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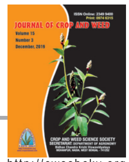

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Variation in seed yield and physiological parameters during seed development in sunflower (*Helianthus annuus* L.) hybrids differing in fatty acid composition

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ABSTRACT

Sunflower (Helianthus annuus L.) is one of the widely cultivated oilseed crops and mainly grown for its seed yield and oil content. The sunflower oil contains saturated and unsaturated fatty acids with different biochemical composition which determines the quality of the oil. Oil content, fatty acids and biochemical composition differ in their accumulation pattern in different hybrids. To study their accumulation pattern, research was conducted with six contrasting sunflower hybrids differing in oleic acid content (high, mid and low) by recording observations at seed developmental stages from anthesis to maturity on several growth parameters, physiological and yield parameters.Though leaf area index decreased at maturity in all hybrids, higher values were observed in mid oleic types. Higher photosynthetic rate, stomatal conductance, transpiration rate was observed at anthesis and decreased during seed development for all hybrid and hybrids differed from each other for seed yield and oil yield with respect to different gas exchange parameters studied. In yield and its attributing characters mid oleic had higher yield as compared to low and high oleic hybrids through lower rates of transpiration and higher photosynthetic rate, increased water use efficiency, balanced stomatal conductance during seed developmental stages, maintenance of higher leaf area index till maturity leading to higher accumulation of biomass. Lower yield in high oleic types among contrasting hybrids were found due to their less attribution of the yield attributing characters.

Keywords: Gas exchange parameters, leaf area duration, leaf area index, oleic sunflower hybrids, total leaf area

Sunflower is one of the four important oilseed crops grown in the world next to peanut, brassicas and soybean (Yadava *et al.,* 2012). It is an annual plant belonging to the family asteraceae which was known to be originated from south USA and Mexico. The cultivation or distribution of sunflower was reported to be spread all over the world with an area of about 26.39 million ha with a production of about 55.05 million tonnes and the productivity of 1.75 metric tonnes per hectare (USDA, 2020). During 2019-20, sunflower was grown in an area of 0.24 million ha with a production and productivity of 0.14 million tonnes and 0.58 metric tonnes per hectare in India (USDA, 2020).

Sunflower seeds are known to contain oil of about 24-42 per cent (Prolea, 2009) and oil is known to have many applications which was determined by the composition of fatty acids. Sunflower oil is rich source of unsaturated fatty acids which contributes about 90 per cent of total fatty acids. Contribution of oleic acid (monounsaturated fatty acid) was reported to be 12-24 per cent and poly unsaturated fatty acid (linoleic acid) is about 60-70 per cent and other fatty acids especially saturated fatty acids contribute for 5-10 per cent of total fatty acids which are mainly palmitic and stearic acid (Claudio *et al.,* 2014).

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Photosynthesis is one of the main metabolic processes responsible for growth and development of plant species. Photosynthetic performance depends on their genetic ability for absorption of light energy (Andrianasolo *et al*., 2016). It has been known for a long time that sunflower has a high photosynthetic potential (like C_4 maize) instead of being a C_3 plant. Such a high photosynthetic rate is due to the presence of stomata on both sides of the leaf, resulting in more CO_2 diffusion, tissue permeability and high RuBisCO activity (Killi *et al*., 2017).

Sunflower crops are characterized by high photosynthetic levels. The gas exchanges are affected by photo respiration which can lead to decrease in CO_2.Vast amounts of water are transpired in comparison with the small amounts of carbon that are fixed by photosynthesis. Increased yields in sunflower have been achieved by extended photosynthesis per unit land area and increased partitioning of crop biomass to the harvested product.

The gas exchange parameters and yield attributing traits were studied in sunflower seeds to understand the effect of physiological parameters on seed yield during different stages of the crop differing in contrasting sunflower hybrids as well as in oleic acid content *i.e.,* high oleic, mid oleic and low oleic types.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* at University of Agricultural Sciences, Bangalore. The research station is geographically situated at 12°58' N latitude and 77°35' N longitude at an altitude of 930 meters above mean sea level. During the experimental period in *kharif* the T_{max} was 28.9°C and T_{min} 19.6 °C with a minimum and maximum rainfall of about 0.4 and 92.4 mm, respectively and total rainfall recorded was 397.6 mm during crop growth period. Average brightness of sunshine hours was about 4.93 hours recorded during the crop growth period. The soil is red sandy clay loam with slightly acidic (pH 6.86) and the electrical conductivity was normal (0.21 m mhos/cm at 25°C). The experiment was conducted following Randomized Complete Block Design in three replications and observations on physiological parameters were recorded on ten plants in each replication and plot yield was considered for seed yield and yield parameters.

To conduct the experiment, different sunflower hybrids were selected based on their oleic acid content in the sunflower seeds and confirmed for their oleic acid content before sowing. Based on their oleic acid content, they were classified as high types with more than 75% oleic acid content, mid oleic with a range of 40 to 75% and low oleic with less than 40%. Accordingly, PAC-3794 (78.03%) and RSFH-1 (82.54%) were considered as high oleic types, DRSH-1(52.27%) and KBSH-44 (46.47%) as mid oleic types and KBSH-71 (25.71%) and RSFH-130 (36.59%) as low oleic types. All the hybrids were grown as per package of practices.

The physiological and morphological parameters were recorded in all the hybrids from anthesis to maturity at 5 days interval [1, 6, 11, 16, 21 and 26 days after anthesis, (DAA)] in 10 plants per replication. The gas exchange parameters such as photosynthetic rate (µmol CO_2 m^{-2} s^{-1}), transpiration rate (mmol H_2O m^{-2} s^{-1}), stomatal conductance (mmol m{ ² s{ ¹) and water use efficiency (mmol of CO_2 per mmol H_2O) were recorded using Infra-Red Gas Analyser (IRGA). After harvest, seed yield per plant (g/pl), 100 seed weight (g), seed density (g/100ml), kernel to husk ratio, total dry matter (g/pl) and harvest index (%) were recorded.The fatty acid composition was determined by using gas chromatography.

The experimental data collected on growth and yield components of plant was subjected to Fisher's method of "Analysis of Variance" (ANOVA) as outlined by Panse and Sukhatme (1967). Wherever, F- test was significant, for comparison among the treatment means, an appropriate value of critical difference (C.D.) was worked out. If F-test was found to be non-significant, then NS (Non-Significant) was indicated. Correlation studies among the various characters were carried out (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Physiological and yield attributing characters

Leaf area index

Among these 6 hybrids, maximum leaf area index at 1 DAA has been observed for hybrids of mid oleic types (DRSH-1 with 8.79 and KBSH-44 with 8.06) followed by high oleic hybrids RSFH-1 (7.69) and low oleic hybrids RSFH-130 (5.75) (Table 1). Lowest leaf area index at 1 DAA has been observed for low oleic type KBSH-71 (4.42) (Table 1). At 11 DAA all the hybrids had the higher leaf area index in respect to that of other seed developmental stage, where mid oleic hybrids DRSH-1 and KBSH-44 had higher leaf area index with 9.40 and 9.22, respectively, as compared to high and low oleic types. At 11 DAA high oleic types RSFH-1 (8.93) had higher leaf area index as compared to that of PAC-3794 (7.23). Lowest leaf area index was found for low oleic types RSFH-130 (6.18) and KBSH-71 (5.37). After 11 days of anthesis leaf area index has been decreased till maturity where mid oleic had higher leaf area index, followed by high oleic and low oleic types. This may be due to senescing and drying up of lower leaves which could not be countable for the calculation of leaf area.

Gas exchange parameters

Instantaneous measurement of gas exchange parameters of plants such as photosynthetic rate, water use efficiency, transpiration rate, stomatal conductance etc. at field levels was measured by gas exchange technique using IRGA which gave us the metabolic functioning of different plants under ambient environmental condition and the data is presented in table 2.

Photosynthetic rate was decreased during seed developmental stages and maximum photosynthetic rate was observed at the time of anthesis in most of the hybrids. KBSH-44 (mid oleic hybrid) had maximum photosynthetic rate on 6 DAA with 31.19 µmol CO_2 m^{-2} s^{-1}. Among the six hybrids, low oleic types KBSH-71 and RSFH-130 had higher photosynthetic rate with 32.62 and 31.37 µmol CO_2 m^{-2} s^{-1} respectively at 1 DAA, followed by the high oleic types, PAC-3794 (30.54 µmol CO_2 m^{-2} s^{-1}) and RSFH-1 (28.39 µmol CO_2 m^{-2} s^{-1}). Least photosynthetic rate at 1 DAA was found for mid oleic types KBSH-44 (27.65 µmol CO_2 m^{-2} s^{-1}) and DRSH-1 (26.26 µmol CO_2 m^{-2} s^{-1}). Photosynthetic rate of the hybrids was found to be decreased during seed

Table 1: Leaf area index at different seed development stages of contrasting sunflower hybrids

Oleic types	Hybrids	Leaf area index						Leaf area duration						
		Days after anthesis						Days after anthesis						
		1	6	11	16	21	26	1	1-6	6-11	11-16	16-21	21-26	Total LAD
High oleic hybrids	PAC-3794	5.26	6.32	7.23	7.19	6.67	6.11	150.04	179.00	212.87	248.90	283.55	315.51	1389.87
	RSFH-1	7.69	8.38	8.93	8.35	7.35	6.31	219.03	259.20	302.49	345.71	384.98	419.14	1930.56
Mid oleic	KBSH-44	8.06	8.64	9.22	8.75	8.24	7.10	229.68	271.44	316.09	361.02	403.51	441.86	2023.60
hybrids	DRSH-1	8.79	9.19	9.40	8.36	7.50	6.12	250.66	295.62	342.09	386.48	426.13	460.19	2161.16
Lowoleic	KBSH-71	4.42	4.86	5.37	4.82	4.43	4.07	126.08	149.29	174.86	200.32	223.43	244.68	1118.64
hybrids	RSFH-130	5.75	6.67	6.18	5.97	5.29	5.00	163.99	195.04	227.16	257.53	285.66	311.39	1440.77
Mean	6.66	7.34	7.72	7.24	6.58	5.79	189.91	251.43	285.76	314.76	340.39	362.44		
Range	4.42-8.79	4.86-9.19	5.37-9.40	4.82-8.75	4.43-8.24	4.07-7.10	126.08-250.66	149.29-295.62	174.86-342.09	200.32-386.48	223.43-426.13	244.68-460.19		
SEm (±)	**0.41**	**0.44**	**0.38**	**0.33**	**0.26**	**0.26**	**11.71**	**12.50**	**10.91**	**9.29**	**7.34**	**7.38**		
LSD (0.05)	**1.29**	**1.38**	**1.21**	**1.03**	**0.81**	**0.82**	**36.89**	**39.39**	**34.38**	**29.29**	**23.13**	**23.24**		

Table 2: Photosynthetic rate and stomatal conductance recorded at different seed development stages of contrasting sunflower hybrids

Oleic types	Hybrids	Photosynthetic rate (ì mol CO_2 m^{-2} s^{-1})							Stomatal conductance (m mol m^{-2} s^{-1})						
		Days after anthesis							Days after anthesis						
		1	6	11	16	21	26	Mean	1	6	11	16	21	26	Mean
High oleic hybrids	PAC-3794	30.54	29.67	29.33	28.71	28.51	20.27	27.84	1.18	1.14	1.12	1.24	0.93	0.77	1.06
	RSFH-1	28.39	28.15	24.30	24.87	22.13	17.98	24.30	1.22	1.10	0.62	0.77	0.77	0.71	0.86
Mid oleic hybrids	KBSH-44	27.65	31.19	26.51	25.28	23.15	14.02	24.63	1.42	1.67	0.63	1.22	0.95	0.48	1.06
	DRSH-1	26.26	23.87	26.67	21.73	22.04	13.44	22.34	1.04	1.02	0.82	0.58	0.65	0.37	0.75
Low oleic hybrids	KBSH-71	32.62	26.82	29.16	27.17	24.53	19.57	26.65	1.53	1.37	1.13	1.02	0.68	0.66	1.07
	RSFH-130	31.37	28.18	27.12	24.64	22.27	13.97	24.59	1.57	1.13	0.66	0.75	0.68	0.42	0.87
Mean		29.47	27.98	27.18	25.40	23.77	16.54	25.06	1.33	1.24	0.83	0.93	0.78	0.57	0.95
Range		26.26-32.62	23.87-31.19	24.30-29.33	21.73-28.71	22.04-28.51	13.44-20.27		1.04-1.57	1.02-1.67	0.62-1.13	0.58-1.24	0.65-0.95	0.37-0.77	
SEm (±)		**0.84**	**0.84**	**0.87**	**0.99**	**0.92**	**1.28**		**0.07**	**0.08**	**0.09**	**0.17**	**0.07**	**0.08**	
LSD (0.05)		**2.53**	**2.54**	**2.54**	**3**	**2.77**	**3.87**		**0.22**	**0.23**	**0.27**	**NS**	**0.21**	**0.23**	

NS: Non-Significant

Table 3: Transpiration rate and water use efficiency recorded at different seed development stages of sunflower hybrids

Oleic types	Hybrids	Transpiration rate (ìmol H_2O m^{-2} s^{-1}) Days after anthesis							Water use efficiency (mmol of CO_2 per mmol H_2O) Days after anthesis						
		1	6	11	16	21	26	Mean	1	6	11	16	21	26	Mean
High oleic hybrids	PAC-3794	5.98	5.69	5.85	5.96	5.11	4.96	5.59	0.51	0.52	0.50	0.48	0.56	0.41	0.50
	RSFH-1	6.44	7.07	4.69	5.60	4.65	5.30	5.63	0.44	0.40	0.52	0.45	0.48	0.34	0.44
Mid oleic	KBSH-44	7.25	7.60	4.96	6.13	4.85	3.73	5.75	0.38	0.41	0.54	0.41	0.48	0.39	0.44
hybrids	DRSH-1	6.59	6.31	5.56	4.80	4.58	3.59	5.24	0.40	0.38	0.48	0.46	0.48	0.38	0.43
Low oleic	KBSH-71	6.95	6.89	6.29	5.67	4.28	4.20	5.71	0.47	0.39	0.46	0.48	0.57	0.47	0.47
hybrids	RSFH-130	7.36	6.84	4.70	5.39	4.49	4.09	5.48	0.43	0.42	0.59	0.46	0.50	0.34	0.46
Mean		6.76	6.73	5.34	5.59	4.66	4.31	5.57	0.44	0.42	0.52	0.46	0.51	0.39	0.46
Range		5.98-7.36	5.69-7.60	4.69-6.29	4.80-6.13	4.28-5.11	4.09-5.30		0.38-0.51	0.38-0.52	0.46-0.59	0.41-0.48	0.48-0.57	0.34-0.47	
SEm (±)	**0.14**	**0.26**	**0.27**	**0.27**	**0.17**	**0.34**			**0.01**	**0.02**	**0.02**	**0.02**	**0.02**	**0.03**	
LSD (0.05)	**0.42**	**0.78**	**0.81**	**0.81**	**0.50**	**1.01**			**0.04**	**0.06**	**0.06**	**NS**	**0.07**	**0.08**	

NS: Non-Significant

Table 4: Seed yield and yield attributing characters of contrasting sunflower hybrids for oleic acid content

Oleic types	Hybrids	Seed yield (g)	TDM (g/plant)	100 seed weight (g)	Seed density (g/100ml)	Kernel to husk ratio	Harvest index	Oil yield (g/plant)
High oleic hybrids	PAC-3794	56.24	154.48	4.54	34.24	1.84	0.27	17.39
	RSFH-1	61.26	146.96	5.91	31.65	2.21	0.29	21.95
Mid oleic hybrids	KBSH-44	78.66	199.15	5.19	46.64	1.81	0.28	27.53
	DRSH-1	70.87	189.10	7.04	41.86	2.24	0.27	24.31
Low oleic hybrids	KBSH-71	66.37	135.63	6.63	39.55	2.47	0.33	23.85
	RSFH-130	77.07	187.93	6.26	40.61	2.63	0.29	23.72
SEm (±)		**2.41**	**4.58**	**0.23**	**0.59**	**0.02**	**0.01**	
LSD (0.05)		**7.61**	**14.42**	**0.72**	**1.87**	**0.26**	**NS**	

NS: Non-Significant

developmental stages. Maximum mean photosynthetic rate at seed developmental stages was observed for high oleic type PAC-3794 (27.84 µmol CO_2 m^{-2} s^{-1}), followed by low oleic type KBSH-71 with 26.65µmol CO_2 m^{-2} s^{-1}. Lowest mean photosynthetic rate at seed developmental stage was observed for hybrid DRSH-1 with 22.34 µmol CO_2 m^{-2} s^{-1}. Among these six hybrids, DRSH-1 showed more variation in photosynthetic rate during seed developmental stage and in KBSH-44 increased in photosynthetic rate was increased upto 6 DAA and decreased thereafter till maturity.

Stomatal conductance is a measure of rate of gas exchange through the stomatal pore. Significant differences were observed among the hybrids for the stomatal conductance and it was found to be maximum at the time of anthesis for most of the hybrids except for the KBSH-44 where it has higher stomatal conductance at 6 days after anthesis with 1.67 m mol m^{-2} s^{-1}. Stomatal conductance at 1 DAA was found to be higher for low oleic hybrids *i.e.,* KBSH-71 (1.53 m mol m^{-2} s^{-1} and RSFH-130 (1.57 m mol m^{-2} s^{-1}, followed by mid oleic KBSH-44 (1.42 m mol m-2 s^{-1}. Among high oleic hybrids RSFH-1 (1.22 m mol m^{-2} s^{-1} had higher stomatal conductance compared to PAC-3794 (1.18 m mol m^{-2} s^{-1}. Least stomatal conductance at 1 DAA was observed for DRSH-1 with 1.04 m mol m^{-2} s^{-1} and thereafter stomatal conductance was found to be decreased from 1 DAA of a hybrid to 26 DAA which is presented in table 3. The maximum mean stomatal conductance was observed for low oleic KBSH-71 (1.07 m mol m^{-2} s^{-1} followed by high oleic PAC-3794 (1.06 m mol m^{-2} s^{-1} and mid oleic hybrid KBSH-44 (1.06 m mol m^{-2} s^{-1}. Lowest mean of stomatal conductance was found in mid oleic hybrid DRSH-1 (0.75 m mol m^{-2} s^{-1}.

By using infrared gas analyzer system, transpiration rate was measured. Transpiration rate was significantly differed among the six hybrids grown. High transpiration rate was observed at the time of anthesis for most hybrids except for KBSH-44 (7.60 mmol H_2O m^{-2} s^{-1}) which was higher at 6 DAA. One day after anthesis, low oleic hybrids KBSH-71 and RSFH-130 showed more transpiration rate with 6.95 and 7.36 mmol H_2O m^{-2} s^{-1}respectively, as compared to other hybrids and lowest transpiration rate was observed for the high oleic hybrids PAC-3794 and RSFH-1 with 5.98 and 6.44 mmol H_2O m^{-2} s^{-1}, respectively. Thereafter transpiration rate was decreased during seed developmental stages. Mean transpiration rate during seed developmental stages was maximum for KBSH-44 (5.75mmol H_2O m^{-2} s^{-1}) and KBSH-71 (5.71mmol H_2O m^{-2} s^{-1}) (Table 3).

Instantaneous water use efficiency (WUE) was measured by gas exchange technique, using infra-red gas analyser in different hybrids during the seed developmental stages and presented in Table 4. WUE differed significantly among the hybrids during seed developmental stages. Higher WUE has been found in high oleic hybrid PAC-3794 with 0.51 mmol of CO_2 per mmol H_2O, followed by low oleic hybrid KBSH-71 with 0.47 mmol of CO_2 per mmol H_2O at 1 DAA. Lowest WUE at 1 DAA has been observed for the mid oleic types DRSH-1 (0.40 mmol of CO_2 per mmol H_2O) and KBSH-44 (0.38 mmol of CO_2 per mmol H_2O). During the seed development mean WUE was increased upto 11 DAA (0.52 mmol of CO_2 per mmol H_2O) and decreased thereafter during seed developmental stages. At 26 DAA the WUE was maximum for low oleic hybrid KBSH-71 with 0.47 mmol of CO_2 per mmol H_2O, followed by high oleic hybrid PAC-3794 with 0.41 mmol of CO_2 per mmol H_2O and lowest was observed for high oleic hybrid RSFH-1 (0.34 mmol of CO_2 per mmol H_2O) and low oleic hybrid RSFH-130 (0.34 mmol of CO_2 per mmol H_2O). Among all the 6 hybrids, high oleic hybrid PAC-3794 was found to be more water use efficient hybrid with higher mean WUE of 0.50 mmol of CO_2 per mmol H_2O during seed developmental stages, followed by low oleic hybrid KBSH-71 (0.47 mmol of CO_2 per mmol H_2O). Lower mean WUE of overall seed development was recorded for mid oleic hybrids, KBSH-44 and DRSH-1 with 0.44 and 0.43 mmol of CO_2 per mmol H_2O respectively.

Seed yield and yield attributing characters

Seed yield was a quantitative trait which was governed by several direct and indirect factors. The direct factors which influenced the seed yield were number of filled seeds per capitulum and test weight and the data is presented in Table 4.

Higher seed yield was observed for mid oleic type *i.e.,* KBSH-44 (78.66g/pl) due to their higher vegetative growth especially, more number of broader leaves, bigger capitulum size and higher specific seed weight, followed by low oleic RSFH-130 (77.07g/pl), mid oleic DRSH-1 (70.87g/pl) and low oleic KBSH-71 hybrid (66.37 g/pl). Lower yields in high oleic (PAC-3794 and RSFH-1 with 63.11 and 64.56g/pl, respectively) hybrids were mainly due to less test weight *i.e.,* 100 seed weight. The differences among hybrids might also be due to the differences in the filled grain number which intern was decided by the percentage of pollination carried out by honeybees (Papatheohari *et al.,* 2015). The results with less yield of high oleic as compared to the mid-oleic types and standard hybrids were found to be in acceptance with the studies of Evci *et al.* (2009), Baldini *et al.* (2000) and Anastasi *et al*. (2010) where high oleic acid hybrid had 10 per cent of less yield as compared to standard.

Significant differences were observed in 100 seed weight amongst hybrids (Table 4). Hundred seed weight was more for mid oleic type, DRSH-1 with 7.04g which was on par with low oleic, KBSH-71 (6.63g), followed by RSFH-130 (6.26g), RSFH-1 (5.91g) and lowest test weight was obtained for high oleic type PAC-3794 with 4.54g. These differences among the oleic types for 100 seed weight was due to the genotypic constitution of the hybrid which was found to be in accordance with the studies of the Karadogan *et al.* (1998) and Ishfaq *et al.* (2009).

Specific seed weight is one of the important yield attributing characters. Significant differences among the hybrids for seed weight on volume basis were observed. Among the contrasting sunflower hybrids differing for oleic acid content, higher specific seed weight was observed for mid oleic types *i.e.* KBSH-44 (46.64g/100ml) and DRSH-1 (41.86g/100ml) as compared to high (PAC-3794 and RSFH-1) and low oleic (KBSH-71 and RSFH-130) hybrids.This could be due to higher mean photosynthetic activity and increase in efficiency of translocation of the photo assimilates to sink (seed) during seed development, which results in high packing of seed material per unit volume of seeds. Followed by mid oleic types higher specific seed weight was observed for low oleic hybrids *i.e.,* RSFH-130 (39.78g/100ml) and KBSH-71 (38.63g/100ml) as they had higher photosynthetic rate and might have less translocation efficiency of assimilates to the seed as compared to mid oleic types. High oleic (PAC-3794 with 36.15g/100ml and RSFH-1 with 34.07g/100ml) types had less specific seed weight but they had higher mean photosynthetic rate which might be resulted in poor pollination and less translocation efficiency of photo-assimilates. Seed weight on volume basis might also depend on genotype and other factors like seed filling efficiency and duration (Papatheohari *et al.,* 2016).

Seed yield in sunflower was found to depend on several yield components among which kernel to husk ratio was one. There was significant difference for kernel to husk ratio among the contrasting sunflower hybrids differing in oleic acid content. Low oleic hybrids RSFH-130 (2.63) and KBSH-71 (2.47) exhibited higher kernel to husk ratio followed by mid oleic DRSH-1 (2.24). Lower kernel to husk ratio was observed for high oleic (RSFH-1 with 2.25 and PAC-3794 with 1.84) and mid oleic KBSH-44 (1.82) as this might be known to be dependent on extent of seed packing in hybrids and also known to be dependent on the genotype (Rodriguez *et al.,* 2002).

Higher TDM was reported in the mid oleic types, followed by low oleic types and least was observed in high oleic types. High TDM in mid oleic type KBSH-44 (199.15g/pl) and DRSH-1 (189.10g/pl) followed by low oleic RSFH-130 (187.93g/pl) was a result of their higher vegetative growth with more plant height, number of leaves and total leaf area. Lower total dry matter observed for high oleic RSFH-1(154.48g/pl) and low oleic KBSH-71 (137.33g/pl) hybrid was due to less plant height and leaf area. Also, the differences among the oleic types were due to the differences in genetic makeup of them. Differences in the cultivars of sunflower for TDM were also reported by Nasim *et al.* (2012) and Rodriguez *et al.* (2002).

The harvest index (HI) represents the physiological competence of plants to change the fraction of photo-assimilates to the grain and it is the ratio of economic yield (seed yield) to that of biological yield (TDM). Higher harvest index was observed for low oleic KBSH-71 (0.33) due to its less vegetative growth. High oleic RSFH-1 (0.29) and low oleic RSFH-130 (0.29) had less harvest index compared to KBSH-71 (low oleic), due to less TDM in RSFH-1 and higher seed yield in RSFH-130. Less harvest index for mid oleic DRSH-1 (0.27) and high oleic PAC-3794 (0.27) compared to other hybrids was due to their high vegetative growth like high plant height, leaf area with lesser seed yield.

Differences among the contrasting hybrids were observed for physiological and yield attributing characters during seed development with higher vegetative growth in mid-oleic (KBSH-44 and DRSH-1) hybrids. Leaf area index was decreased till maturity where mid oleic had higher leaf area index, followed by high oleic and low oleic types. This may be due to senescing and drying up of lower leaves which could not be countable for the calculation of leaf area. Photosynthetic rate differed among the oleic hybrids during seed development with maximum values for PAC-3794 and photosynthetic rate was decreased during seed development. Difference in the yield and its attributing characters were found among the oleic hybrids, with higher seed yield for mid oleic (KBSH-44) and lower seed yield for high oleic (PAC-3794 and RSFH-1) hybrids due to higher vigour and higher contribution in yield attributing characters in mid oleic hybrids, which depends on genotype.

Sunflower hybrids differed from each other for seed yield and oil yield with respect to different gas exchange parameters studied. Interestingly, mid oleic and low oleic type of hybrids *viz.,*KBSH-44 followed by RSFH-130 and DRSH-1 achieved maximum seed yield and oil yield through lower rates of transpiration and higher photosynthetic rate, increased water use efficiency and balanced stomatal conductance during seed developmental stages (from 1 to 26 DAA) and through higher accumulation of biomass.

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