experiment was laid out in Split-split plot design with three replications. The treatments consists of three hybrids as main plots [RSFH-12-700 (H_1), RSFH-12-705 (H_2) and RSFH 1887 (H_3)], two spacings as sub plots (S_1-60 × 30 cm and S_2-75 × 30 cm) and three fertilizer levels as sub-sub plots (F_1-100 percent RDF, F_2-125 percent RDF and F_3-150 percent RDF). Regional recommended dose of fertilizer (RDF) for sunflower hybrids was 90:90:60 kg N:P:K ha^{-1}.

The soil was clay in texture with a pH of 7.60 (Piper, 1966), electrical conductivity of 0.23 dS m^{-1} (Piper, 1966) and bulk density of 1.30 Mg m^{-3} (Dastane, 1967) [12]. The soil was medium in organic carbon status (0.62%), low in available nitrogen (200.48 kg ha^{-1}) (Subbiah and Asija, 1956) [40], medium in phosphorus (21.42 kg ha^{-1}) (Jackson, 1973) [18] and potassium (232.56 kg ha^{-1}) (Jackson, 1973) [18]. Fertilizers such as urea, DAP and MOP were calculated and applied as per the treatments. Plant height (cm) was measured using a linear meter scale from base of the plant to the apex of the terminal bud or head of the tagged plants at 30, 60 and at maturity. The number of functional green leaves were counted and recorded from the tagged plants at 30, 60 and at maturity. The leaf area was worked out by disc method on dry weight basis at 30, 60 DAS and at maturity as per the procedure suggested by Vivekanandan *et al*. (1972) [43]. The average leaf area was expressed in cm^2 plant^{-1}.

$$LA = \frac{W_a \times A}{W_d}$$

Where,

LA = Leaf area (cm^2 plant^{-1}).

W_a = Oven dry weight of all leaves (inclusive of 10 discs weight).

W_d = Oven dry weight of 10 discs in g.

A = Area of the 10 discs (cm^2).

Leaf area index (LAI) was worked out by dividing the leaf area per plant by land area occupied by the plant.

$$LAI = \frac{A}{P}$$

Where,

A= Leaf area plant^{-1} (cm^2).

P= Land area occupied by the plant^{-1} (cm^2).

Crop growth rate (CGR) is defined as the rate of dry matter production per unit land area per unit time.

It was worked out by using the formula

$$\text{Crop growth rate (g m}^{-2}\text{ day}^{-1}) = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where, W_1 and W_2 are whole plant dry weights in grams at times t_1 and t_2, respectively in days and P is the ground area (m^2) and expressed in g m^{-2} day^{-1}.

Harvesting: At maturity, the crop was harvested and net plot area were threshed. Seeds were cleaned and seed weight per plot was recorded and expressed as kg ha^{-1}. The stalks (after removing heads) from each plot area was sun dried completely for a week and the weight was recorded and expressed in kg ha^{-1}. Harvest index was recorded as the ratio of economic yield to biological yield (Singh and Stoskoff, 1971) [39].

$$HI (\%) = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

Quality parameters: The sampled seeds of each treatment was used for determination of oil content (%) by using NMR (Nuclear Magnetic Resonance) spectrometer available at MARS, Raichur. For each estimation 12 g (40 mL) seed was used. The oil yield (kg ha^{-1}) was worked out by multiplying oil content with the seed yield kg ha^{-1}.

Statistical analysis: The data recorded on various parameters during the course of investigation was statistically analyzed duly following the analysis of variance technique for split plot design as suggested by Panse and Sukhatme (1978) [31]. The statistical significance was tested with F test at 0.05 level of probability and wherever the F value was found significant, critical difference (CD) was worked out to test the significance.

Results and Discussion

Plant height: The plant height was found to progressively increase at all the stages of crop growth until maturity. The rate of increase in plant height was higher during initial stage of crop growth up to 60 days. Thereafter the rate of increase was slow up to maturity (Table 1). Among Hybrids, RSFH-12-700 has recorded significantly taller plants at 30 DAS (30.7 cm), 60 DAS (175.9 cm) and at maturity (181.8 cm) over RSFH-12-705 (29.5, 169.9 and 172.4 cm, respectively) and RSFH 1887 (28.2, 159.4 and 164.3 cm, respectively). The significant differences in plant height among different sunflower hybrids were found due to genotypic character and its genetic makeup. Similar findings were also recorded by Sarwar *et al*. (2013) [36] and Khan *et al*. (2018) [22].

Plant height was significantly influenced by varied plant spacings at 60 DAS and at maturity except at 30 DAS. The narrow row spacing of 60 cm recorded taller plants at 60 DAS (171.6 cm) and at maturity (175.6 cm) as compared to wider row spacing at 75 cm (165.1 and 170.0 cm). The greater plant height in narrow spaced plots might be due to increased competition among the sunflower plants for light (Ali *et al*., 2007) [2]. Similar results were reported by Basha (2000) [10] and Bassal (2003) [11]. The higher crop canopy in wider spacing increases the interception of radiation due to more light penetration than denser plants. Increased light intensity disturbed the level of auxin in plants that finally decreased plant height in wider spacing.

The average plant height was significantly influenced by rate of fertilizer application at 30, 60 DAS and at maturity. Application of 150 percent RDF has recorded taller plants at 30 (30.1 cm), 60 DAS (173.7 cm) and at maturity (178.6 cm) by over 100 percent RDF (28.8, 160.3 and 163.6 cm, respectively) but on par with application of 125 percent RDF (29.6, 171.2 and 176.2 cm, respectively). Plant height was improved with the higher level of fertilizer application. Ali *et al*. (2014) [45] reported that sufficient application of fertilizer has significantly influenced on plant height of sunflower by improving vegetative growth, root growth and better absorption of nutrients. Adequate supply of fertilizer has helped the plants to grow taller compared to others as stated by Kadasiddappa (2007) [19] and Pavani *et al*. (2012) [32]. Combination of hybrids and fertilizer rate had no significant effect on sunflower plant height throughout the crop season.

Table 1: Effect of spacing and fertilizer levels on periodical plant height (cm) of different sunflower hybrids

Treatment	H_1:RSFH-12-700		H_2: RSFH-12-705		H_3: RSFH 1887		Mean
	S_1: 60 cm x 30 cm	S_2: 75 cm x 30 cm	S_1: 60 cm x 30 cm	S_2: 75 cm x 30 cm	S_1: 60 cm x 30 cm	S_2: 75 cm x 30 cm	
	30 DAS						
F_1: 100% RDF	30.8	29.3	29.0	28.4	27.9	27.2	28.8
F_2: 125% RDF	30.9	30.5	29.8	29.5	28.5	28.3	29.6
F_3: 150% RDF	31.3	31.5	30.4	29.8	28.7	28.5	30.1
Mean	31.0	30.4	29.7	29.2	28.3	28.0	29.5
Mean of H	30.7	29.5	28.2	Mean of S	29.7	29.2	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	0.4	0.3	0.3	0.5	0.6	0.5	0.8
C.D. @ 5%	1.46	NS	0.98	NS	NS	NS	NS
	60 DAS						
F_1: 100% RDF	175.4	165.5	163.0	154.4	154.1	149.5	160.3
F_2: 125% RDF	180.4	173.8	177.2	171.3	165.5	159.0	171.2
F_3: 150% RDF	183.5	177.1	177.3	174.3	166.4	161.5	173.7
Mean	179.7	172.1	172.5	166.6	162.0	156.6	168.4
Mean of H	175.9	169.9	159.4	Mean of S	171.6	165.1	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	2.8	1.8	2.3	3.2	4.1	3.3	5.8
C.D. @ 5%	10.85	6.49	6.95	NS	NS	NS	NS
	At maturity						
F_1: 100% RDF	174.7	172.0	162.3	158.0	162.2	152.3	163.6
F_2: 125% RDF	186.3	184.4	178.5	175.6	171.7	160.8	176.2
F_3: 150% RDF	187.9	185.1	181.4	178.6	175.3	163.3	178.6
Mean	182.9	180.5	174.1	170.7	169.7	158.8	172.8
Mean of H	181.8	172.4	164.3	Mean of S	175.6	170.0	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	2.3	1.6	2.1	2.7	3.6	2.9	5.1
C.D. @ 5%	9.14	5.56	6.07	NS	NS	NS	NS

Number of leaves: The number of leaves per plant increased with the advancement up to 60 DAS and thereafter declined upto maturity (Table 2). At 30 DAS, among hybrids there was no significant difference in number of leaves per plant. While, at 60 DAS, RSFH-12-700 recorded greater number of leaves per plant (22.4) and at maturity (18.1) as compared to RSFH 1887 (19.5 and 16.3, respectively) at respective growth stage (Table 2). Increased number of leaves might be due to the genetic potential of the hybrid. Observed significant differences in number of leaves among different sunflower hybrids. The results revealed that number of leaves per plant at different crop growth stages was not significantly influenced by row spacings.

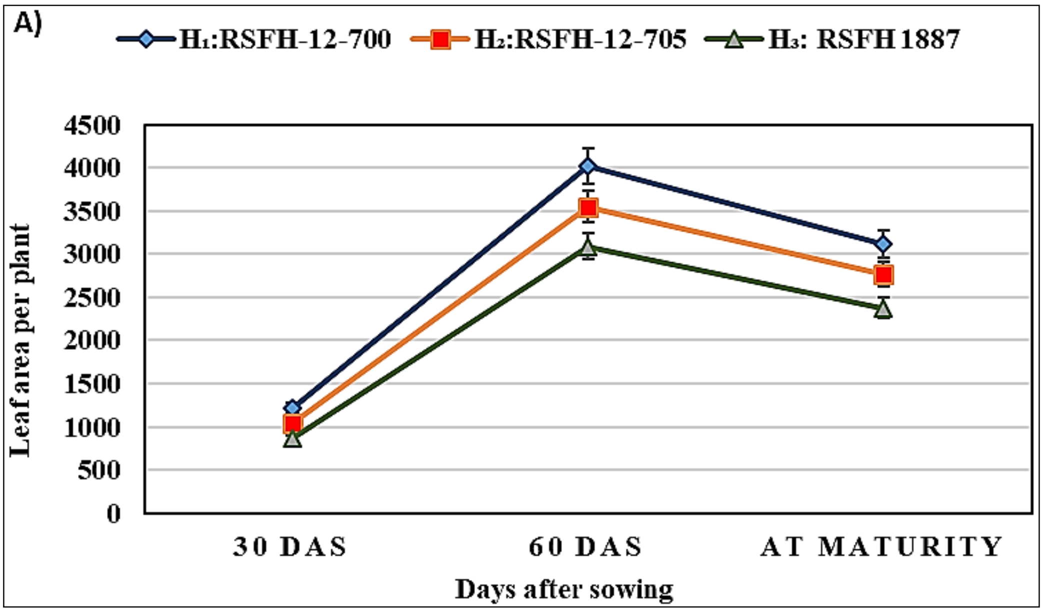
Different rate of fertilizers significantly influenced number of leaves per plant at all the growth stages (Table 2). The crop fertilized with 150 percent RDF recorded significantly highest number of leaves at 30, 60 DAS and at maturity (12.5, 22.0 and 17.6, respectively) as compared to rest of the fertilizer rates. It implies that application of graded fertilizers increased the number of leaves in sunflower. The optimum nutrient application enhances stem height of sunflower plants. Thereby, longer stem possess more number of nodes, which in turn results in more number of leaves. More number of leaves per plant may be due to enhanced plant height and vegetative growth (Banerjee *et al*., 2014) [9]. The results are in conformity with findings of Nawaz *et al*. (2003) [30] and Pavani *et al*. (2012) [32]. All the interaction effects among sunflower hybrids, spacing and levels of fertilizers did not reach to the levels of significance in case of number of leaves per plant at all the crop growth stages.

Table 2: Effect of spacing and fertilizer levels on number of leaves per plant of sunflower hybrids at different intervals

Treatment	H1:RSFH-12-700		H2: RSFH-12-705		H3: RSFH 1887		Mean
	S1: 60 cm x 30 cm	S2: 75 cm x 30 cm	S1: 60 cm x 30 cm	S2: 75 cm x 30 cm	S1: 60 cm x 30 cm	S2: 75 cm x 30 cm	
30 DAS							
F1: 100% RDF	12.0	12.0	11.3	11.0	11.3	11.3	11.5
F2: 125% RDF	13.0	13.0	12.3	12.3	12.0	11.6	12.4
F3: 150% RDF	13.6	13.3	12.6	12.6	11.0	11.6	12.5
Mean	12.8	12.7	12.1	11.9	11.4	11.5	12.1
Mean of H	12.8	12.1	11.5	Mean of S	12.1	12.1	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	0.4	0.2	0.2	0.4	0.3	0.3	0.5
C.D. @ 5%	NS	NS	0.6	NS	NS	NS	NS
60 DAS							
F1: 100% RDF	20.6	20.3	18.6	18.3	19.0	18.0	19.2
F2: 125% RDF	23.3	22.6	21.6	21.3	20.3	19.3	21.4
F3: 150% RDF	24.0	23.6	22.3	21.6	21.0	19.6	22.0
Mean	22.6	22.1	20.8	20.4	20.1	18.9	20.8
Mean of H	22.4	20.7	19.5	Mean of S	21.2	20.6	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	0.4	0.3	0.2	0.5	0.4	0.3	0.6
C.D. @ 5%	1.4	NS	0.7	NS	NS	NS	NS
At maturity							
F1: 100% RDF	16.9	16.7	15.9	16.0	16.0	15.8	16.3
F2: 125% RDF	18.6	18.3	17.2	17.0	16.4	16.3	17.3
F3: 150% RDF	19.2	18.7	17.3	17.2	16.8	16.4	17.6
Mean	18.2	17.9	16.8	16.7	16.4	16.2	17.1
Mean of H	18.1	16.8	16.3	Mean of S	17.2	16.9	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	0.3	0.2	0.2	0.4	0.4	0.3	0.5
C.D. @ 5%	1.3	NS	0.7	NS	NS	NS	NS

Leaf area: The results revealed that leaf area per plant increased with growth advancement in age of the crop up to 60 DAS, thereafter, it was decreased towards the maturity of the crop (Fig. 1). Leaf area was significantly differed among treatment combination at all the crop growth stages. At 30, 60 DAS and at maturity sunflower hybrid RSFH-12-700 recorded significantly higher leaf area per plant (1213.5, 4021.2 and 3119.5 cm^2, respectively) as compared to RSFH 1887 (859.3, 3091.2 and 2373.3 cm^2, respectively). Differences in leaf area might be due to the genetic potential among various hybrids. Similar results were reported by Lodh (1988) [24]. The data indicated that leaf area per plant at different crop growth stages was not significantly influenced by row spacings.

Application of 150 percent RDF (1180.7, 3882.9 and 3077.2 cm^2, respectively) has recorded significantly greater leaf area per plant at 30, 60 DAS and at maturity, respectively than that of 100 percent RDF (837.9, 3080.4 and 2291.9 cm^2, respectively). The increased leaf area might be due to higher application of N, P and K which encouraged production of more carbohydrates by influencing cell division and its enlargement (Sharma, 1994) [38]. The leaf area per plant was not significantly influenced by combination of row spacings and fertilizer rate at all the stages of crop growth.



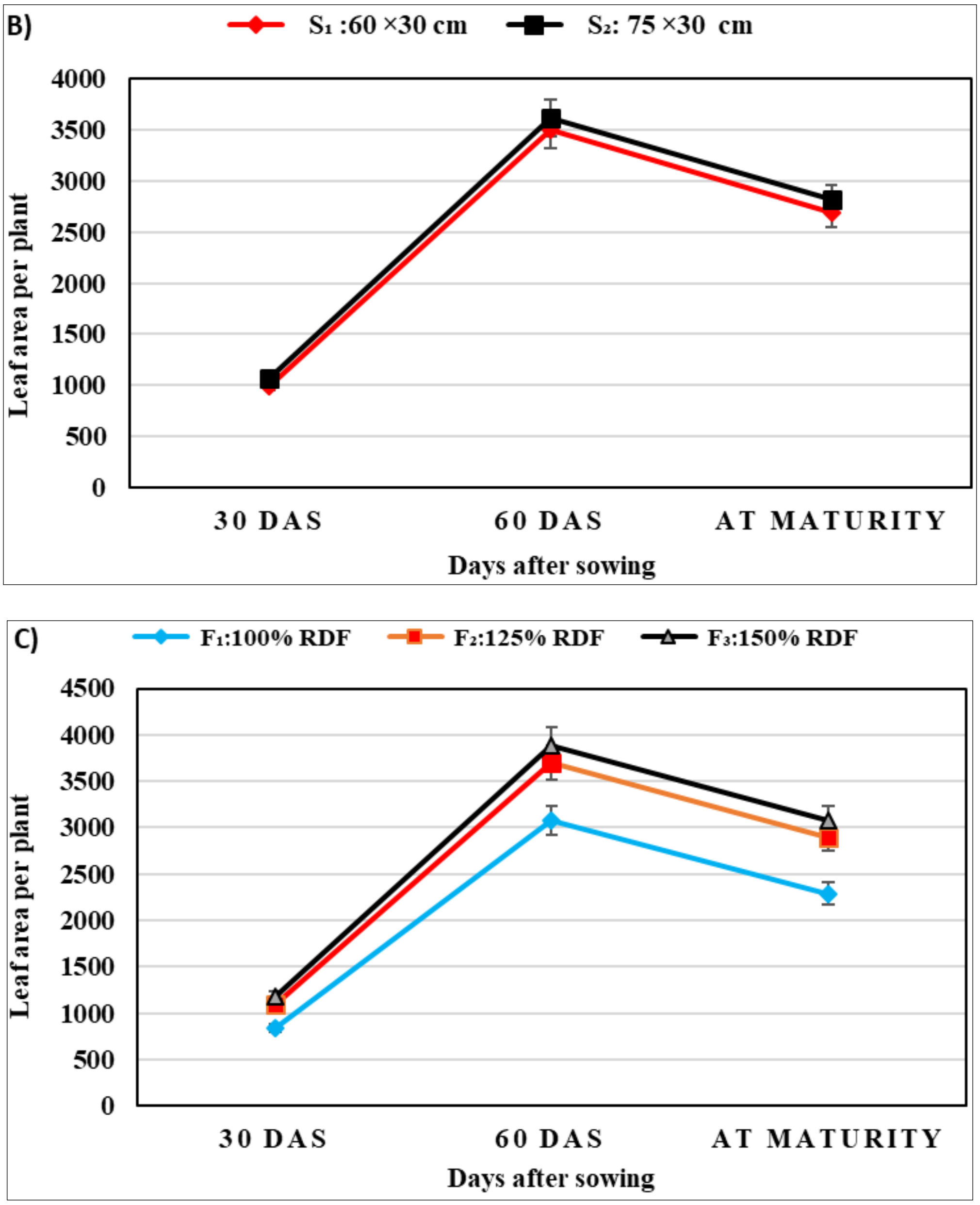


Fig 1: Effect of different a) hybrids b) spacing and c) fertilizer levels on leaf area of sunflower at different growth stages

Leaf area index: The leaf area index was lowest up to 30 days and peaked at 60 DAS and thereafter slightly decreased towards maturity (Fig. 2). Greater LAI was recorded in RSFH-12-700 (0.61, 2.01 and 1.60) followed by RSFH-12-705 (0.52, 1.77 and 1.40) and the lowest with RSFH 1887 (0.43, 1.54 and 1.20) at 30, 60 DAS and at maturity, respectively. The higher leaf area index was mainly attributed due to higher number of leaves in RSFH-12-700. Among sunflower hybrids, varied LAI was observed due to differential genetic makeup of hybrids (Ali *et al*., 2000 and Sarwar *et al*., 2013) [3, 36]. Similarly, among different spacings, the spacing at 60 cm (0.55, 1.94 and 1.50, respectively) recorded greatest LAI as compared to 75 cm (0.48, 1.60 and 1.25, respectively) at 30, 60 DAS and at maturity. Ishfaq *et al*. (2009) [17] indicated that reduced ground area per plant with higher plant population in lower plant spacing caused more LAI in sunflower. The similar trend was observed by Aguilar-Garcia *et al*. (2005) [1] and Khan and Akmal (2016) [23].

Application of 150 percent RDF (0.59, 1.93 and 1.53) recorded the higher magnitude of LAI over 100 percent RDF and was on par with 125 percent (0.54, 1.84 and 1.44) at 30 DAS, 60 DAS and at maturity, respectively. The lowest LAI was obtained in 100 percent RDF (0.41, 1.54 and 1.14) at 30, 60 DAS and at harvest, respectively. Maximum LAI values were observed under 150 percent RDF can be due to sufficient supply of N that produced larger leaves and more number of leaves per plant that has resulted enhanced photosynthetic surface area. The greater leaf expansion in sunflower hybrid could be attributed to high rate of cell division and cell enlargement (Waqas *et al*., 2017) [44]. Thavaprakash and Malligawad (2002) [42] reported that N:P ratio of more than 1.0 resulted in higher LAI was due to the increased leaf area per plant which was influenced by the higher leaf dry matter per plant. Combined effect of sunflower row spacing, rate of fertilizer application and hybrids had no significant effect on LAI at various growth stages.

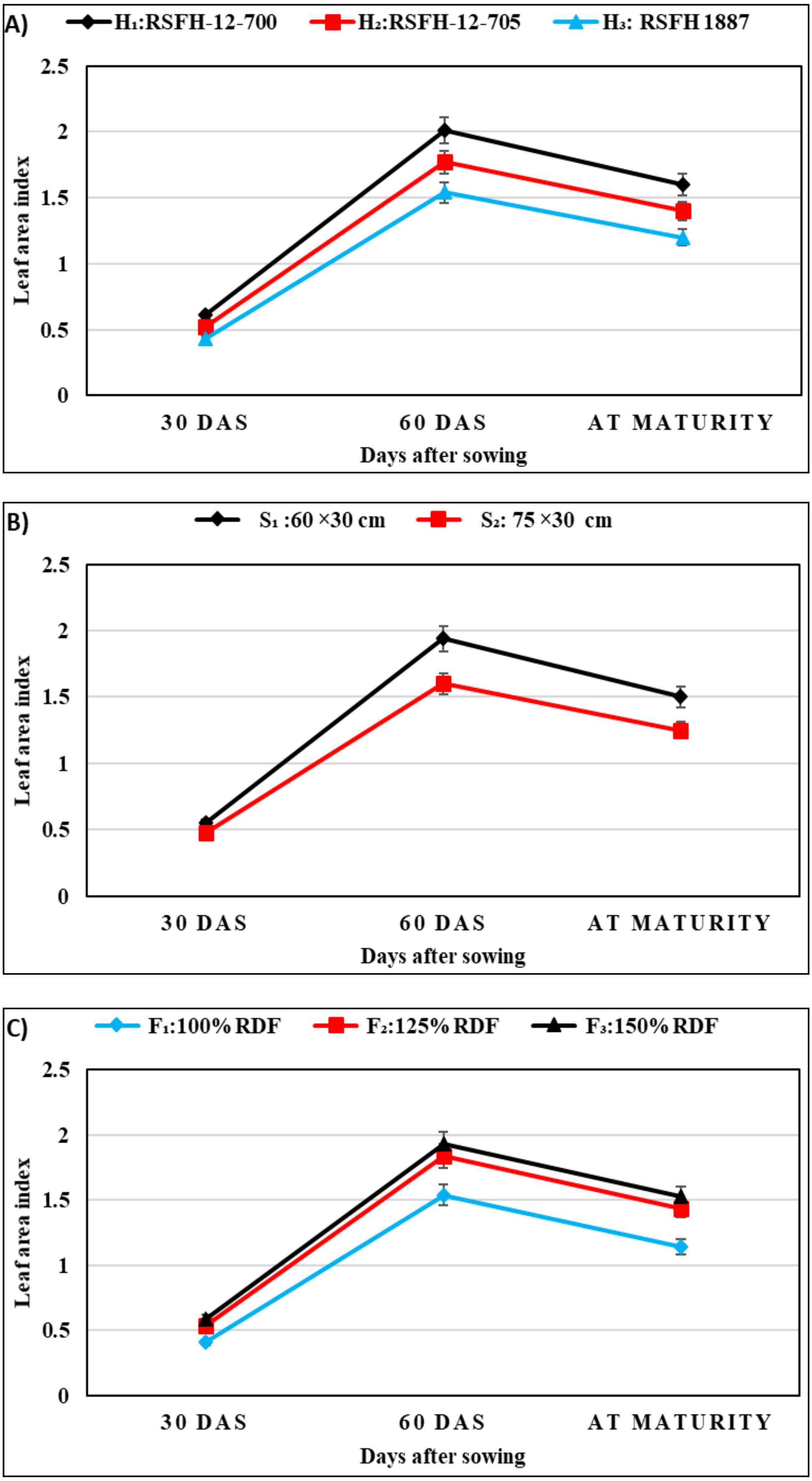


Fig 2: Effect of different a) hybrids b) spacing and c) fertilizer levels on leaf area index of sunflower at different growth stages

Leaf area duration (LAD): The LAD has increased gradually with the advancement of crop age (Fig. 3). The results showed significant effect of hybrids on LAD, at 0 to 30 DAS, 31 to 60 DAS and 61 DAS to maturity. RSFH-12-700 (9.1, 39.2 and 53.5 days, respectively) had significantly the higher LAD followed by RSFH-12-705 (7.7, 34.3 and

47.3 days, respectively). Lowest LAD was observed in RSFH 1887 (6.4, 29.4 and 40.8 days, respectively). However, the cultivars with highest LAI and whose leaf surfaces lasted longer time had maximum LAD as reported by Miralles *et al.* (1997) [25] in sunflower crop. Row spacing at 60 cm (8.3, 37.4 and 51.5 days) recorded maximum and significantly more LAD over 75 cm (7.2, 31.2 and 42.9 days) row spacing at 0 to 30 DAS, 31 to 60 DAS and 61 DAS to maturity, respectively. Thus, narrow row spacing of 60 cm recorded significantly higher LAD compared to wider spacing of 75 cm.

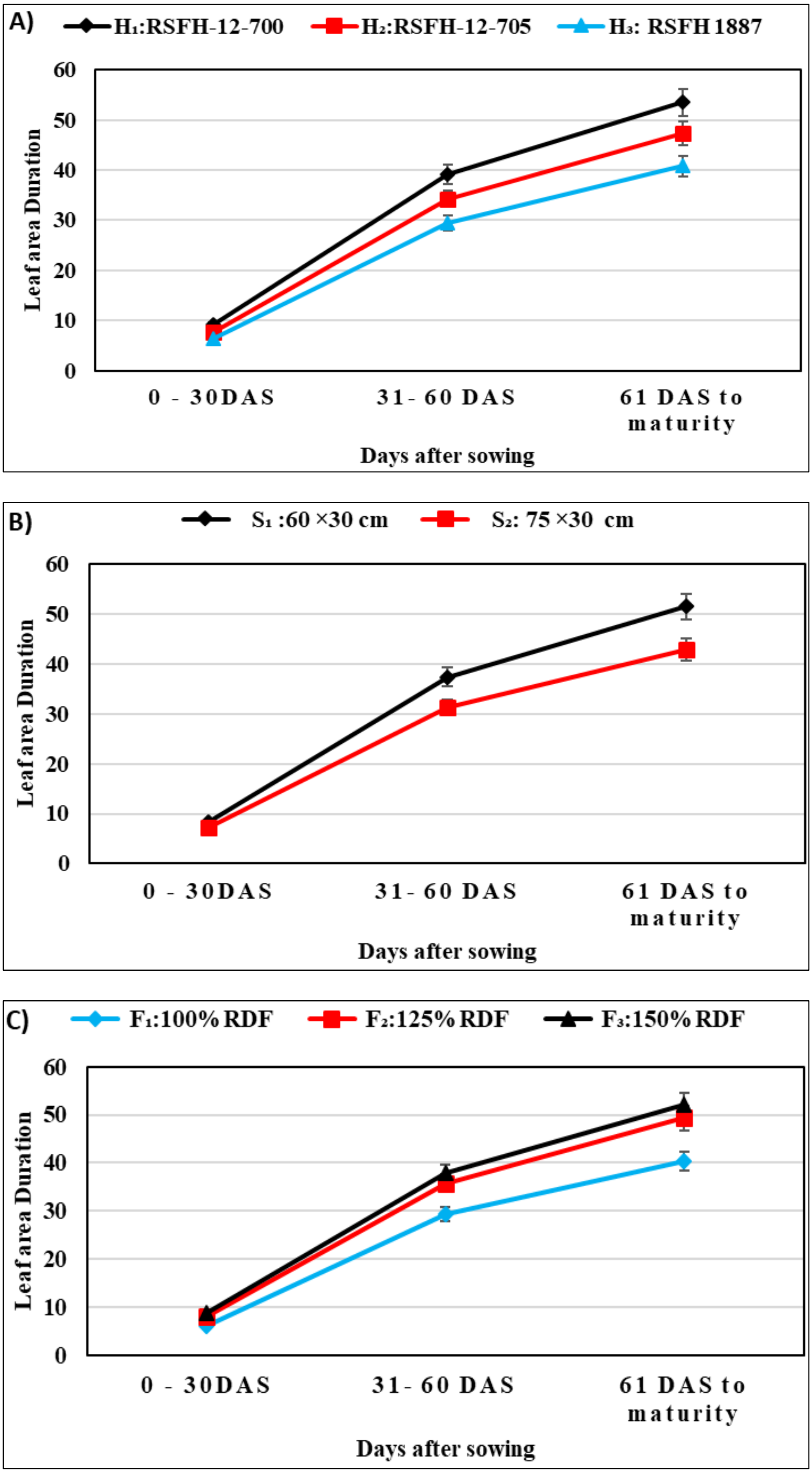


Fig 3: Effect of different a) hybrids b) spacing and c) fertilizer levels on leaf area duration of sunflower at different growth stages

Crop growth rate (g m^{-2} day^{-1})

Crop growth rate (CGR) was lower during the initial crop growth stage (30 DAS), it had reached maximum at 60 DAS thereafter declined towards maturity (Fig. 4). Sunflower hybrids affected the CGR significantly except at 61 DAS to maturity. At 30 DAS (0.96 g m^{-2} day^{-1}) and 31-60 DAS, (17.15 g m^{-2} day^{-1}) RSFH-12-700 recorded significantly higher CGR than RSFH-12-705 (0.87 and 15.80 g m^{-2} day^{-1}, respectively) and RSFH 1887 (0.81 and 14.17 g m^{-2} day^{-1}, respectively). Greater CGR in new hybrid was mainly due to increased leaf number, size and vegetative growth of plant.

Row spacing at 60 cm (0.97 and 17.18 g m^{-2} day^{-1}) recorded significantly higher crop growth rate than wider spacing of 75 cm (0.79 and 14.23 g m^{-2} day^{-1}) at 0-30 DAS and 31-60 DAS, respectively. Awais *et al*. (2013) [6] opined that sunflower achieved more CGR with greater plant population due to higher interception of radiant light. The results showed significant differences among different fertilizer levels at 0 to 30 DAS and 31 to 60 DAS with respect to CGR. In general, there was a corresponding increase in CGR with increased fertilizer rate from 100 to 150 percent RDF.

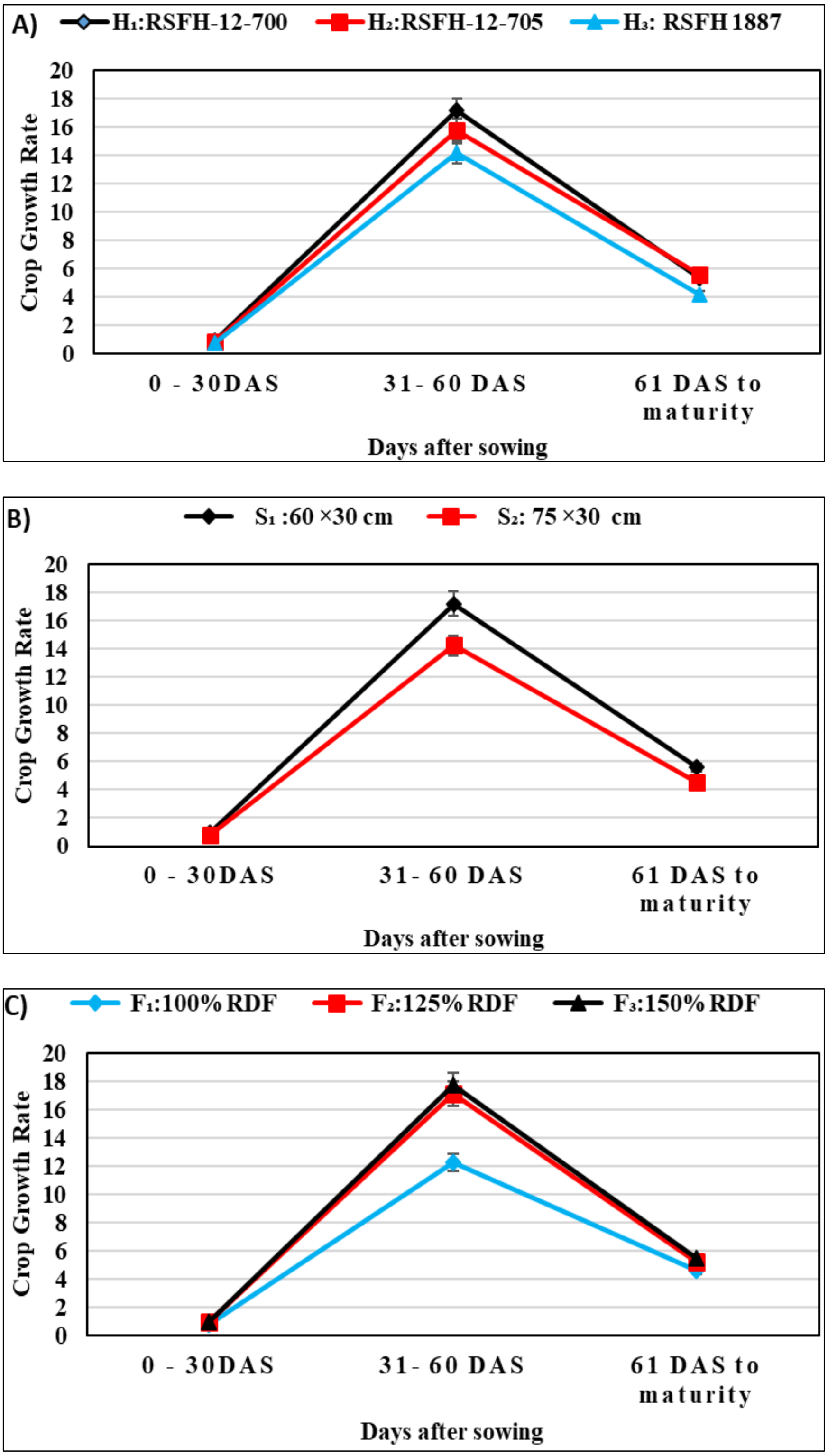


Fig 4: Effect of different a) hybrids b) spacing and c) fertilizer levels on crop growth rate (g m^{-2} day^{-1}) of sunflower at different growth stages

Grain yield (kg ha^{-1}): Yield is the resultant of different metabolic activities taking place in different stages of the growth of the plants. Yield of the crop depends on both external and internal factors. Internal factors like growth and yield parameters *viz*., dry matter accumulation and distribution in different growth stages and external factors like optimum light, water and nutrients. The sunflower hybrid RSFH-12-700 (2144 kg ha^{-1}) recorded significantly higher grain yield followed by RSFH 12-705 (1996 kg ha^{-1}) and RSFH 1887 (1855 kg ha^{-1}) (Table 3). The improvement in grain yield of hybrid RSFH-12-700 and RSFH-12-705 were 15.58% and 7.60%, respectively over RSFH 1887. Among hybrids the differences in grain yield may be attributed to higher LAI, head diameter, number of seeds per head and 1000 seed weight which is due to its genetic potential and better adaptability under present climatic conditions. These results are in conformity with the findings of Ekin *et al*. (2005) [13] and Ali *et al*. (2007) [2]. There was no significant difference observed in terms of grain yield due to different row spacings. However, higher yield was recorded with wider spacing (2024 kg ha^{-1}) compared to narrow spacing (1972 kg ha^{-1}).

Among fertilizers levels, application of 150 percent RDF (2104 kg ha^{-1}) has recorded significantly higher grain yield over 100 percent RDF (1840 kg ha^{-1}) but on par with the application of 125 percent RDF (2051 kg ha^{-1}). Remarkable improvement in grain yield were 14.34% and 11.47% with application of 150 percent and 125 percent RDF over 100 percent RDF. The higher grain yield could be attributed to an improved yield attributing characters *viz*., head diameter, number of filled seeds and test weight under sufficient supply of fertilizers. Head diameter is the most important character that enhances grain yield by providing maximum florets for higher seed set (Syed *et al*., 2006) [41]. Significantly higher dry matter production and its accumulation in different plant parts had an indirect impact on the grain yield and relied on various growth functions *viz*., plant height, number of leaves, leaf area and leaf area index. The combined effect of growth and yield components was reflected on higher seed yield. The results are in conformity with Reddy *et al*. (2002) [34] and Sarkar and Mallick (2009) [35]. The accumulation of more dry matter in the leaves in treatments with higher supply of N and P produced more leaf area per plant, thereby improving the supply of photosynthates and in turn increasing the grain yield of sunflower (Thavaprakash and Malligawad, 2002) [42]. Interaction effect of spacing and fertilizer levels of sunflower hybrids was not significantly influenced on grain yield.

Stalk yield (kg ha^{-1})

The results revealed that Sunflower hybrid RSFH-12-700 has produced significantly superior stalk yield (3158 kg ha^{-1}) over RSFH-12-705 (2894 kg ha^{-1}) and RSFH 1887 (2669 kg ha^{-1}). Higher stalk yield in RSFH-12-700 is attributed to superior growth and yield attributing characters. Sunflower stalk yield was not significantly influenced by row spacing.

Among the fertilizer levels, application of 150 percent RDF (3361 kg ha^{-1}) has recorded significantly higher stalk yield over 125 percent RDF (2913 kg ha^{-1}) and 100 percent RDF (2448 kg ha^{-1}). The magnitude of increase due to application of 150 percent RDF was 37.29% and 15.37% over 100 percent RDF and 125 percent RDF plots, respectively. It was higher with the application of 150 percent RDF due to the higher plant height, number of leaves, leaf area, head diameter and capitulum weight. The availability of nutrient enhanced photosynthetic activity and nutrient uptake which increased sunflower growth and development. Combined effect of row spacing, fertilizer rate and sunflower hybrids was not significantly influenced on stalk yield.

Harvest index (HI)

The hybrid RSFH-12-700 has recorded higher Harvest index (0.39) over RSFH 1887 (0.34) (Table 3). Higher harvest index was due to efficient translocation of photosynthates towards seed formation which was expressed in seed yield. The higher HI for a hybrid was due to its genotypic dominance to utilize more photo-assimilates for grain yield formation (Nasim *et al*., 2012) [28]. Similar results were also reported by Gholinezhad *et al*. (2009) [14].

The row spacing of 75 cm (0.39) recorded maximum HI as compared to 60 cm (0.36). The increased plant density has resulted decreased HI due to severe reduction of assimilates distribution to grain. Higher HI in sunflower might be due to minimum plants per unit area which received maximum balanced fertilizer, plenty of sunlight and space, as a result produced large discs with large seed size and maximum number of seed per disc (Gholinezhad *et al*. 2009) [14]. Similar results were also reported by Khakwani *et al*. (2014) [21].

Significantly higher HI was observed with application of 125 percent RDF (0.41) over 100 percent RDF (0.34). Higher HI with the application of 125 percent RDF was due to higher grain yield and optimal nutrient supply. The higher HI under minimum sunflower plants per unit area was due to maximum balanced fertilizers, greater sunlight and space (Khakwani *et al*., 2014) [21]. Waqas *et al*. (2017) [44] also stated that increased HI might be due to optimum supply of the NPK for their magnanimous role in vegetative and reproductive phase of the plant. The results are also in line with the work of Thavaprakash *et al*. (2003) [46]. Interaction effect of row spacing, fertilizer levels and hybrids on harvest index was found to be not significant.

Table 3: Grain yield (kg ha^{-1}), Stalk yield (kg ha^{-1}) and harvest index of sunflower hybrids as influenced by row spacing and fertilizer application

Treatment	H_1: RSFH-12-700		H_2: RSFH-12-705		H_3: RSFH 1887		Mean
	S_1: 60 cm x 30 cm	S_2: 75 cm x 30 cm	S_1: 60 cm x 30 cm	S_2: 75 cm x 30 cm	S_1: 60 cm x 30 cm	S_2: 75 cm x 30 cm	
Grain yield (kg/ha)							
F_1: 100% RDF	1944	1953	1810	1814	1701	1819	1840
F_2: 125% RDF	2199	2223	2035	2097	1841	1913	2051
F_3: 150% RDF	2233	2312	2109	2112	1881	1977	2104
Mean	2125	2163	1985	2008	1808	1903	1998
Mean of H	2144	1996	1855	Mean of S	1972	2024	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	23	17	25	29	43	35	61

C.D. @ 5%	91	NS	73	NS	NS	NS	NS
Stalk yield (kg/ha)							
F_1: 100% RDF	3204	2455	1783	2144	2469	2629	2448
F_2: 125% RDF	3385	2973	3351	2895	2547	2326	2913
F_3: 150% RDF	3748	3184	3911	3279	2788	3255	3361
Mean	3445	2870	3015	2772	2601	2736	2907
Mean of H	3158	2894	2669	Mean of S	3021	2794	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	65	66	132	115	229	187	324
C.D. @ 5%	255	NS	386	NS	NS	NS	NS
Harvest index							
F_1: 100% RDF	0.29	0.40	0.44	0.36	0.28	0.29	0.34
F_2: 125% RDF	0.40	0.45	0.36	0.40	0.38	0.42	0.41
F_3: 150% RDF	0.38	0.43	0.33	0.37	0.36	0.34	0.37
Mean	0.35	0.42	0.37	0.37	0.34	0.35	0.37
Mean of H	0.39	0.38	0.34	Mean of S	0.36	0.39	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	0.010	0.010	0.016	0.015	0.027	0.022	0.039
C.D. @ 5%	0.03	0.03	0.04	NS	NS	NS	NS

Quality parameter

Oil content (%): Among the sunflower hybrids, RSFH-12-700 was recorded highest oil content (38.42%) over other two hybrids (Table 4). While, Hybrids RSFH-12-705 (36.94%) and RSFH 1887 (36.31%) were found to be on par with each other. The differential oil content in sunflower hybrids was due to their genetic potential as well as interactive effects of environmental variables during achene development and physiological maturity of the crop (Kaleem *et al*., 2011) [20]. also reported that these differences may be due to its genetic superiority over other hybrids. There was no significant effect of row spacing on seed oil content of all the hybrids. However, seed oil content was significantly influenced by different rates of fertilizers. Application of 150 percent RDF (38.00%) has recorded significantly higher oil content but it was on par with 125 percent RDF (37.42%) and both were significantly higher than 100 percent RDF (36.27). The application of higher dose of N enhanced oil content in seed by increasing vegetative growth and production of more carbohydrate in plant thereby transferring to seeds. Similarly, higher levels of K fertilizer also aids in increased oil content. These results are in agree with Scheiner *et al*. (2002) [37], who reported reduction of seed oil content due to N addition was relatively small (2 to 5%) and was over compensating by the seed yield at the responsive site. Interaction effect of row spacing, fertilizer levels and hybrids on oil content was found non-significant.

Oil yield (kg ha^{-1})

The data pertaining to oil yield was significantly influenced by the different treatment combinations (Table 4). Oil yield was significantly influenced by sunflower hybrids. The hybrid RSFH-12-700 (820 kg ha^{-1}) recorded maximum oil content and found significantly superior over RSFH-12-705 (740 kg ha^{-1}) and RSFH 1887 (678 kg ha^{-1}). The increase in oil yield owing to RSFH-12-700 and RSFH-12-705 over RSFH 1887 was 20.94% and 9.14%, respectively. Differences in oil yield was mainly indicated by oil content and seed yield. Ekin *et al*. (2005) [13] observed differences in oil yield of sunflower was due to variations in yield components *i.e.*, seed yield. also reported that higher oil percent and seed yield that has resulted greater oil yield.

There were no significant differences observed in terms of oil yield (kg ha^{-1}) due to plant spacing. The non-significant seed yield and oil content recorded under different spacings is also reflected in oil yield. Oil yield was significantly influenced by different fertilizer rates. Application of 150 percent RDF (801 kg ha^{-1}) had recorded significantly higher oil yield over 100 percent RDF (668 kg ha^{-1}) but was comparable with 125 percent RDF (769 kg ha^{-1}). Oil yield is the function of seed yield and oil content in seed, the more seed yield and oil content with application of 150 percent RDF was reflected in maximum oil yield. Similar results were reported by Mollashahi *et al*. (2013) [26]. The combined effect of spacing, fertilizer rate and hybrids was found to be non-significant on oil yield.

Table 4: Oil Content (%) and oil yield (kg/ha) of sunflower hybrids as influenced by row spacing and fertilizer application

Treatment	H_1: RSFH-12-700		H_2: RSFH-12-705		H_3: RSFH 1887		Mean
	S_1: 60 cm x 30 cm	S_2: 75cm x 30 cm	S_1: 60 cm x 30 cm	S_2: 75 cm x 30 cm	S_1: 60 cm x 30 cm	S_2: 75 cm x 30 cm	
Oil Content (%)							
F_1: 100% RDF	36.99	37.17	35.92	35.95	35.66	35.93	36.27
F_2: 125% RDF	38.61	38.91	37.07	37.07	36.32	36.53	37.42
F_3: 150% RDF	39.31	39.54	37.67	37.97	36.51	36.90	38.00
Mean	38.30	38.54	37.00	37.00	36.16	36.45	37.23
Mean of H	38.42	36.94	36.31	Mean of S	37.12	37.33	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	0.36	0.40	0.44	0.70	0.76	0.62	1.07
C.D. @ 5%	1.39	NS	1.28	NS	NS	NS	NS
Oil yield (kg/ha)							
F_1: 100% RDF	715	721	651	654	611	657	668
F_2: 125% RDF	845	859	756	779	673	703	769
F_3: 150% RDF	872	908	796	804	691	734	801

Mean	811	829	734	746	658	698	746
Mean of H	820	740	678	Mean of S	734	757	
	H	S	F	H x S	H x F	S x F	H x S x F
S.Em. ±	9.06	7.87	12.47	13.64	21.61	17.64	30.56
C.D. @ 5%	35.36	NS	36.42	NS	NS	NS	NS

Conclusion

The sunflower hybrid RSFH-12-700 produced higher growth and yield which was followed by RSFH-12-705 and RSFH 1887. The growth parameters *viz*., plant height, number of leaves, LAI, LAD and CGR were favorably influenced by narrow spacing of 60 × 30 cm over wider spacing of 75 × 30 cm. Application of 150 percent RDF produced higher growth and yield parameters over 100 percent RDF and was on par with 125 percent RDF. Thus, planting of sunflower hybrid RSFH-12-700 with application of 150 percent RDF was found productive and remunerative.

References

1. Aguilar-Garcia L, Escalante-Estrada JA, Fucikovsky-Zak L, Tijerina-Chavez L, Engleman EM. Leaf area, net assimilation rate, yield and plant density in sunflower. TERRA Latino Americana. 2005;23(3):303-310.
2. Ali A, Tanveer A, Nadeem MA, Tahir M, Hussain M. Effect of varying planting pattern on growth, achene yield and oil contents of sunflower (*Helianthus annuus* L.). Pakistan Journal of Agricultural Sciences. 2007;44(3):449-452.
3. Ali M, Khalil SK, Nawab K. Response of sunflower hybrids to various levels of nitrogen and phosphorus. Sarhad Journal of Agriculture. 2000;16(5):477-483.
4. Allam AY, El-Nagar GR, Galal AG. Response of two sunflower hybrids to planting dates and densities. Acta Agronomica Hungarica. 2003;51(1):25-35.
5. Anonymous, Agricultural Statistics at a Glance, Directorate of Economics and Statistics, Govt. of India, 2020.
6. Awais M, Wajid A, Ahmad A, Bakhsh A. Narrow plant spacing and nitrogen application enhances sunflower (*Helianthus annuus* L.) productivity. Pakistan Journal of Agricultural Sciences. 2013;50(4):689-697.
7. Awais M, Wajid A, Ahmad A, Saleem M, Bashir M, Saeed U, *et al*. Nitrogen fertilization and narrow plant spacing stimulates sunflower productivity. Turkish Journal of Field Crops. 2015;20(1):99-108.
8. Bakth J, Mohammad S, Mohammad Y, Hamid US. Physiology, phenology and yield of sunflower (Autumn) as affected by NPK fertilizer and hybrids. Pakistan Journal of Botany. 2010;42(3):1909-1922.
9. Banerjee H, Dutta SK, Pramanik SJ, Ray K, Phonglosa A, Bhattacharyya K. Productivity and profitability of spring planted sunflower hybrid with nitrogen, phosphorus and potassium fertilizer. Annuals of Plant and Soil Research. 2014;16(3):250-256.
10. Basha HA. Response of two sunflower cultivars to hill spacings and nitrogen fertilizer levels under sandy soil conditions. Zagazig Journal of Agricultural Research (Egypt), 2000, 617-633.
11. Bassal SAA. Impact of tillage systems, hill spacings and bio and chemical phosphatic fertilization regimes on yield and its components of sunflower (*Helianthus annuus* L.). Zagazig Journal of Agricultural Research (Egypt), 2003, 619-634.
12. Dastane NG. A practical manual for water use research. Navabharat Prakashan, Poona, India, 1967, 5.
13. Ekin Z, Tuncturk M, Yilmaz I. Evaluation of seed, oil yields and yield properties of different sunflower (*Helianthus annuus* L.) hybrid varieties in Van, Turkey. Pakistan Journal of Biological Sciences. 2005;8(5):683-686.
14. Gholinezhad E, Aynaband A, Ghorthapeh AH, Noormohamadi G, Bernousi I. Study of the effect of drought stress on yield, yield components and harvest index of sunflower hybrid iroflor at different levels of nitrogen and plant population. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 2009;37(2):85-94.
15. Girme MR. Effect of land configuration and fertilizer level on yield and quality of sunflower hybrids. Ph.D. Thesis, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, 2009.
16. Gungula DT, Kling JG, Togun AO. CERES Maize predictions of maize phenology under nitrogen stressed conditions in Nigeria. Agronomy Journal. 2003;95:892-899.
17. Ishfaq M, Ali A, Khaliq A, Yaseen M. Allometry, agronomic traits and yield of autumn planted sunflower hybrids under varying row spacing. Pakistan Journal of Agricultrual Sciences. 2009;46(4):248-257.
18. Jackson ML. Soil chemical analysis, Prentice Hall of India, Pvt. Ltd., New Delhi, 1973, 498.
19. Kadasiddappa MM, Mohammad S, Rao PV. Effect of fertility on growth, yield and economics of sunflower (*Helianthus annuus* L.). Journal of Oilseeds Research. 2007;24(1):200-202.
20. Kaleem S, Hassan FU, Ahmad M, Mahmood I, Wasaya A, Randhawa MA, *et al*. Effect of growing degree days on autumn planted sunflower. African Journal of Biotechnology. 2011;10(44):8840-8846.
21. Khakwani AA, Sharif N, Muhammad S, Awan IU, Muhammad M, Baloch MS, *et al*. Impact of plant densities and NPK fertilization on growth and optimum economic return of sunflower. Sarhad Journal of Agriculture. 2014;30(2):157-164.
22. Khan H, Safdar A, Ijaz A, Khan I, Hussain S, Khan BA, *et al*. Agronomic and qualitative evaluation of different local sunflower hybrids. Pakistan Journal of Agricultural Research. 2018;31(1):69-78.
23. Khanj MA, Akmal M. Plant arrangement effect on the sunflower yield and yield traits in spring season crop. Sarhad Journal of Agriculture. 2016;32(3):151-155.
24. Lodh SS. Performance of sunflower genotypes under different geometries. Doctoral dissertation, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, 1988.
25. Miralles OB, De Juan Valero JA, De Santa Olalla FM. Growth, development and yield of five sunflower hybrids. European Journal of Agronomy. 1997;6(1-2):47-59.
26. Mollashahi M, Ganjali H, Fanaei H. Effect of different levels of nitrogen and potassium on yield, yield components and oil content of sunflower. International

Journal of Farming and Allied Sciences. 2013;2:1237-1240.
27. Mondal T, Datta JK, Mondal NK. Chemical fertilizer in conjunction with biofertilizer and vermicompost induced changes in morpho-physiological and bio-chemical traits of mustard crop. Journal of Saudi Society for Agricultural Sciences. 2017;16(2):135-144.
28. Nasim W, Ahmad A, Hammad HM, Chaudhary HJ, Munis MFH. Effect of nitrogen on growth and yield of sunflower under semi-arid conditions of Pakistan. Pakistan Journal of Botany. 2012;44(2):639-648.
29. Nasim W, Ahmad A, Wajid A, Akhtar J, Muhammad D. Nitrogen effects on growth and development of sunflower hybrids under agro-climatic conditions of Multan. Pakistan Journal of Botany. 2011;43(4):2083-2092.
30. Nawaz N, Sarwar G, Yousaf M, Naseeb T, Ahmed A, Shah MJ. Yield and yield components of sunflower as affected by various NPK levels. Asian Journal of Plant Science. 2003;2:561-562.
31. Panse VG, Sukhatme PV. 'Statistical methods for agriculture workers' I.C.A.R., New Delhi, 1978.
32. Pavani S, Rekha KB, Babu SS, Padmaja G. Effect of different levels of nitrogen and sulphur on growth and yield of sunflower (*Helianthus annuus* L.). Journal of Research. ANGRAU. 2012;40(3):90-93.
33. Reddy BN, Sudhakarababu SN, Bhanurekha K. Productivity and nutrient uptake of sunflower (*Helianthus annuus* L.) as influenced by site specific integrated nutrient management on Alfisol. Journal of Oilseeds Research. 2007;24(2):331-333.
34. Reddy SS, Yadahalli YH, Kumar VKK, Kumara O, Naik AHK. Effect of fertilizer, gypsum and boron application on yield and economics of sunflower hybrids. Crop Research. 2002;23(3):450-453.
35. Sarkar RK, Mallick RB. Effect of nitrogen, sulphur and foliar spray of nitrate salts on performance of spring sunflower (*Helianthus annuus* L.). Indian Journal of Agricultural Sciences. 2009;79(12):986-990.
36. Sarwar MA, Khalil-ur-Rehman MN, Javeed HMR, Ahmad W, Shehzad MA, *et al*. Comparative performance of various sunflower hybrids for yield and its related attributes. Cercetari Agronomice in Moldova. 2013;46(4):57-64.
37. Scheiner JD, Gutiérrez-Boem FH, Lavado RS. Sunflower nitrogen requirement and 15N fertilizer recovery in Western Pampas, Argentina. European Journal of Agronomy. 2002;17(1):73-79.
38. Sharma RS. Influence of irrigation schedule and fertility levels on yield of sunflower. Indian Journal of Agronomy. 1994;39(3):496-497.
39. Singh ID, Stoskoff NC. Harvest index in cereals. Agronomy Journal. 1971;63(2):224-226.
40. Subbiah KK, Asija CL. A rapid procedure for the estimation of available nitrogen in soil. Current Sciences. 1956;25:259-260.
41. Syed TH, Ganai MR, Ali T, Mir AH. Effect of nitrogen and sulphur fertilization on yield and nutrient uptake by sunflower. Journal of Indian Society of Soil Sciences. 2006;54(3):375-376.
42. Thavaprakash N, Malligawad LH. Effect of nitrogen and phosphorus levels and ratios on yield and economics of sunflower. Research on Crops. 2002;3(1):40-43.
43. Vivekanandan AS, Gunasena HPM, Sivanayagam T. Statistical evaluation of the accuracy of three techniques used in the estimation of leaf area of crop plants. Indian Journal of Agricultural Sciences. 1972;42:847-860.
44. Waqas M, Ghazanfar U, Abdul AK, Ejaz AK, Kashif W, Taseer AK. Effect of fertilizers (NPK) on growth indices, yield and quality of hybrid sunflower. International Journal of Biology and Biotechnology. 2017;14(1):101-107.
45. Yeoh WK, Ali A, Forney CF. Effects of ozone on major antioxidants and microbial populations of fresh-cut papaya. Postharvest Biology and Technology. 2014 Mar;89:56-8.
46. Thavaprakash N, Senthilkumar G, Sivakumar SD, Raju M. Photosynthetic attributes and seed yield of sunflower (*Helianthus annuus* L.) as influenced by different levels and ratios of nitrogen and phosphorus fertilizers. Acta Agronomica Hungarica. 2003 Jul 1;51(2):149-55.