Bangladesh Agron. J. 2016, 19(1): 19-28

PHOTOSYNTHESIS, DRY MATTER PARTITIONING AND YIELD VARIATION IN SESAME GENOTYPES

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Key words: Photosynthetic rate, Light interception, Dry matter partitioning, Seed and oil yield, Sesame

Abstract

An experiment was conducted at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706 from March to June 2014 to evaluate growth and yield performance of sesame genotypes. Five sesame genotypes i.e. DB-6992, BD-6995, BD-7001, BD-7011 and Hathazari-4 were used in the study. The genotypes significantly differed in photosynthetic rate, dry matter partitioning and seed yield. The earliest genotype was Hathazari-4 and the latest was BD-7011. The highest stem dry weight, leaf dry weight, capsule dry weight, leaf area index, light interception, photosynthetic rate were recorded in genotype Hathazari-4. The number of capsules plant^{-1} and the number of seeds capsule^{-1} were also highest in the genotype Hathazari-4, while the lowest was being noticed in the genotype BD-7001. Weight of 1000-seed was the maximum in genotype BD-6992 and the minimum in the genotype BD- 7011. The highest seed yield (3.52 tha^{-1}) was recorded in the genotype Hathazari-4 and the lowest in the genotypes BD-6992 followed by BD-7001. The highest oil content (41.39%) was recorded in the genotype BD-6992 and the lowest (39.72%) in the genotype Hathazari-4 but the highest oil yield (1.53 t ha^{-1}) was recorded in the genotype Hathazari-4. It may be concluded that the sesame genotype Hathazari-4 may be cultivated for higher seed yield and oil production.

Introduction

Sesame (*Sesamum indicum* L.), known as “Til” in Bangladesh, belongs to the family Pedaliaceae. Average sesame yield in Bangladesh is about ha^{-1}. Currently, about 33275 hectares of land are under sesame cultivation and annual production is about 29,965 m tons (BBS, 2012). In Bangladesh it is grown in almost all districts but grows well in greater Khulna, Faridpur, Pabna, Barisal, Rajshahi, Jessore, Comilla, Dhaka, Rangpur, Sylhet, and Mymensingh districts. Sesame is cultivated in both kharif I and kharif II seasons, but two-third of sesame is produced in kharif I season. Sesame needs a constant high temperature ranging from 26 to 30^{0}C for optimum growth. Sesame requires a minimum of 300–400 mm rainfall (Carlsson *et al.,* 2008).

Sesame seeds contain 38-54% oil, 18-20% protein, 567 kcal energy, 26.04 g carbohydrates, 5 g water, 131 mg calcium, 7.78 mg iron etc. in 100 g of seed (Banglapedia, 2012). The oil is utilized for the manufacture of soap, insecticide and paint (Vaughan, 2000). The seed is used in making various food items like bread, cakes, pastry, khaja, biscuits, etc. Sesame produces no seed or a very low seed yield if it is grown under unfavorable environmental conditions (Pham *et al.,* 2010). Another major cause of poor yield of sesame is low yielding cultivars. The yield ability of sesame crop is determined by many yield components, all of which are substantially influenced by environmental conditions and agronomic practices

(Caliscan, 2004). It is important to understand yield potential and the improvement in partitioning of photosynthetic products. Photosynthesis is considered as the most important physiological process that governs the growth and yield of crops. Photosynthesis process of sesame varied over a wide range of genetical and environmental conditions (Ojima *et al.*, 1969). Information relating to photosynthetic rate, dry matter partitioning and yield variation in sesame is very limited. Therefore, the present study was undertaken to identify the best sesame genotypes based on photosynthetic rate, dry matter partitioning and yield.

Materials and Methods

The experiment was conducted at the Field Research Site of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706 from March, 2014 to June, 2014. It is located in Madhupur Tract under Agro Ecological Zone (AEZ) 28. The soil of the experimental site is silty clay in topsoil and silty clay loam in subsoil. The site is situated in the sub-tropical region characterized by heavy rainfall during monsoon at the months from March to June and scanty rainfall in the rest of the months of the year. The five selected sesame genotypes were BD-6992, BD-6995, BD-7001, BD-7011 and Hathazari-4. The land preparation was done well by repeated ploughing and cross-ploughing with a tractor drawn disc plough and then harrowed. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The unit plot size was 1.2m × 1.5m. All the treatment plots were fertilized with 43.4, 23, 40.5, 18, 2 and 0.8 kg of N P K S Zn and B ha^{-1}, respectively as urea, triple super phosphate, muriate of potash, gypsum and borax (BARC, 2012). Total amount of triple super phosphate, muriate of potash and gypsum fertilizers were applied plot wise during final land preparation before sowing. 2/3 (43.4 kg) nitrogen as basal and all the fertilizers were applied by broadcasting and mixed thoroughly with soil. One- third (21.6 kg) N was top dressed at 20 days after emergence (DAE). Sesame seeds at the rate of 3.5 kg ha^{-1} were sown in line by hand on 3 March, 2014. Sesame took 3-4 days to emergence. Pre-sowing irrigation was given to ensure the maximum germination percentage. Subsequent irrigation was also provided to avoid moisture stress. Three times weeding and mulching, two times insecticides spraying were performed to keep the field free from pests. Data on agronomic traits regarding on phenological and morphological characters of sesame including days to first flowering, days to maturity, plant height, number of leaves per plant, leaf area index, dry weight of leaves per plant, dry weight of stem per plant were recorded. Data on yield and yield contributing characters were measured from randomly selected plants. Leaf area index (LAI) and Light interception (LI) were measured by using standard formulae. The formulae used for different parametrs are given below.

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area}}{\text{Ground area occupied by plant}}$$

$$\text{Light transmission ratio (LTR)} = \frac{I}{Io} \times 100$$

Where, I_o = Photosynthetically active radiation on the top of the canopy,
I = Photosynthetically active radiation on the base of the canopy.

Light interception (LI %) = 100 (%) - LTR (%)

$$\text{Dry weight of leaves per plant} = \frac{\text{Leaf dry weight (g)}}{\text{Number of plants}}$$

$$\text{Dry weight of stem per plant} = \frac{\text{Leaf dry weight (g)}}{\text{Number of plants}}$$

$$\text{Oil content (percent)} = \frac{\text{Weight of oil extracted(g)}}{\text{Weight of samples}} \times 100$$

Oil yield was determined as follows:

$$\text{Oil yield (t ha}^{-1}\text{)} = \frac{\text{Grain yield}}{\text{Oil content (\%)}}$$

The collected data were analyzed statistically and the mean differences were adjusted by Least Significance Difference (LSD) test at a significance level of 0.05 (Gomez and Gomez, 1986).

Results and Discussion

Phenology

There was variation among the genotypes in relation to flowering. Table 1 showed that days required for first flowering of sesame genotypes varied from 26 to 32 days and 50% flowering from 43 to 51 days. The genotype Hathazari-4 flowered within 34 days while BD-7001 took 41 days for flowering. Other genotypes such as BD-6992, BD-6995 and BD-7011 also took longer time for flowering. Four sesame genotypes required intermediate time for flowering ranging from 35 to 41 days. Among the genotypes the hathazari-4 flowered and matured earlier than other genotypes.

Table 1. Phenological events of five sesame genotypes

Genotypes	Days to		
	1st flowering	50% flowering	Maturity
BD-6992	32	41	85
BD-6995	30	40	83
BD-7001	31	41	83
BD-7011	30	41	85
Hathazari-4	26	34	76
LSD (0.05)	0.64	0.64	1.14
CV (%)	1.39	1.06	0.90

Morpho-physiological characters

Plant height

The sesame genotypes differed significantly in height at all stages of their growth but not at initial stage. Irrespective of genotypes, the height of sesame plants increased rapidly at the early stages of growth and rate of progression in height was slow at the later stages (Table 2). The genotypes attained their peak height at maturity. Plant height ranged between 124.7 cm and 137.3 cm. Hathazari-4 produced the tallest plants (137.3cm) and BD-6992 the shortest (124.7 cm). All genotypes attained their peak height at 85 Days After Emergence (DAE) . Plant height is an important morphological character of crop that showed positive correlation with seed yield of sesame although it may be reversed in other circumstances (Rubio *et al*., 2004).

Number of leaves per plant

Table 2 shows the number of leaves in sesame genotypes throughout the crop duration. In sesame plant, the highest number of leaves per plant (35.3) was found in the genotype Hathazari-4. Number of leaves per plant increased during early growth stages of sesame and decreased later due to leaf senescence. Leaves play a major role in synthesis and translocation of photo-assimilates to the seeds and affect grain yield. A strong relationship exists between LAI and number of leaves per plant i.e. more number of leaves per plant ensures increased canopy cover and increased photosynthetic activity (Saipan *et al*. 2010).

Table 2. Variation in plant height and leaf number over time in five sesame genotypes

Genotypes	Plant height (cm)				Leaf number		
	20DAE	40DAE	60DAE	85DAE	20 DAE	40 DAE	60 DAE
BD-6992	32.47	101.20	123.00	124.70	8.65	26.70	18.35
BD-6995	32.47	103.50	133.01	134.40	8.35	23.00	18.35
BD-7001	33.88	102.10	129.20	130.60	8.80	27.90	21.35
BD-7011	33.92	112.20	129.70	131.20	9.00	26.00	20.05
Hathazari-4	33.17	114.60	136.30	137.30	10.55	35.30	25.95
LSD (0.05)	NS	6	8	8	1.42	5.32	5.04
CV (%)	7.69	4.66	4.47	4.44	10.13	12.43	14.90

NS = Non-significant

Leaf area indices

Table 3 shows the LAI of sesame genotypes throughout the crop duration. LAI increased progressively from early growth stages of sesame and attained peak at 40 DAE and then decreased gradually. The genotypes differed in LAI at all the sampling dates. Among the genotypes Hathazari-4 had the highest LAI in all sampling dates. Leaf area index is most important for interception of light and photosynthesis. The more LAI caused more photosynthesis and produced more dry matter. The initial increase of LAI in sesame is associated with the higher number of leaves per plant and higher photosynthetic leaf surface area. The decline in LAI after attaining the peak might be due to senescence of leaves from the base of the stem approaching upward. Leaf area index and activity per unit leaf area are components of field photosynthetic performance (De Costa and Shanmugathasan, 2002).

Table 3. Variation in leaf area and leaf area index over time in five sesame genotypes

Genotypes	Leaf area per plant (cm^2)			Leaf area index		
	20 DAE	40 DAE	60 DAE	20DAE	40DAE	60 DAE
BD-6992	227.9	819.1	705.4	0.57	2.05	1.76
BD-6995	239.7	845.1	715.3	0.59	2.12	1.79
BD-7001	200.3	848.8	730.9	0.50	1.87	1.80
BD-7011	205.3	746.9	719.4	0.51	2.12	1.83
Hathazari-4	316.1	1246	889.1	0.79	3.11	2.22
LSD (0.05)	67.50	210.1	56.47	0.17	0.53	NS
CV (%)	18.42	15.23	15.36	18.36	15.26	0.53

NS = Non-significant

Light interception

Interception of light at capsule initiation stage of sesame genotype is presented in Table 4. In Hathazari-4 the maximum amount of light was intercepted at capsule initiation stage. From the Table 4 it is revealed that light penetration through the canopy is genotype dependent. The genotypes BD-7001 transmitted more portion of radiation to ground level in comparison to Hathazari-4 indicating that canopy of BD-7001 is less efficient in light interception. The genotype Hathazari-4 intercepted highest amount of light at capsule initiation stage which was 95.00%. The more the LAI, greater was the light interception. The lowest light interception was 87.21% in the genotype BD-7001. This was attributed to lower LAI. The amount of light intercepted by a canopy is a function of LAI. Maximizing light interception during seed formation is required for maximum yield. Light capture is highly affected by canopy size, and the amount of PAR intercepted by crops along the season is commonly related to crop growth and grain yield (Singer, 2001).

Table 4. Variation in light interception at capsule initiation stage in sesame genotypes

Genotypes	Light interception at capsule initiation stage (%)
BD-6992	93.02
BD-6995	94.63
BD-7001	87.21
BD-7011	92.49
Hathazari-4	95.00
LSD (0.05)	NS
CV (%)	3.94

Photosynthesis

Growth, dry matter production and yield depend almost entirely on photosynthesis of crop plants. Photosynthesis depends on the leaf area development and the extent of light intercepted by the canopy. Variation in leaf photosynthesis was low at the capsule development stage in five sesame genotypes (Table 5). Higher leaf photosynthetic rate was recorded in the genotype Hathazari-4 (28.87$\mu molm^{-2}s^{-1}$) but it was not significant compared to the sesame genotypes. The amount of photosynthate is a function of total leaf area and solar radiation intercepted by the crop canopies. Differences in photosynthetic rate among crop varieties are important for understanding the plant capacity to produce economic yield (Islam *et al.,* 1994).

Intercellular CO_2 concentration

There was no significant difference in intercellular CO_2 concentration (Ci) in sesame leaves due to genotypic variation and it ranged from 222.9 to 239.9 ppm at capsule initiation stage (Table 5). The lowest intercellular CO_2 (222.9 ppm) was observed in the genotype Hathazari-4 and the highest (239.9 ppm) in the genotype BD-7001. Higher intercellular CO_2 concentration might have been due to slower photosynthetic rates of leaves (Hasan, 1993).

Stomatal conductance

Stomatal conductance was positively correlated to the photosynthetic rates of sesame. At capsule initiation stage, the highest stomatal conductance (0.80 cms^{-1}) was recorded from the genotype Hathazari-4. This apparently was due to faster rate of intercellular CO_2 utilization compared to the rate of CO_2 uptake through stomata in this genotype.

Table 5. Variation in photosynthetic rate, stomatal conductance and intercellular CO_2 concentration at capsule initiation stage in five sesame genotypes

Genotypes	Photosynthetic rate ($\mu molm^{-2} s^{-1}$)	Stomatal conductance (cms^{-1})	Intercellular CO_2 concentration (ppm)

BD-6992	27.98	0.59	238.3
DB-6995	27.49	0.56	233.1
DB-7001	27.40	0.54	239.9
BD-7011	27.09	0.62	234.1
Hathazari-4	28.87	0.80	222.9
LSD (0.05)	NS	NS	NS
CV (%)	6.28	0.25	5.36

NS = Non-significant

SPAD value

The SPAD value is closely correlated with leaf chlorophyll content. Chlorophyll is a basic component for photosynthesis. Higher the leaf chlorophyll content, faster is the photosynthesis. At early stage of plant leaf chlorophyll concentration was lower. With the advancement of crop growth, chlorophyll content of leaf increased at a parabolic shape reaching peak at around 50DAE and then declined. The highest SPAD value (48.15) was obtained at 40 DAE in the genotype BD-6995 and lowest (42.95) in the genotype BD-7011 (Table 6). The variation observed in SPAD value among the genotypes might be due to difference in genetic constituents and environmental effect. Reduction in SPAD value in later stage due to maturity of leaves and leaf senescence has already occurred in reproductive stage.

Table 6. Variation in SPAD value over time in five selected sesame genotypes

Genotypes	SPAD				
	20DAE	30DAE	40DAE	50DAE	60DAE
BD-6992	36.20	42.15	45.28	41.08	35.70
BD-6995	34.45	43.50	48.15	43.08	34.95
BD-7001	37.25	41.88	46.65	43.03	35.45
BD-7011	33.72	41.50	42.95	40.20	34.22
Hathazari-4	41.95	45.28	47.6	43.70	39.00
LSD (0.05)	3.45	3.22	4.80	4.48	3.50
CV (%)	6.10	4.87	6.75	6.89	6.28

Dry matter partitioning

Leaf dry weight

Dry matter partitioning into leaf increased linearly up to a certain period and then gradually decreased regardless of genotypes (Figure 1). Regardless of genotypes, the accumulation of dry matter in leaf increased over time reaching a peak at around 60 DAE in sesame genotypes. At the attainment of peaks, leaf dry weights were 4.73g plant^{-1} (BD-6992), 4.12 g plant^{-1} (BD-6995), 4.31gplant^{-1} (BD-7001), 4.78g plant^{-1} (7011) and 6.15g plant^{-1} (Hathazari-4) in sesame genotypes, respectively. The maximum leaf dry weight was recorded in the genotype Hathazari-4 (6.15g plant^{-1}). The genotypes showed significant differences in dry matter accumulation in leaf in all sampling periods. The leaf dry weight decreased after the attainment of the peak in all the genotypes. This decrease in leaf dry weight might be due to translocation of assimilates from leaves to reproductive organs. Leaf dry weight increased with increase in leaf size and chlorophyll content, delayed maturity time and increased vegetative growth period as stated by (Haruna *et al*., 2011).

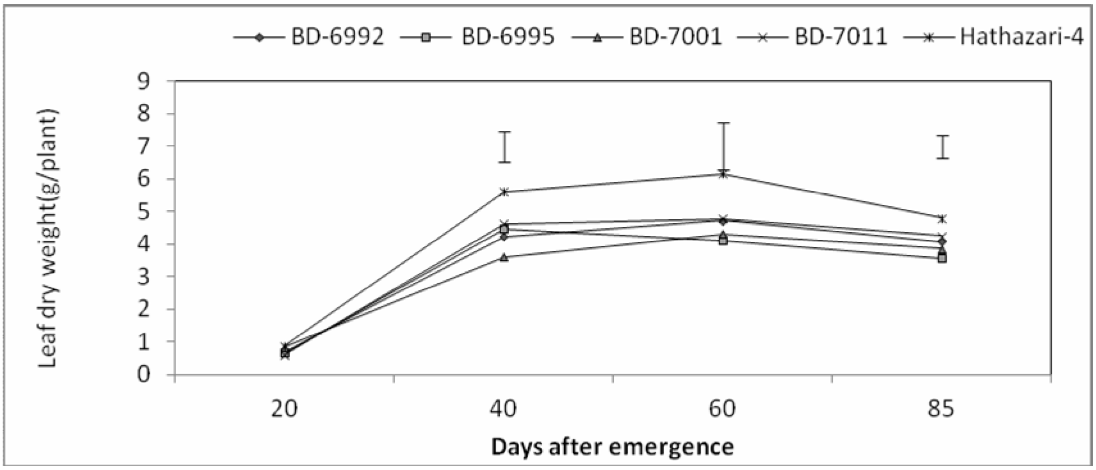

Fig. 1. Vatiation in leaf dry matter accumulation over time in sesame genotypes. Vertical bars indicate LSD (0.05).

Stem dry matter

Dry matter accumulation in stem as a result of stem elongation and stored photosynthates showed a significant variation in sesame genotypes over time as shown in Figure 2. The stem dry weight increased slowly up to 20DAE and continued to increase till maturity. The highest stem dry weight was obtained at 60 DAE which was 9g plant $^{-1}$, 9.6 g plant^{-1}, 9.1 g plant^{-1},9.46 g plant^{-1} and 11g plant^{-1} in BD-6992, BD-6995, BD-7001, BD-7011 and Hathazari-4, respectively. The dry weight of stem declined after the attainment of the peak in all the genotypes. There was slight decrease in stem dry weight at final harvest. This might be due to continuous supply of current assimilates for the development of grains.

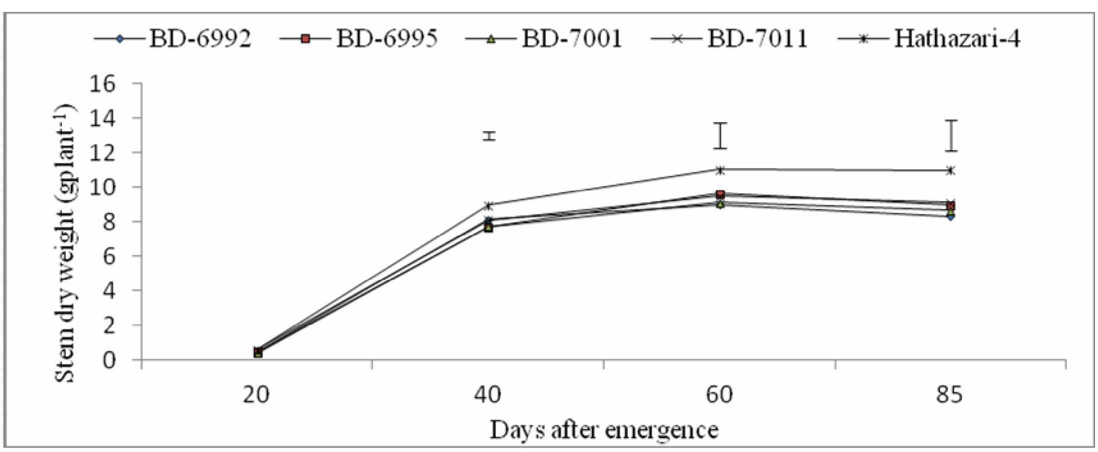

Fig. 2. Variation in stem dry matter accumulation over time in sesame genotypes. Vertical bars indicate LSD (0.05).

Capsule dry matter

Figure 3 shows that the accumulation of dry matter in capsule was less at the beginning and it increased rapidly later on. Dry matter accumulation in capsule started earlier in hathazari-4. Capsule dry weight continued to increase till maturity. The genotypes showed significant differences in capsule dry weight in 40 DAE and 85 DAE. Capsule dry weight ranged from

9.7 g plant^{-1} (Hathazari-4) to 6.98 g plant^{-1} (BD-7011). The highest contribution to total dry weight per plant was made by capsule dry weight per plant. The highest contribution of capsule to the total dry weight could be attributed to the fact that at flowering, most of the assimilation was partitioned to the sink (capsule). This continued until physiological maturity is attained. (Haruna *et al*., 2011).

Fig. 3. Variation in capsule dry matter accumulation over time in sesame genotypes. Vertical bars indicate LSD (0.05).

Yield components of sesame

Number of capsules per plant

There was significant variation in the number of capsules per plant in sesame genotypes (Table 7). The highest number of capsules plant^{-l} (63.65) was obtained in the genotypes Hathazari-4 and the lowest number of capsules plant^{-l} (38.40) in genotypes BD-7001.

Number of seeds per capsule

The highest number of seeds capsule^{-l} (77) was obtained in genotype Hathazari-4. The lowest number of seeds capsule^{-l} (59.83) was obtained in genotype BD-7001which was statistically different. Delay in harvesting reduced the number of seeds capsule^{-l} (Mondal *et al*., 2004).

Thousand seed weight

The 1000-grain weight did not vary significantly in the genotypes (Table 7). The 1000-grain weight varied from 2.93g to 3.40 g. The highest 1000-grain weight (3.40 g) was recorded in the genotype-BD 6992 and the lowest (2.93 g) in the genotype-BD 7011. The direct effects of 1000-seed weight on seed yield were low and positive. (Yadava *et al.,* 1983).

Seed yield

Seed yield of five sesame genotypes ranged from 1.83 to 3.52 t ha^{-1} (Table 7). The highest seed yield (3.52 t ha^{-1}) was found in the genotype, Hathazari-4 and the lowest (1.82 t ha^{-1}) in the genotypes BD-6992 and BD-7001.

Oil content in seed

Genotypic variation in seed oil content of sesame is shown in Table 7. Percentage of oil in seeds varied slightly among the genotypes. The seed oil contents were 41.39% in the genotype BD-6992, 39.73% in BD-6995, 40.26% in BD-7001, 41.2% in BD-7011 and 39.72% in the genotype Hathazari-4. The highest oil yield was obtained from the genotype Hathazari-4 (151.99 tha^{-1}) and the lowest (73.27 tha^{-1}) from BD-7000.

Table 7. Yield component and seed yield, oil content in seeds and oil yield in five selected sesame genotypes

Genotypes	Capsules $plant^{-1}$	Seed $capsule^{-1}$	1000-seed Weight (g)	Seed yield (tha^{-1})	Seed oil content (%)	Seed oil yield (tha^{-1})
BD-6992	47.1	67.15	3.40	1.83	41.39	0.753
BD-6995	44.08	67.63	2.94	2.02	39.73	0.803
BD-7001	38.4	59.83	3.30	1.82	40.26	0.733
BD-7011	45.78	70.07	2.94	2.51	41.20	1.04
Hathazari-4	63.65	77.00	3.38	3.52	39.72	1.53
LSD (0.05)	5.00	9.53	NS	0.48	0.62	0.29
CV(%)	6.80	8.89	5.44	13.37	.99	13.23

NS = Non-significant

Conclusion

Genotypic variability in terms of photosynthetic rate, dry matter partitioning, seed and oil yield was found in five sesame genotypes. Based on the present study it could be concluded that sesame genotype Hathazari-4 showed the best performance in terms of photosynthetic rate, dry matter partitioning, seed yield and oil yield.

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