Physiological and biochemical traits of sesame 
(Sesamum indicum L.) varieties under rainfed 
conditions

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Abstract
A field experiment was conducted to evaluate the performance of ten sesame varieties viz., RT-346, RT-351, RT-127, GT-10, TKG-22, Swetha til, JCSDT-26, DS-1, YLM-66 and KMS-59 for physiological, biochemical and yield traits using randomized block design with three replications under rainfed conditions. Results showed that the varieties significantly differed for the physiological parameters such as photosynthetic rate, stomatal conductance, internal CO₂ concentration where as transpiration rate remain non-significant. Variety JCSDT-26 recorded high photosynthetic rate which is positively correlated with the seed yield and low transpiration rate and internal CO₂ concentration which are negatively correlated with the seed yield. The highest value of oil content was observed in JCSDT-26 (48.5 %) because of its white seed colour. The maximum value of palmitic acid was also recorded in the variety JCSDT-26 (10.57%). Hence, the variety JCSDT-26 is considered as suitable for cultivation under the rainfed conditions.

Keywords: Physiological traits, rainfed conditions, oil content, palmitic acid, sesame

Introduction
Rainfed agriculture dominates global agriculture and plays a critical role in achieving global food security. However growing world population, water scarcity and climate change threaten rainfed farming through increased vulnerability to abiotic stresses. Rainfed areas experience 3 to 4 years of drought in every 10 years. Of these two to three are in moderate and one or two may be of severe stress intensity (Minhas et al., 2017) [13]. About 80% of the world and 60% of the Indian Agriculture is rain-dependent, diverse, complex, under-invested, risky, distress prone and vulnerable (NRAA reports, 2018) [12]. Uncertainties and seasonal migrations have been further compounded due to the high frequency of extreme weather events like droughts due to global warming (IPCC 2018) [17]. Sesame, the ‘queen of oilseeds’ is known for its high oil content and quality (Johnson et al., 1979) [19] belongs to Pedaliaceae family. It is a widely grown crop in tropical and subtropical areas and this crop is documented as the most ancient oil crop providing humans with essential daily energy. Vegetable oil consumption is expected to reach almost 200 billion kilograms by 2030 (Troncoso-Ponce et al., 2011) [19], which will increase the demand for oil-rich crops. Compared to other edible oil crops such as soybean, rapeseed, groundnut and olive, sesame has innately higher oil content (approximately 55% of dry seed) (Wei et al., 2013) [21] and it is also used in therapeutic medicine. The annual area put under it in India is about 1.6 M ha (45 % of the world hectarage) and the total production is 0.78 million tonnes productivity of 501 kg ha⁻¹(AICRP report 2019). Sesame is grown mostly in West Bengal, Uttar Pradesh, Rajasthan, Madhya Pradesh, Telangana, Andhra Pradesh, Maharashtra, Gujarat, Tamil Nadu and Orissa and Karnataka. (Status paper on oilseeds, 2006) [18]. Generally, sesame is cultivated in kharif season under rainfed areas with minimum inputs, and crop often expose to water stress and results in low yields. Therefore it is essential to identify the existing variety that adopts the rainfed situation of India.

Materials and methods
An experiment was conducted during kharif, 2018 at ICAR-IIOR Research farm, Narkhoda, Hyderabad. The experiment was laid out in a Randomized Block Design (RBD), replicated
Thrice with a plot size of 12 square meters and the row spacing of 45 cm and in row spacing of 15 cm. Sowing was done by dibbling and recommended dose of fertilizers were applied (40 Kg N + 20 Kg P₂O₅ + 20 Kg K₂O) in two splits and other packages of practices were followed to raise a healthy crop. Propaletic measures were adopted against pests and diseases. A set of ten sesame varieties including national and local checks were selected for the study. Five random plants from each variety were selected in each replication to record the data on gas exchange parameters viz., photosynthetic rate (Pn), transpiration rate (E), stomatal conductance (Gs) and internal CO₂ concentration (Ci). The photosynthetic rate was measured at the capsule initiation stage by using Infra-Red Gas Analyser (IRGA; Model-LICOR 6100) from leaves that had fully expanded recently from main stem apex during 10.30 to 13.00 hr (IST) on sunny days. The net exchange of CO₂ between a leaf and the atmosphere is measured by enclosing the leaf in a closed chamber, and monitoring the rate at which the CO₂ concentration in chamber changes over a fairly short time interval. Transpiration rate, stomatal conductance and internal CO₂ concentration measurements were also measured at capsule initiation stage by using Infra-Red Gas Analyser.

SCMR was measured in the same leaf where gas exchange was measured using SPAD meter (SPAD-502; Make:Konica). The oil content was analysed taking 10 grams of seed for each variety by Nuclear Magnetic Resonance (NMR) spectrometer by the modified method of Yadav and Murthy, 2016. Oil from seed was extracted in hexane on a soxhlet apparatus. Methyl esters were obtained according to the method of Anjani and Yadav, 2017. The organic phase was extracted with hexane and washed with water till neutral pH. The hexane was dried over anhydrous sodium sulphate and concentrated with nitrogen gas to get methyl esters. Fatty acid composition was determined using an Agilent 7890B gas chromatograph (GC) equipped with a flame ionization detector (FID) and an auto sampler.

Results and Discussion

Physiological parameters

Assessment of various physiological characteristics of the sesame varieties under rainfed conditions is essential to understand the traits contributing to better yields and can be used for the identification of varieties with better seed yield which are having the adaptability to the rainfed conditions. The maximum values of net photosynthesis were recorded in JCSDT-26 (30.1 μmoles CO₂ m⁻² s⁻¹) followed by RT-351 (29.6 μmoles CO₂ m⁻² s⁻¹) and Swetha til (29.2 μmoles CO₂ m⁻² s⁻¹). The minimum values of net photosynthesis were recorded in KMS59 (27.8 μmoles CO₂ m⁻² s⁻¹), YLM-66 (26.8 μmoles CO₂ m⁻² s⁻¹) and DS-1 variety (25.8 μmoles CO₂ m⁻² s⁻¹). Growth, dry matter production and yield depends entirely on photosynthetic rate of crop plants. In the present study photosynthetic rate has a positive correlation with seed yield (R²: 0.012, (Fig.1). The variations among varieties were also observed. These variations in photosynthetic rates are due to leaf area development of different varieties and the extent of light intercepted by the canopy. These results are in accordance with the studies by Ravitej et al., (2019) [15]

The decreased photosynthetic rate in few varieties can be attributed to reduced SPAD readings. These varieties are incapable to withstand water deficit due to dry spells under rainfed conditions. Both stomatal and non-stomatal limitation was generally accepted to be the main determinant of reduced photosynthesis under water deficit conditions. (Farooq et al., 2009) [6]. The rate of photosynthate is a function of total leaf area and solar radiation intercepted by the crop canopies. These results suggest that the differences in photosynthetic rate among crop varieties are important for understanding the plant capacity to produce economic yield as reported by Islam et al., (1994) [10].

The transpiration rate values revealed that YLM-66 (1.28 m mol H₂O m⁻² s⁻¹) followed by TKG-22 (1.25 m mol H₂O m⁻² s⁻¹) and KMS-59 (1.23 m mol H₂O m⁻² s⁻¹) recorded the highest values whereas Swetha til (1.05 m mol H₂O m⁻² s⁻¹), RT346 (1.02 m mol H₂O m⁻² s⁻¹) and JCSDT-26 (1.01 m mol H₂O m⁻² s⁻¹) recorded the lowest values of transpiration rate. There was no significant difference among the varieties for transpiration rate. The relationship between transpiration rate and yield was found to be negative (Fig. 2), indicating that conservative use of water through transpiration under water scarcity condition due to rainfed situations, those varieties yielded more seed. The similar results were also observed in other oilseeds like groundnut (Ratnakumar and Vadez, 2012; Vadez and Ratnakumar, 2016) [14, 20].

There were significant differences among the varieties for stomatal conductance. The highest values of stomatal conductance were recorded in RT-22 (0.99 m mol H₂O m⁻² s⁻¹) followed by RT-127 (0.98 m mol H₂O m⁻² s⁻¹) and RT-351 (0.92 m mol H₂O m⁻² s⁻¹). The lowest values were recorded in DS-1 and GT-10 (0.65 m mol H₂O m⁻² s⁻¹). Stomatal conductance has a negative correlation with yield (Fig. 3). If the stomatal conductance is low there will be faster rate of intercellular CO₂ utilization compared to the rate of CO₂ uptake through stomata. This result is in agreement with the studies made by Akter et al., (2016) [15] in sesame.

The maximum values of internal CO₂ were documented for RT-346 (358 ppm) followed by RT-127 (346 ppm) and TKG-22 (338 ppm). The minimum values were recorded in Swethatil (312 ppm) and JCSDT-26 (306 ppm) and the variety KMS-59 was found to be statistically on par with the variety YLM-66. Internal CO₂ concentration of leaves have negative correlation with yield (Fig. 4). There was a significant difference among the varieties for internal CO₂ concentration. Though Ci was low in JCSDT-26 followed by Swethatil, indicated that these varieties were able to fix CO₂ even under lesser stomatal conductance and transpiration.
Oil content and fatty acid profile

There was a significant difference among the varieties for oil content (%). The highest values of oil content was observed in JCSDT-26 (48.5 %) followed by GT-10 (45.03%) and RT-351 (43.9%) under rainfed conditions. The lowest values for oil content (%) were observed in KMS-59 (40.87%) and DS-1 (41.09%). The variety JCSDT-26 is white in colour and has high oil percentage.

These results are in agreement with the results obtained by Akinoso et al., (2010) [11], who suggested that oil content in the seeds is associated with the seed colour. Still further conformation is required to confirm oil content based on seed colour. A major cause of the yield reduction under water deficit condition resulting from scarce rainfall could be due to inadequate photosynthesis owing to stomatal closure and consequently limited carbon dioxide uptake (Kadhkodaie et al., 2014) [10] and also the results of Connor and Sadras (2016) [6], who reported that a larger amount of abscisic acid, produced in leaves of stressed plants, was translocated to the seeds and led to a decline in the oil/protein ratio of the seeds. The values of oleic acid content ranged from 24.99 % to 50.73 %, linoleic acid content ranged from 34.33 % to 42.89 % and palmitic acid content ranged from 9.02 % to 10.57 %. Oleic acid is the main mono-unsaturated fatty acid of sesame seed oil (Crews et al., 2006). In this study highest oleic acid percentage was recorded in RT-127 (50.73 %) followed by GT-10 (49.32%) and the lowest percentage was recorded in YLM-66 (45.4 %) and RT-346 (24.99 %). The findings of this study are close to the results of Sowmya et al., (2009) [17]. A Significant negative effect of water stress on oleic acid content in sesame has been reported by Kim et al., (2006) [11].

The maximum values of linoleic acid were recorded in RT-346 (42.89 %) followed by JCSDT-26 (38.85 %) and minimum values were recorded in GT-10 (34.33 %) followed by Swethatil (33.87 %).

These results are in accordance with the studies by Kadhkodaie et al., (2014) [10] who reported that the linoleic acid content of some genotypes increases, while those of other genotypes decreases under water stress conditions. Palmitic acid is the major saturated fatty acid of sesame seed oil (Crews et al., 2006) [5]. The maximum values of palmitic acid were recorded in the variety JCSDT-26 (10.57 %) followed by Swethatil (10.3 %) and the minimum values were recorded in RT346 (9.02 %). The findings of this study are close to the results of Sowmya et al., (2009) [17]. Palmitic acid contents of oilseed crops depend on the genotype and the level of water stress as suggested by Kadhkodaie et al., (2014) [10].

All the varieties expressed significant difference for seed yield under rainfed conditions. JCSDT-26 has recorded high seed yield (584.58) followed by Swethatil and DS-1 whereas minimum seed yield was recorded in RT-351 followed by RT-346 and RT-127 (402.06). There was significant difference between the varieties for total dry matter and the reduction of total dry matter in some varieties may be due to reduction in rate of photosynthesis under deficit rainfall conditions (Ravitej et al., 2019) [15]. There was significant difference among the varieties for harvest index (HI). Maximum harvest index recorded in varieties is known to be due to higher number of branches and better retention of capsules in sesame (Saha and Bhargava, 1980) [16].

Table 1: Photosynthetic rate (Pn), Transpiration rate (E), Stomatal conductance (Gs) and Internal CO2 concentration (Ci) of the sesame varieties under rainfed conditions.

| S. No. | Varieties | Photosynthetic Rate (µ moles CO₂ m⁻² s⁻¹) | Transpiration Rate (m mol H₂O m⁻² s⁻¹) | Stomatal Conductance (m mol H₂O m⁻² s⁻¹) | Internal CO₂ Concentration (ppm) |
|--------|-----------|------------------------------------------|----------------------------------------|----------------------------------------|-------------------------------|
| 1      | RT-346    | 28.4                                     | 1.02                                   | 0.86                                   | 358                           |
| 2      | RT-351    | 29.6                                     | 1.06                                   | 0.92                                   | 341                           |
| 3      | RT-127    | 29.1                                     | 1.10                                   | 0.98                                   | 346                           |
| 4      | GT-10     | 28.2                                     | 1.20                                   | 0.65                                   | 328                           |
| 5      | TKG-22    | 27.9                                     | 1.25                                   | 0.99                                   | 338                           |
| 6      | Swethatil | 29.2                                     | 1.05                                   | 0.85                                   | 312                           |
| 7      | JCSDT-26  | 30.1                                     | 1.01                                   | 0.86                                   | 306                           |
| 8      | DS-1      | 25.8                                     | 1.21                                   | 0.65                                   | 321                           |
| 9      | YLM-66    | 26.8                                     | 1.28                                   | 0.69                                   | 314                           |
| 10     | KMS-59    | 27.8                                     | 1.23                                   | 0.75                                   | 316                           |
| Mean   | 28.29      | 1.14                                     | 0.82                                   | 328                                   |
| S.E.   | 0.93       | 0.11                                     | 0.04                                   | 2.91                                   |
| CV(%)  | 4.05       | 12.32                                    | 6.38                                   | 1.08                                   |

Fig 3: Association between stomatal conductance at 45 DAS and yield of sesame varieties.

Fig 4: Relationship between internal CO₂ concentration at 45 DAS and yield of sesame varieties.
Table 2: Oil content and fatty acid content (Oleic, linoleic and palmitic acid) of the sesame varieties under rainfed conditions.

| Sl. No. | Varieties | Oil content (%) | Fatty acid content (%) |
|---------|-----------|-----------------|------------------------|
|         |           |                 | Oleic acid | Linoleic acid | Palmitic acid |
| 1       | RT-346    | 42.44           | 24.99      | 42.89        | 9.02         |
| 2       | RT-351    | 43.98           | 47.50      | 36.66        | 9.13         |
| 3       | RT-127    | 43.47           | 50.73      | 34.85        | 9.96         |
| 4       | GT-10     | 45.03           | 49.32      | 34.33        | 9.67         |
| 5       | TKG-22    | 41.79           | 45.64      | 38.29        | 9.96         |
| 6       | Swethatil | 42.67           | 49.02      | 33.87        | 10.31        |
| 7       | JCSDT-26  | 48.52           | 44.21      | 38.83        | 10.22        |
| 8       | DS-1      | 41.09           | 46.71      | 36.70        | 9.98         |
| 9       | YLM-66    | 42.38           | 45.40      | 38.47        | 9.64         |
| 10      | KMS-59    | 47.87           | 45.46      | 37.83        | 10.22        |
| Mean    |           | 43.22           | 44.89      | 37.27        | 9.84         |
| SE      |           | 1.14            | 1.41       | 1.95         | 0.43         |
| CD (p=0.05) |       | 2.39            | 3.00       | 4.03         | 0.98         |
| CV(%)   |           | 3.23            | 3.86       | 4.51         | 1.65         |

Table 3: Seed yield, Total plant dry matter and Harvest index of the sesame varieties under rainfed conditions.

| Sl.No. | Varieties | Total plant dry matter (kg ha⁻¹) | Seed yield (kg ha⁻¹) | Harvest index (%) |
|--------|-----------|----------------------------------|---------------------|------------------|
| 1      | RT-346    | 2207.0                           | 453.32              | 20.56            |
| 2      | RT-351    | 2653.4                           | 471.08              | 17.76            |
| 3      | RT-127    | 2482.6                           | 402.06              | 16.20            |
| 4      | GT-10     | 2891.4                           | 486.51              | 16.82            |
| 5      | TKG-22    | 2423.4                           | 466.66              | 19.26            |
| 6      | Swethatil | 2751.8                           | 560.39              | 20.38            |
| 7      | JCSDT-26  | 3037.2                           | 584.58              | 19.24            |
| 8      | DS-1      | 2836.9                           | 538.36              | 18.97            |
| 9      | YLM-66    | 3037.2                           | 584.58              | 19.24            |
| 10     | KMS-59    | 2590.0                           | 515.54              | 19.90            |
| Mean   |           | 2613.71                          | 495.82              | 19.03            |
| SE     |           | 67.51                            | 12.09               | 0.63             |
| CD (p=0.05) |       | 142.93                          | 25.60               | 1.34             |
| CV(%)  |           | 3.16                             | 2.98                | 2.27             |

References

1. Akinoso R, Aboaba SA, Olayanju TMA. Effects of moisture content and heat treatment on peroxide value and oxidative stability of un-refined sesame oil. African Journal of Food Agriculture Nutrition and Development. 2010; 10(10):4268-4285.
2. Akter M, Khaliq QA, Islam MR, Ahmed JU. Photosynthesis, dry matter partitioning and yield variation in sesame genotypes. Bangladesh Agronomy Journal. 2016; 19(1):19-28.
3. Anjani K, Yadav P. High yielding-high oleic non-genetically modified Indian safflower cultivars. Industrial Crops and Products. 2017; 104:7-12.
4. Connor DJ, Sadras VO. Physiology of yield expression in sunflower. Field Crops Research. 1992; 30(3-4):333-389.
5. Crews C, Hough P, Godward J, Breteron P, Lees M, Guit S. Quantitation of the main constituents of some authentic grape-seed oils of different origin. Journal of Agricultural and Food Chemistry. 2006; 54:6261-6265.
6. Farooq M, Wahid A, Kobayashi N, Fujita D, Basra SMA. Plant drought stress: Effects, mechanisms and management. In: Lichtfouse, E., Navarrete, M., Debakee, P., Veronique, S. and Alberola, C. (eds.). Sustainable Agriculture.; Netherlands: Springer, 2009.
7. IPCC (Intergovernmental Panel on Climate Change) report, 2018.
8. Islam MT. Eco-physiological studies on photosynthesis and dry matter production in mungbean. Ph.D. Dissertation, Kyushu University, Fukuoka, Japan, 1994.
9. Johnson LA, Suleiman TM, Lusas EW. Sesame protein: A review and prospectus. Journal of American Oil Chemists Society. 1979; 56:463-468.

10. Kadkhodaie A, Razmjoo J, Zahedi M, Pessarakli M. Selecting Sesame genotypes for drought tolerance based on some physicochemical traits. Agronomy journal. 2014; 106:111–118.

11. Kim MJ, Kim H, Shin JS, Chung CH, Ohlrogge JB, Suh MC. Seed-specific expression of sesame microsomal oleic acid desaturase is controlled by combinatorial properties between negative cis-regulatory elements in the SeFAD2 promoter and enhancers in the 5-UTR intron. Molecular Genetics and Genomics. 2006; 276:351-368.

12. NRAA (National Rainfed Area Authority) report, Drought mitigation strategy for Bundelkhand, 2018.

13. Minhas PS, Rane J, Ratnakumar P. Abiotic Stress Management for Resilience Agriculture. Springer Nature. DOI:10.1007/978-981-10-5744-1,Pp-507

14. Ratnakumar P, Vadez V. Tolerant groundnut (Arachis hypogaea L.) genotypes to intermittent drought maintains high harvest index and has small leaf canopy under stress. Functional Plant Biology. 2012; (38):1016-1023.

15. Raviteja KN, Ratnakumar P, Pandey BB, Reddy SN, Shnaker G, Padmaja D. Morpho-physiological and yield traits of sesame varieties under rainfed conditions. Journal of Oilseeds Research. 2019; 36(3):16-21.

16. Saha SN, Bhargava SC. Physiological analysis of the growth, development and yield of oil-seed sesame. Journal of Agricultural Science. 1980; 95(3):733-736.

17. Sowmya M, Thangaraj J, Jyostna R, Indrani D. Effect of replacement of fat with sesame oil and additives on rheological, microstructural, quality characteristics and fatty acid profile of cakes. Food Hydrocolloids. 2009; 23(7):1827-1836.

18. Status paper on oilseeds. DOD, GOI, 2006.

19. Troncoso-Ponce MA, Kilaru A, Cao X, Durrett TP, Fan J, Jensen JK et al. Comparative deep transcriptional profiling of four developing oilseeds. Plant Journal. 2011; 68:1014-1027.

20. Vadez V, Ratnakumar P. High transpiration efficiency increases pod yield under intermittent drought in dry and hot atmospheric conditions but less so under wetter and cooler conditions in groundnut (Arachis hypogaea L.). Field Crops Research, 2016; http://dx.doi.org/10.1016/j.fcr.2016.03.001.

21. Wei W, Zhang Y, Lv H, Li D, Wang L, Zhang X. Association analysis for quality traits in a diverse panel of Chinese sesame (Sesamum indicum L.) germplasm. Journal of Integrated Plant Biology. 2013; 58:745-758.

22. Yadav P, Murthy IYLN. Calibration of NMR spectroscopy for accurate estimation of oil content in sunflower, safflower and castor seeds. Current Science. 2016; 110(1):73-76.