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Response of newly developed sunflower hybrids to planting geometry and fertilizer levels

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Abstract
A field experiment was conducted to study the response of newly developed sunflower hybrids to planting geometry and fertilizer levels**.** 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, yield attributes *viz*., dry matter partitioning, total dry matter production, head diameter, seed volume, grain yield, stalk yield and harvest index (HI). Narrow row spacing at 60 cm had significant effect on growth attributes *viz.* dry matter partitioning, total dry matter production. 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: Fertilizer levels, sunflower, hybrids, seed yield, dry matter partitioning

Introduction
Oilseeds play an important role in agricultural economy of India. With the ever increasing demographic pressure the gap between domestic needs and production of agricultural produce in general and edible oil in particular is widening at an alarming rate. Coupled with the dwindling resources and their increasing cost, there is an urgent necessity to improve the productivity by improving production and resource use efficiency of oilseed crops for realizing higher yield potential.
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 0.27 m ha with a production of 0.25 m t and a productivity of 923 kg ha^{-1}. In India, 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 (923 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. Planting geometry determines the distribution pattern of plants in a field.

It affects evaporation, water use efficiency of the crop and weed intensity/competition. Proper spacing of plants in a particular area makes plant canopy more effective in intercepting the radiant energy and shading effect on weeds (Saleem *et al.*, 2008) [20]. Inadequate or imbalance use of fertilizer has been one of the critical constraints in sunflower production. Application of fertilizers having nutrients like nitrogen, phosphorous and potash can increase sunflower growth and yield substantially (Reddy *et al.*, 2007) [19]. Application of nitrogenous, phosphatic and potashic fertilizer at sub optimal level adversely affects the growth and yield. Hence, balanced fertilizer application is important for high crop yield and consequently more oil yield. 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.

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) [5]. The soil was medium in organic carbon status (0.62%), low in available nitrogen (200.48 kg ha^{-1}) (Subbiah and Asija, 1956) [23], medium in phosphorus (21.42 kg ha^{-1}) (Jackson, 1973) [10] and potassium (232.56 kg ha^{-1}) (Jackson, 1973) [10]. Fertilizers such as urea, DAP and MOP were calculated and applied as per the treatments.

Results and Discussion

Dry matter accumulation in leaf (g $plant^{-1}$)

The data pertaining to dry matter accumulation in leaf at various growth stages was significantly influenced by fertilizer levels and hybrids (Table 1). The dry matter accumulation in leaf increased with the advancement of the crop age up to 60 DAS and subsequently declined due to leaf senescence towards maturity.

Sunflower hybrids did not show significant difference with respect to dry matter accumulation in leaf at 30 DAS and 60 DAS. However, at maturity, RSFH-12-700 (26.86 g) recorded maximum dry matter in leaf and was on par with RSFH-12-705 (24.72 g) and lowest dry matter in leaf was observed in RSFH 1887 (20.72 g). This was due to greater leaf area, LAI and number of leaves in hybrid RSFH-12-700.

At all the growth stages spacing had no significant effect on leaf dry matter (g $plant^{-1}$). Dry matter accumulation in leaf was significantly influenced by rates of fertilizer application at all the crop growth stages. Application of 150 percent RDF (4.19, 32.61 and 26.26 g) recorded significantly greater leaf dry matter over 100 percent RDF (3.62, 26.94 and 20.93 g) but was on par with application of 125 percent RDF (4.03, 31.64 and 25.10 g) at 30, 60 DAS and at maturity, respectively. Greater dry matter accumulation in leaf was observed at higher levels of fertilizers over lower rates. It was attributed to the improved growth parameters such as number of leaves, LAI and photosynthates accumulated in sunflower. These findings are in conformity with those of Sarkar and Mallick (2009) [21].

At all the crop growth stages, the interaction effect of row spacing, fertilizer levels and hybrids on dry matter accumulation in leaf was found to be not significant.

Table 1: Dry matter accumulation in leaf (g $plant^{-1}$) of sunflower hybrids as influenced by spacing and fertilizer levels at different growth stages

Treatment	H_1:RSFH-12-700		H_2:RSFH-12-705		H_3:RSFH 1887		
	S_1	S_2	S_1	S_2	S_1	S_2	Mean
	30 DAS						
F_1:100% RDF	3.78	3.78	3.53	3.61	3.40	3.62	3.62
F_2:125% RDF	4.30	4.31	4.03	4.07	3.75	3.75	4.03
F_3:150% RDF	4.64	4.71	4.07	4.11	3.75	3.86	4.19
Mean	4.24	4.27	3.87	3.93	3.63	3.74	3.95
Mean of H	4.25		3.90		3.69		
Mean of S	3.91 (S_1)		3.98 (S_2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	0.12	0.06	0.07	0.11	0.13	0.11	0.18
C.D. @ 5%	NS	NS	0.22	NS	NS	NS	NS
	60 DAS						
F_1:100% RDF	31.00	30.76	25.15	26.21	23.45	25.32	26.94
F_2:125% RDF	34.10	35.27	33.15	33.21	25.98	28.15	31.64
F_3:150% RDF	34.90	34.90	33.83	33.90	26.83	31.26	32.61
Mean	33.33	33.64	30.71	31.11	25.42	28.24	30.40
Mean of H	33.45		30.91		26.83		
Mean of S	29.79 (S_1)		31.00 (S_2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	1.28	0.57	0.50	0.98	0.87	0.71	1.24
C.D. @ 5%	NS	NS	1.47	NS	2.05	NS	NS
	At maturity						
F_1:100% RDF	23.13	24.57	19.73	19.87	18.27	20.03	20.93
F_2:125% RDF	27.53	28.37	26.90	26.93	20.20	20.70	25.10

F3:150% RDF	28.40	29.17	27.40	27.47	20.40	24.73	26.26
Mean	26.35	27.37	24.68	24.75	19.62	21.82	24.10
Mean of H	26.86		24.72		20.72		
Mean of S	23.55 (S1)		24.65 (S2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	0.71	0.40	0.55	0.69	0.95	0.77	1.34
C.D. @ 5%	2.79	NS	1.60	NS	NS	NS	NS

S1: 60 cm × 30 cm; S2: 75 cm × 30 cm

Dry matter accumulation in stem (g plant^{-1})

The data pertaining to dry matter accumulation in stem at various growth stages was significantly influenced by hybrids and fertilizer levels (Table 2). Dry matter accumulation in stem was increased with the progress of crop age.

At all the crop growth stages, the significant differences among the hybrids were observed in dry matter accumulation in stem. The greater stem dry matter was recorded in RSFH-12-700 (1.59, 66.57 and 72.59 g) over rest of the hybrids at 30, 60 DAS and at maturity, respectively.

At all the crop growth stages, row spacing had no significant effect on stem dry matter accumulation. However, dry matter accumulation in stem was significantly influenced by different levels of fertilizers at all the crop growth stages. At 30, 60 DAS and at maturity, greater stem dry matter accumulation was observed with the application of 150 percent RDF (1.55, 64.11 and 73.22 g, respectively) over 100 percent RDF (1.17, 46.53 and 50.00 g, respectively) but was comparable with 125 percent RDF (1.48, 60.80 and 67.91 g, respectively). Due to better cell multiplication and elongation under sufficient nutrient availability, higher dry matter accumulation in stem was observed with 150 percent RDF. These findings are in conformity with those of Sarkar and Mallick (2009) [21] and Pavani *et al*. (2012) [17]. Combination of hybrids, row spacing and fertilizer rates had no significant effect on dry matter accumulation in stem throughout the crop season.

Table 2: Dry matter accumulation in stem (g plant^{-1}) of sunflower hybrids as influenced by spacing and fertilizer levels at different growth stages

Treatment	H1:RSFH-12-700		H2:RSFH-12-705		H3:RSFH 1887		
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	Mean
	30 DAS						
F1:100% RDF	1.41	1.42	0.95	1.01	0.93	1.27	1.17
F2:125% RDF	1.64	1.64	1.46	1.46	1.28	1.38	1.48
F3:150% RDF	1.66	1.75	1.52	1.55	1.36	1.46	1.55
Mean	1.57	1.60	1.31	1.34	1.19	1.37	1.40
Mean of H	1.59		1.33		1.28		
Mean of S	1.36 S1)		1.44 (S2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	0.04	0.03	0.03	0.05	0.06	0.05	0.08
C.D. @ 5%	0.16	NS	0.10	NS	NS	NS	NS
	60 DAS						
F1:100% RDF	55.13	56.60	38.83	39.83	38.17	50.63	46.53
F2:125% RDF	62.57	73.20	59.00	61.30	54.20	54.50	60.80
F3:150% RDF	71.20	80.73	61.74	61.77	52.33	56.90	64.11
Mean	62.97	70.18	53.19	54.3	48.23	54.01	57.15
Mean of H	66.57		53.74		51.12		
Mean of S	54.80 (S1)		59.50 (S2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	2.43	2.34	2.04	4.05	3.53	2.88	5.00
C.D. @ 5%	9.50	NS	5.96	NS	NS	NS	NS
	At maturity						
F1:100% RDF	56.83	57.83	44.83	45.27	44.60	50.67	50.00
F2:125% RDF	78.03	78.17	70.87	72.03	51.70	56.67	67.91
F3:150% RDF	81.63	83.07	75.60	76.17	54.87	68.00	73.22
Mean	72.16	73.02	63.76	64.49	50.39	58.45	63.71
Mean of H	72.59		64.13		54.42		
Mean of S	62.11 (S1)		65.32 (S2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	2.06	1.98	2.24	3.44	3.89	3.17	5.50
C.D. @ 5%	8.06	NS	6.55	NS	NS	NS	NS

S1: 60 cm × 30 cm; S2: 75 cm × 30 cm

Dry matter accumulation in capitulum (g plant^{-1})

Dry matter accumulated in sunflower capitulum at various growth stages was significantly influenced by hybrids and fertilizer levels (Table 3). It is evident from the data that there was considerable increase in dry matter accumulation in capitulum from 60 DAS to maturity in all the treatment combinations.

Among sunflower hybrids, RSFH-12-700 (10.23 and 47.15 g, respectively) accumulated significantly higher dry matter in capitulum at 60 DAS and at harvest as compared to RSFH-12-705 (8.66 and 43.83 g, respectively) and RSFH 1887 (7.78 and 41.24 g, respectively). Dry matter accumulation in head was maximum in RSFH-12-700 due to the higher head diameter and 1000 seed weight.

From the data, it could be observed that the dry matter accumulation in capitulum both at 60 DAS and at harvest did not differ significantly by row spacing.

The dry matter accumulation in capitulum was significantly influenced by rates of fertilizer. Application of 150 percent RDF (10.00 and 47.00 g, respectively) recorded significantly greater dry matter in capitulum over 100 percent RDF (7.62 and 40.13 g, respectively) and 125 percent RDF at 60 DAS (9.13 g) and at maturity (45.10 g) but was found to be on par with the application of 125 percent RDF. The higher percentage of dry matter accumulation in sunflower head might be due to increased photosynthetic capacity during head development and increased translocation of photosynthates from source to sink under adequate availability of nutrients. It was also evident from the greater head diameter and seed weight under 150 percent RDF than others.

All the interaction effects between hybrids, spacing and fertilizer levels on dry matter accumulation in capitulum was found to be non-significant both at 60 DAS and at maturity.

Table 3: Dry matter accumulation in capitulum (g plant^{-1}) of sunflower hybrids as influenced by spacing and fertilizer levels at different growth stages

Treatment	H_1:RSFH-12-700		H_2:RSFH-12-705		H_3: RSFH 1887		
	S_1	S_2	S_1	S_2	S_1	S_2	Mean
	60 DAS						
F_1:100% RDF	8.93	8.93	6.76	7.10	6.53	7.47	7.62
F_2:125% RDF	9.97	11.03	9.20	9.20	7.27	8.10	9.13
F_3:150% RDF	10.83	12.03	9.83	9.87	7.97	9.33	10.00
Mean	9.91	10.67	8.59	8.72	7.26	8.30	8.91
Mean of H	10.23		8.66		7.78		
Mean of S	8.59 (S_1)		9.23 (S_2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	0.19	0.19	0.18	0.33	0.33	0.27	0.46
C.D. @ 5%	0.75	NS	0.55	NS	NS	NS	NS
	At maturity						
F_1:100% RDF	43.43	43.69	34.83	41.16	38.06	39.60	40.13
F_2:125% RDF	46.16	50.36	45.36	46.16	42.63	39.93	45.10
F_3:150% RDF	47.63	51.63	47.26	48.23	42.03	45.20	47.00
Mean	45.74	48.56	42.48	45.18	40.91	41.57	44.08
Mean of H	47.15		43.83		41.24		
Mean of S	43.04 (S_1)		45.10 (S_2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	0.93	0.68	0.78	1.17	1.35	1.10	1.91
C.D. @ 5%	3.65	NS	2.27	NS	NS	NS	NS

S_1: 60 cm × 30 cm; S_2: 75 cm × 30 cm

Total dry matter production (TDMP) (g plant^{-1})

The data on TDMP (g plant^{-1}) at various growth stages revealed that TDMP was significantly influenced by fertilizer levels and hybrids (Table 4 and Fig. 1). The TDMP per plant increased continuously from emergence to maturity. The greater TDMP per plant was recorded at maturity. The rate of increase of dry matter was faster between 30 to 60 DAS and thereafter the increase was slow up to maturity.

At all the crop growth stages, the significant TDMP differences were observed among the hybrids. The maximum TDMP at 30, 60 DAS and at maturity was found in RSFH-12-700 (5.7, 113.7 and 145.9 g, respectively) which was significantly superior over RSFH-12-705 (5.2, 100.3 and 133.8 g, respectively) and RSFH 1887 (4.9, 90.4 and 115.8 g, respectively). Inherently, hybrid RSFH-12-700 produced more vegetative growth in terms of larger leaves, resulting in larger leaf area per plant and ultimately more photo-assimilates resulting in higher dry matter per plant. Differences in TDM of different hybrids was due to different growth habits, crop growth duration, moisture availability *etc*., Kaleem *et al*. (2011) [11] opined that differences among hybrids could be due to genetic potential of the sunflower hybrids. Ibrahim (2012) [9] stated that the hybrid superiority might be due to its ability to make better use of available resources compared with other hybrids to give higher dry matter production.

The total dry matter per plant was not significantly influenced by row spacing at all the crop growth stages. The TDMP was significantly influenced by rate of fertilizer application. Application of 150 percent RDF (5.7, 113.4 and 146.2 g) has recorded significantly greater TDMP over 100 percent RDF (4.7, 82.9 and 110.2 g) and found to be on par with the application of 125 percent RDF (5.4, 108.2 and 139.2 g) at 30, 60 DAS and at maturity, respectively. The rise in TDMP with increased rates of fertilizer was attributed to better crop growth rate, which resulted in maximum photosynthates and LAI. Yadav *et al*. (2009) [28] further opined that improved growth attributes under graded NPK might have helped in better nutrient uptake by the sunflower crop which in turn resulted in assimilation of photosynthates towards sink as well as higher dry matter accumulation. The study also corroborates with the work done by Dordas and Sioulas (2009) [6] on safflower, Murthy *et al*. (2011) [14] and Nasim *et al*. (2011) [16] on sunflower.

The interaction effect of hybrids, row spacing and rate of fertilizer application had no significant effect on TDMP per plant at all the growth stages of crop.

Table 4: Effect of spacing and fertilizer levels on total dry matter accumulation (g plant^{-1}) of sunflower hybrids at different growth stages

Treatment	H_1:RSFH-12-700		H_2:RSFH-12-705		H_3:RSFH 1887		
	S_1	S_2	S_1	S_2	S_1	S_2	Mean
	30 DAS						
F_1:100% RDF	5.1	5.2	4.4	4.5	4.4	4.7	4.7
F_2:125% RDF	5.9	5.9	5.4	5.6	4.8	5.1	5.4
F_3:150% RDF	6.2	6.2	5.6	5.7	5.0	5.3	5.7
Mean	5.7	5.7	5.1	5.3	4.7	5.0	5.3
Mean of H	5.7		5.2		4.9		
Mean of S	5.2 (S_1)		5.3 (S_2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	0.1	0.1	0.1	0.1	0.2	0.2	0.3
C.D. @ 5%	0.2	NS	0.3	NS	NS	NS	NS
	60 DAS						
F_1:100% RDF	96.9	97.6	72.4	75.1	69.9	85.3	82.9
F_2:125% RDF	117.0	120.6	109.7	111.9	93.7	96.4	108.2
F_3:150% RDF	123.1	127.3	116.4	116.4	94.0	102.9	113.4
Mean	112.3	115.2	99.5	101.1	85.8	94.8	101.5
Mean of H	113.7		100.3		90.4		
Mean of S	99.3 (S_1)		103.7 (S_2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	1.5	1.7	2.2	3.0	3.8	3.1	5.4
C.D. @ 5%	6.0	NS	6.5	NS	NS	NS	NS
	At maturity						
F_1:100% RDF	119.7	121.8	103.7	105.5	102.1	108.4	110.2
F_2:125% RDF	155.3	157.1	143.2	146.1	114.9	118.4	139.2
F_3:150% RDF	158.0	163.9	151.8	152.5	116.8	134.2	146.2
Mean	144.3	147.6	132.9	134.7	111.3	120.3	131.8
Mean of H	145.9		133.8		115.8		
Mean of S	129.5 (S_1)		134.2 (S_2)				
	H	S	F	H × S	H × F	S × F	H×S×F
S.Em. ±	2.2	1.8	3.1	3.1	5.4	4.4	7.6
C.D. @ 5%	8.5	NS	9.1	NS	NS	NS	NS

S_1: 60 cm × 30 cm; S_2: 75 cm × 30 cm

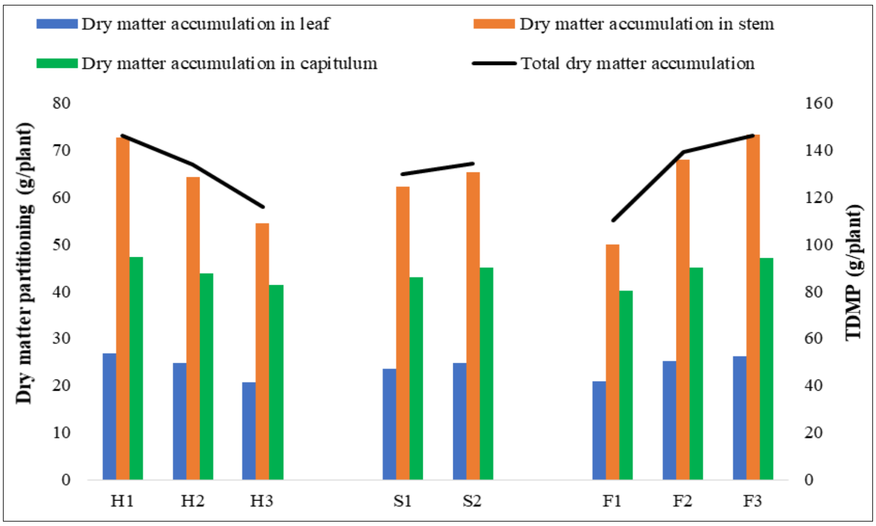

Fig 1: The data on TDMP (g plant^{-1}) at various growth stages revealed that TDMP was significantly influenced by fertilizer levels and hybrids

Yield and yield parameters

The data on head diameter (cm), 100 seed weight (g), seed volume (g/100 ml), seed filling percentage (%), grain yield (kg ha^{-1}), stalk yield (kg ha^{-1}) and harvest index of sunflower hybrids as influenced by row spacing and fertilizer rate are presented as Table 5 and 6.

Head diameter (cm)

The head diameter was significantly influenced by fertilizer levels of sunflower hybrids at maturity (Table 5). Significantly greater head diameter was recorded in hybrid RSFH-12-705 (19.88 cm) which was on par with RSFH-12-700 (18.64 cm). Lowest head diameter was observed in RSFH 1887 (16.79 cm). This could be mainly due to genetic make-up of the crop. The results are in line with earlier findings of Ali *et al*. (2013) [1].

It was observed from the data that there was no significant differences observed in terms of head diameter due to row spacing. However, the varied fertilizer rates significantly influenced head diameter. Increased head diameter was favoured by application of graded fertilizer rate. Significantly larger head diameter was noticed in 150 percent RDF (19.61 cm) and was superior over 125 percent RDF (18.43 cm) and was lowest by application of 100 percent RDF (17.24 cm). Waqas *et al*. (2017) [27] opined that improvement in head diameter was attributed to more vegetative growth due to increased plant's metabolic activities. Babu *et al*. (2013) [4] confirmed that higher NP fertilization contributed to better carbohydrates assimilation thereby increased head size. Ali *et al*. (2004) [1], Malik *et al*. (2004) [13] and Nasim *et al*. (2011) [16] also reported that sunflower head diameter was enhanced by increased level of N, P and K. Head diameter was not significantly influenced by combination of spacing and fertilizer levels.

100 seed weight (g)

The data on hundred seed weight was influenced by hybrids (Table 5). Among the sunflower hybrids, RSFH-12-700 (5.84 g) recorded significantly higher seed weight and was on par with hybrid RSFH-12-705 (5.66 g) and lowest in RSFH-1887 (5.07 g). These findings are in conformity with the findings.

Further, there were no significant differences influenced by different row spacings and fertilizer rate. Individual seed weight being a genetic character, have not been significantly influenced by different treatment combinations expect hybrids. All the interactions of hybrid, row spacing and fertilizer rate was found to be significant except hybrids × row spacing with respect to 100 seed weight.

Seed volume (g/100 ml)

Data on sunflower seed volume (g/100 ml) differed significantly by different hybrids, row spacing and fertilizer levels (Table 5). The significant differences among the hybrids were observed in respect with seed volume. The hybrid, RSFH-12-700 (45.29 g/100 ml) recorded maximum seed volume and was significantly superior to RSFH-12-705 (41.73 g/100 ml) and RSFH 1887 (39.24 g/100 ml). Sunflower row spacing had significant effect on seed volume significantly, greater in 60 cm (41.70 g/100 ml) over 75 cm (41.15 g/100 ml) row spacing.

Application of fertilizers at the rate of 150 percent RDF (42.51 g/100 ml) recorded significantly greater seed volume over 125 percent RDF (41.05 g/100 ml). However, application of 125 and 100 percent RDF (40.72 g/100 ml) was found on par with each other. The higher seed volume might be due to higher photosynthetic rate that had resulted in more translocation of photosynthates from source to sink. Interaction *viz*., H × S, S × F and H×S×F significantly influenced the seed volume except H × F.

Seed filling percentage (%)

Data on sunflower seed filling percentage (%) differed significantly by hybrids and fertilizer levels (Table 5). The significant differences among the hybrids were observed in respect with seed filling percentage. The hybrid, RSFH-12-700 (78.15%) recorded maximum seed filling percentage and was significantly superior to RSFH-12-705 (74.83%) and RSFH 1887 (72.47%). This was due to higher leaf area and dry matter which reflected in production of more number of filled seeds thereby higher seed filling percentage. Similar findings were reported by Lodh (1988). Sunflower row spacing did not show any significant differences with respect to seed filling percentage.

Application of fertilizers at the rate of 150 percent RDF (77.43%) recorded significantly greater seed filling percentage over 100 percent RDF (71.70%) and on par with 125 percent RDF (76.31%). However, application of 150 and 125 percent RDF was found on par with each other. Seghatoleslami *et al*. (2012) [22] reported that filled seed number per head increased with the increase in fertilizer level due to increased head diameter mainly through increasing plant photosynthesis potential, leaf area index and duration and providing assimilates which it allowed the formation of more filled seeds per head.

Interaction effect of row spacing, fertilizer levels and hybrids on seed filling percentage was found to be not significant.

Table 5: Yield attributing characters of sunflower hybrids as influenced by row spacing and fertilizer application

Treatment	Head diameter (cm)		100 seed weight (g)		Seed volume (g/100 ml)		Seed filling percentage	
Hybrids (H)								
H_1: RSFH-12-700	18.64		5.84		45.29		78.15	
H_2: RSFH-12-705	19.88		5.66		41.73		74.83	
H_3: RSFH-1887	16.79		5.07		39.24		72.47	
S. Em ±	0.33		0.07		0.21		1.08	
C.D. (P=0.05)	1.27		0.28		0.84		4.20	
Spacing (S)								
S_1: 60 cm × 30 cm	18.45		5.03		41.70		75.46	
S_2: 75 cm × 30 cm	18.41		5.11		41.15		75.84	
S.Em. ±	0.19		0.05		0.10		1.00	
C.D. (P=0.05)	NS		NS		0.36		NS	
Fertilizer levels (F)								
F_1: 100% RDF	17.24		5.49		40.72		71.70	
F_2: 125% RDF	18.43		5.53		41.05		76.31	
F_3: 150% RDF	19.61		5.55		42.51		77.43	
S.Em. ±	0.21		0.04		0.26		1.03	
C.D. (P=0.05)	0.62		NS		0.76		3.00	
Interaction	S.Em. ±	C.D.@5%	S.Em. ±	C.D.@ 5%	S.Em. ±	C.D.@ 5%	S.Em. ±	C.D.@ 5%
H × S	0.32	NS	0.08	NS	0.18	0.62	1.73	NS
H × F	0.37	NS	0.06	0.19	0.45	NS	1.78	NS
S × F	0.30	NS	0.05	0.15	0.37	1.07	1.45	NS
H × S × F	0.52	NS	0.09	0.26	0.64	1.86	2.52	NS

Seed yield (kg ha^{-1})

Seed yield of sunflower was significantly influenced by hybrids and fertilizer levels (Table 6). The sunflower hybrid RSFH-12-700 (2144 kg ha^{-1}) recorded significantly higher seed yield followed by RSFH 12-705 (1996 kg ha^{-1}) and RSFH 1887 (1855 kg ha^{-1}). The improvement in seed yield of hybrid RSFH-12-700 and RSFH-12-705 were 15.58% and 7.60%, respectively over RSFH 1887. The differences among hybrids for seed yield could be attributed to LAI, head diameter, number of seeds per head and 100 seed weight which is in turn depended on the genetic potential and better adaptability of hybrids under present climatic conditions. These results are in confirmity with the findings of Ekin *et al*. (2005) [7] and Ali *et al*. (2007) [1]. There were no significant differences observed in terms of seed yield due to different row spacings.

Different rates of fertilizer exerted significant influence on seed yield of sunflower hybrids. Among them, application of 150 percent RDF (2104 kg ha^{-1}) recorded significantly higher seed yield over 100 percent RDF (1840 kg ha^{-1}) but was on par with the application of 125 percent RDF (2051 kg ha^{-1}). Remarkable improvement in seed yield were 14.34% and 11.47% with application of 150 percent and 125 percent RDF over 100 percent RDF.

Syed *et al*. (2006) [24] confirmed that the higher seed 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 seed yield by providing maximum florets for higher seed set. 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. These results find support from those of Reddy *et al*. (2002c) [18]. Thavaprakash and Malligawad (2002) [25] stated that 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 seed yield of sunflower. Babu *et al*. (2013) [4] opined that better partitioning of photosynthates from source to sink could have resulted in higher yield attributes that ultimately resulted in higher yield of sunflower. Interaction effect of spacing and fertilizer levels of sunflower hybrids were not significantly influenced on seed yield.

Stalk yield (kg ha^{-1})

The data on stalk yield was significantly affected by the hybrids and fertilizer levels (Table 6). Sunflower hybrid, RSFH-12-700 (3158 kg ha^{-1}) produced maximum stalk yield which is significantly superior over RSFH-12-705 (2894 kg ha^{-1}) and RSFH 1887 (2669 kg ha^{-1}). Higher stalk yield in RSFH-12-700 was attributed to superior growth and yield attributing characters. Sunflower stalk yield was not significantly influenced by row spacing.

Among the rates of fertilizer, application of 150 percent RDF (3361 kg ha^{-1}) 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 highest with the application of 150 percent RDF due to the higher plant height, number of leaves, leaf area, head diameter and capitulum weight. Waqas *et al*. (2017) [27] reported that biomass yield enhancement was due to the increment of NPK by efficient 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 significant results in harvest index were found among the sunflower hybrids, row spacing and fertilizer levels (Table 6). The hybrid, RSFH-12-700 (0.39) recorded higher HI, which was followed by RSFH-12-705 (0.38) and both were significantly superior over RSFH 1887 (0.34). Higher HI in RSFH-12-700 was due to efficient translocation of photosynthates towards seed formation which was expressed in seed yield. Nasim *et al*. (2012) [15] opined that higher HI for a hybrid was due to its genotypic dominance to utilize more photo-assimilates for seed yield formation. Similar results were also reported by Gholinezhad *et al*. (2009) [8].

The remarkable HI difference was observed between row spacings. However, row spacing of 75 cm (0.39) recorded maximum HI as compared to 60 cm (0.36). Gholinezhad *et al*. (2009) [8] reported that increased plant density has resulted in 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. The results were also supported by Khakwani *et al*. (2014) [12].

Remarkable differences in harvest index were noticed among fertilizer rates. The maximum HI was observed in 125 percent RDF (0.41) which was significantly higher than 150 (0.37) and 100 percent RDF (0.34). However, application of 150 and 100 percent RDF was found to be at par with each other. Higher HI with the application of 125 percent RDF was due to higher seed yield and optimal NPK supply. Khakwani *et al*. (2014) [12] reported that highest HI under minimum sunflower plants per unit area was due to maximum balanced fertilizers, greater sunlight and space. Waqas *et al*. (2017) [27] 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) [26]. Interaction effect of row spacing, fertilizer levels and hybrids on harvest index was found to be not significant.

Table 6: Seed yield, stalk yield and harvest index of sunflower hybrids as influenced by row spacing and fertilizer application

Treatment	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index
Hybrids (H)			
H_1: RSFH-12-700	2144	3158	0.39
H_2:RSFH-12-705	1996	2894	0.38
H_3: RSFH-1887	1855	2669	0.34
S. Em ±	23	65	0.01
C.D. (P=0.05)	91	255	0.03
Spacing (S)			
S_1: 60 cm × 30 cm	1972	3021	0.36
S_2:75 cm × 30 cm	2024	2794	0.39
S.Em. ±	17	66	0.01
C.D. (P=0.05)	NS	NS	0.03

Fertilizer levels (F)						
F_1: 100% RDF	1840		2448		0.34	
F_2: 125% RDF	2051		2913		0.41	
F_3:150% RDF	2104		3361		0.37	
S.Em. ±	25		132		0.02	
C.D. (P=0.05)	73		386		0.04	
Interaction	S.Em. ±	C.D. @5%	S.Em. ±	C.D.@ 5%	S.Em. ±	C.D.@ 5%
H × S	29	NS	115	NS	0.01	NS
H × F	43	NS	229	NS	0.03	NS
S × F	35	NS	187	NS	0.02	NS
H × S × F	61	NS	324	NS	0.04	NS

Conclusion
The sunflower hybrid RSFH-12-700 produced higher growth and yield which was followed by RSFH-12-705 and RSFH 1887. Application of 150 percent RDF produced higher growth, yield parameters and yield 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 more productive.

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