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Study of drought tolerant associated morpho-physiological traits and yield of linseed under rainfed condition

Suraj Shriram Pokale, SB Amarshettiwar, Shilpa Rananawre, PV Shende, PR Manapure, SK Sasane and SR Barde

Abstract
A field experiment was conducted during *rabi* 2021-22, to study the drought tolerance studies in different genotypes of linseed under rainfed condition genotypes NL -339, NL -367, NL -369, NL -371, NL- 407, NL -408, TL- 99, LSL -93, PKV NL- 260 (LC), T- 397 (NC) were studied. The experiment was laid down in randomized block design and complete randomized design with ten genotypes and three replications at research farm of AICRP on Linseed and Mustard, College of Agriculture, Nagpur. The aim of this work was to study the drought tolerant associated morpho-physiological traits and yield of linseed under rainfed condition. Observations about morpho-physiological parameters like plant height, number of leaves plant^{-1}, total dry matter production, leaf area, leaf area index, relative water content, germination stress index (GSI) and dry matter stress index (DMSI) were also estimated. Observations on yield traits like grain yield plant^{-1}, plot^{-1}, ha^{-1}, harvest index recorded. Genotypes PKV NL-260 followed by NL-369 and NL-371 significantly enhanced morpho-physiological traits and yield of linseed under rainfed condition, when compared with national check T-397 and rest of the genotypes under study.

Keywords: Linseed, relative water content, germination stress index, dry matter stress index, morpho-physiological traits, growth analysis

Introduction
Linseed (*Linum usitatissimum* L.) is an important multipurpose oilseed crop commonly known as alsi or flax seed. It is an ancient crop that has been the part of the human diet for thousands of years. Linseed belongs to the family Linaceae, the genus Linum has approximately 200 species. It is cultivated as a rabi crop In India and is mostly grown in marginal rainfed soils, with a heavy texture and good water retention capacity. Linseed is an annual herb with erect, slender stems. It is known for its medicinal value since 5000. B.C. and is grown from ancient times for its valuable fiber and seed which is rich in oil. Like other edible oils, linseed oil is also a rich source of protein, fat, fiber and contains good amount of carbohydrates it is cultivated in most temperate and tropical regions of the world. The major linseed growing states of country are Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Maharashtra, Bihar, Orissa, Jharkhand, Karnataka, Nagaland and Assam accounting for about 97% of total area of nation. In Maharashtra it is cultivated mainly in Bhandara, Gondia, Chandrapur, Gadchiroli, Osmanabad districts and some regions of Beed, Latur, Nagpur and Solapur districts with an area of 5160 hectares with production of 1499 tones and having productivity of 291 kg ha-1. In vidarbha districts the crop occupies area of 5160 ha with production of 1292 tonnes and productivity of 267 kg/ha.
Linseed (*Linum usitatissimum* L.) is a conventional oilseed as well as a fiber crop. Linseed has numerous medicinal uses. It is worldwide cultivated commercially for flax, while in India it is cultivated for oil. Linseed oil is used in the manufacturing of paints and varnish oil cloth and linoleum. Every part of linseed plant is utilized commercially, either directly or after processing. Seed contains 33 to 47 per cent oil. A small quantity is directly used for edible purposes. Linseed oil, squeezed out of flax seed, used as a preservative finish on wood. Linseed oil is a drying oil, as it can polymerize into a solid form. Seeds of linseed contain high levels of dietary fibers as well as lignans, an abundance of micronutrients and omega-3 fatty acids. The oil is rich in linolenic acid (>66%) and is a perfect drying oil. The nutritive value of flax seed. Linseed cannot stand much rain during growing period and well distribution of rainfall throughout the growing period is very important to obtain optimum yield.

It is also grown under irrigation in dry climate. More than 80 per cent of global agricultural land area is rainfed and due to erratic and untimely distribution of rainfall in winter and undulating topography, poor productivity of crop is obtained in hills. (Bray *et al.* 2000) [5] reported that resistance or sensitivity to the stress depends on the species, the genotype, and the developmental stage of the plant. The growth and yield of the crop depends on the interaction between environmental factors with numerous physiological processes of the plant (Sanap *et al.* 2004) [2].

Material and Methods

The project entitled "Drought tolerance studies associated with biochemical traits on yield of linseed under rainfed condition" was conducted during *Rabi* season 2021-22 at the farm of All India Coordinated Research Project on Linseed (AICRP on Linseed and Mustard), College of Agriculture, Nagpur (MS) in a Randomized Block Design with ten genotypes and three replications. Genotypes consists NL-339, NL-367, NL-369, NL-371, NL-407, NL-408, TL-99, LSL-93, PKV NL-260 (LC), T-397 (NC) were tested. The gross plot size was 3.00 m x 2.20 m and net plot size was 2.40 m x 2.00 m with spacing of 30 cm x 10 cm. Five plants from each plot were selected randomly and data were collected at 30, 45, 60 and 90 DAS on plant height, number of leaves plant^{-1}, total dry matter plant^{-1}, leaf area, leaf area index, days to 50% flowering and days to maturity. Growth analysis was carried out by computing relative growth rate, net assimilation rate and crop growth rate. Relative Growth Rate (g g^{-1} day^{-1}) the rate of increment is known as relative growth rate. It was computed by using the Fischer' s formula (1971) [8], The Net Assimilation Rate (g dm^{-2} day^{-1}) was calculated by using the formula suggested by Williams (1946) and expressed as g dm^{-2} day^{-1} and the Crop Growth Rate (g m^{-2} day^{-1}) was calculated by using the formula suggested by Watson (1958) [29] and expressed as g m^{-2} day^{-1}.

Drought tolerance study

Leaf relative water content was calculated by the method of Barrs and weatherly (1962) [3].

$$\text{RWC (\%)} = \frac{\text{Fresh weight} - \text{oven dry weight}}{\text{Turgid weight} - \text{oven dry weight}} \times 100$$

Promptness Index (PI) as described by George, (1967) [9] as under.

PI (promptness index) = nd_2 (1.00) + nd_4 (0.75) + nd_6 (0.50) + nd_8 (0.25)

Were,

PI = Promptness Index.

nd_2, nd_4, nd_6 and nd_8 = Percent of seeds observed to germinate after 2, 4, 6 and 8th day after observation. (George, 1967) [9]

A germination stress index (GSI) was expressed as follows as under.

$$\text{Germination stress index (\%)} = \frac{\text{PI of stressed seeds (PIS)}}{\text{PI of controlled seeds (PIC)}} \times 100$$

After drying the plant in oven at 70 °C for 48 hours the dry matter stress tolerance index was determined as per Sammer Raza (2012) [21] as under.

$$\text{Dry matter stress index (DMSI) (\%)} = \frac{\text{Dry matter of stressed seeds (DMS)}}{\text{Dry matter of controlled seeds (DMC)}} \times 100$$

Test weight, number pods, grain yield plant^{-1}, plot^{-1}, ha^{-1}and harvest index were calculated after harvest. Data was estimated by to statistical analysis as per method suggested by Panse and Sukhatme (1954) [16].

Results and Discussion

Plant height (cm)

Plant height at 60 DAS were found statistically significant and range recorded was 21.00 to 49.67 cm. At 90 DAS the range of plant height was observed 24.67 to 55.67 cm. The significantly highest plant height was observed in genotypes NL-369 (55.67 cm), NL-339 (54.67 cm), PKV NL-260 (LC) (54.33 cm), NL-371 (54.00 cm), NL-407 (53.67 cm) and T-397 (NC) (52.33) genotypes. This might be due to their genetic constitution as compared to other genotypes.

The increase in plant height might be due to an increase in the photosynthetic activity, chlorophyll formation, nitrogen metabolism and auxin contents in the plants which ultimately improving the plant height. These findings were supported by Boyer (1975) [4] who reported that the reduction in plant height and leaf area in severe water stress condition could be related to the lack of enough turgor pressure required for complete cell expansion. Pande *et al.* (1970) [14] reported that on increasing levels of irrigation in linseed significantly increased the height of plants, seed and straw yield. There was a marked reduction in plant height and dry matter accumulation under limited water conditions

Number of leaves plant^{-1}

Number of leaves gives a better idea of the photosynthetic activity of the plant. The number of leaves directly influences the dry matter accumulation of plants.

Observations recoded at 60 DAS indicated significant variation. NL-407 (230.00) recorded significantly higher number of leaves plant^{-1} NL-369 (227.00), NL-408 (206.33), T-397 (NC) (200.67), LSL-93 (187.33) PKV NL-260 (LC) (180.67) and NL-339 (175.67). The number leaves linseed genotypes highest number of leaves at 60 DAS and due to moisture stress resulting that, leaf falls down at 90 DAS caused leaf senescence constitutes the final stage of crop development. The similar result supported our findings by Abayomi (2009) [2] cowpea responses of plant growth parameters. Plant height in cowpea has been shown to be decreased by water stress (Hiler *et al.*, 1972) [10]. Similarly, reduction in leaf production and or increase in leaf senescence and abscission due to water stress have been reported (Abidoye, 2004) [1].

Total dry weight (g)

At 90 DAS grain filling stage NL-407 (8.00 g plant^{-1}) recorded significantly highest TDM plant^{-1} over T-397 (NC) (6.50 g plant^{-1}) followed by PKV NL-260 (LC) (7.97 g plant^{-1}), LSL-93 (7.13 g plant^{-1}) and found at par away among each other. NL-367 (5.43 g plant^{-1}) recorded significantly lowest TDM than all other genotypes. Except TL-99 (5.80 g plant^{-1}) and NL-371 (6.30 g plant^{-1}) which are found at par among themselves. Wang *et al.* (2004) [28] when subjected nine-day old seedlings of ten soybean cultivars to drought stress and compared with the non-stressed control. They found that plant height, shoot dry weight, root dry weight, main root length, leaf area, chlorophyll content decreased, and proline content increased in the drought treated seedlings. Findings of shikh *et al.* (2005) [24] agreed with our research which stated that under water stress all traits *viz.* plant height, shoot dry weight, number of siliquae and relative water content decreased under water deficit.

Leaf area plant^{-1}

AT 60 DAS, NL-407 (5.42 dm^2 plant^{-1}) recorded significantly highest Leaf area per plant over local check PKV NL-260 (4.26 dm^2 plant^{-1}) followed by NL-369 (5.35 dm^2 plant^{-1}). NL-369 (2.66 dm^2 plant^{-1}) recorded significantly lowest leaf area plant^{-1} than all other genotypes. Pattern of Leaf area development was like sigmoid growth, attaining its maximum potential at flowering stage is at 60 DAS and decline continuously up to harvest this might be described by the ageing of leaves, leaf senescence and water stress at later growth stages. These results are in accordance with the findings of Jatoi *et al.* (2011) [11] who observed similar result that is total leaf area decreased 40.40% was due to water stress condition from flowering stage.

Days to maturity (days)

Early maturing genotypes are preferred for rainfed situation. This escapes the moisture stress situation. Due to water stress condition maturity come in minimum days.

Growth analysis

Growth analysis was carried out by computing relative growth rate and net assimilation rate based on dry matter accumulation, leaf area and period of accumulation as per the method suggested by Fischer (1971) [8].

Relative Growth Rate (g g^{-1} day^{-1})

During flowering period i.e., between 45-60 DAS T-397 (NC) was recorded by best check variety significantly highest RGR (0.090 g g^{-1} day^{-1}) day followed by NL-408 (0.081 g g^{-1} day^{-1}). However, both are found at par with each other & significantly super over all genotypes under study, PKV NL-260 (LC) (0.067 g g^{-1} day^{-1}), followed by NL-407 (0.054 g g^{-1} day^{-1}) however, both are at par with each other. NL-339 (0.038 g g^{-1} day^{-1}) recorded significantly lowest RGR followed by TL-99 (0.039 g g^{-1} day^{-1}), LSL-93 (0.043 g g^{-1} day^{-1}), NL-371 (0.049 g g^{-1} day^{-1}), NL-367 and NL-369 each (0.050 g g^{-1} day^{-1}). These genotypes showed significantly lowest RGR with both checks. Results are in conformity with findings of Rajput *et al.* (2017) [19]. The study interpreted that Relative Growth Rate (RGR) measures the increase in dry matter with a given amount of assimilatory material at a given point of time.

Net Assimilation Rate (g dm^{-2} day^{-1})

The study of Net Assimilation Rate (NAR) is the net gain in total dry matter unit^{-1} leaf area unit^{-1} time. In view of results at 45-60 DAS significantly highest NAR was recorded in NL-408 (0.104g dm^{-2} day^{-1}) followed by T-397 (NC) (0.094g dm^{-2} day^{-1}) than PKV NL-260 (LC) (0.081g dm^{-2} day^{-1}) were found at par with each other. In view of results significantly lower NAR was recorded in genotypes TL-99 (0.049g dm^{-2} day^{-1}), LSL-93 (0.051g dm^{-2} day^{-1}), NL-339 (0.055 g dm^{-2} day^{-1}), NL-371 (0.060 g dm^{-2} day^{-1}), NL-369 (0.067 g dm^{-2} day^{-1}), NL-367 (0.075 g dm^{-2} day^{-1}) and NL-407 (0.076 g dm^{-2} day^{-1}) over best check genotype. Shipley (2006) conducted a field experiment to investigate Net Assimilation Rate, specific leaf area and leaf mass ratio which is most closely correlated with Relative Growth Rate. He compiled 1240 observations (614 species) from 83 different experiments in 37 different studies, to quantify the relative importance of Net Assimilation Rate (NAR). The study showed NAR was the best general predictor of variation in RGR. Physiological parameters *viz.*, leaf area index, Crop Growth Rate, Relative Growth Rate and Net Assimilation Rate of different varieties of rice grown under different planting geometries and depths in SRI were studied by Rajput *et al.* (2017) [19].

Crop Growth Rate (g m^{-2} day^{-1})

At flowering stage i.e., 45-60 DAS significantly maximum CGR was noticed in genotype NL-408 (4.939 g m^{-2} day^{-1}) followed by check variety T-397 (NC) (4.780 g m^{-2} day^{-1}) & were found at par followed by NL-407 (4.007 g m^{-2} day^{-1}). Genotype TL-99 (1.711 g m^{-2} day^{-1}) recorded significantly lowest CGR compared with other genotypes. Genotypes LSL-93 (2.455 g m^{-2} day^{-1}), NL-339 (2.495 g m^{-2} day^{-1}), NL-367 (2.538 g m^{-2} day^{-1}), NL-371 (2.825 g m^{-2} day^{-1}), and NL-369 (3.753 g m^{-2} day^{-1}) were recorded moderated CGR & recorded significantly lowest CGR found check genotypes PKV NL-260 (LC) (4.069 g m^{-2} day^{-1}) and T-397 (4.780 g m^{-2} day^{-1}). Similar result also reported in Indian mustard (*Brassica Juncea*) by Panda *et al.* (2004) [15]. They reported that Crop Growth Rate was increase between 42 to 72 DAS. Irrigation applied to the crop at flowering and pod development stages increase the CGR by 81.10% higher as compared to the unirrigated plot. Similar results also reported in mustard by Maurya *et al.* (2022) [13].

Drought tolerance study

Relative water content (%)

The data recorded about the RWC were found statistically significant at 45 DAS. The range of RWC recorded was 64.27 to 72.50%. At 60 DAS the range of RWC recorded was 61.67 to 68.77%.

At 90 DAS the range of RWC recorded was 51.66 to 64.53%. Genotype NL-339 recorded significantly highest LRWC (64.53%) than both checks. However, these genotypes were found, at par among themselves. NL-367 recorded significantly lowest LRWC (51.66%) followed by TL-99 (53.77%). These genotypes are found at par with each other. Similar observations had been state that our results showed that under WS conditions RWC was decreased by 12-13% and these results are comparable to those of Son *et al.* (2011) [26], Seyni *et al.* (2010) [22], Pinto *et al.* (2014) [17] in sesame, who stated that the plants adapt their vegetative apparatus by reducing leaf area, leaf water content, radial, and vertical growth to resist WS conditions.

Germination stress index (%)

The range germination stress index recorded was 38.33 to 51.67%. The significantly highest germination stress index was recorded in genotype PKV NL-260 (LC) (51.67%) followed by NL-369 (50.42%) and NL-371 (49.71%) were found at par with each other. More than 50% of germination occurred under water stress condition which was called as drought tolerant genotype. Our results supported by findings of Dharanguttikar *et al.* (2015) [17] On the basis of stress parameters, the genotypes, NBeG 47-1, PBC-161 and BBG-2 for germination, GJG-1010 and PBC-161 for seedling growth and NBeG 47-1 and PBC-161 for higher dry matter production were found to be moisture stress tolerance. (Debez *et al.* 2004) [6]. Our results indicate that water stress had a strong inhibitory effect on germination, with germination rates gradually decrease with PEG concentration. The similar genotypes maintain maximum GSI.

Dry matter stress index

The data recorded about dry matter stress index was found statistically significant. The range of dry matter stress index recorded was 72.93 to 94.43%. The dry matter stress index was recorded highest in genotype PKV NL-260 (LC) (94.43%) followed by NL-369 (93.04%), NL-371 (92.56%) and NL-339 (92.50%)

Yield and yield contributing parameters

Yield is a complex character determined by several traits, internal plant processes and environmental factors. Data on effect of water stress on yield and yield contributing characters like number of seed capsules^{-1}, 1000 seed weight (g), number of capsules plant^{-1}, seed yield plant^{-1}, plot^{-1}, ha^{-1}, harvest index are presented, and results obtained are discussed under following headings

Number of capsules plant^{-1}

The range of capsules plant^{-1} was 29.00 to 61.67 capsules. The highest number of capsules plant^{-1} was recorded in genotype T-397 (61.67) followed by NL-369 (61.00) and NL-371 (53.67) however, found at par with each other. In present study this, findings conformity with Sravanti *et al*. (2021) [31] show that seed yield indicated that the plant height and number of capsules plant^{-1} were highly and positively correlated with seed yield under both well-watered and water stressed conditions.

Number of seeds capsule^{-1}

The range of number of seeds capsule^{-1} was 7.67 to 9.00 capsules. Results in present study correlates with findings of Rahimi Nader *et al.* (2020) [18] showed that rainfed condition compared to supplementary irrigation cause to decrease biological yield, 1000 seed weight, plant height, number of seeds per capsule and oil per cent.

Test weight (1000 Seed Weight) (g)

The range of test weight was 5.61 to 7.92 grams. Significantly highest test weight was recorded in genotype LSL-93 (7.92 g) over both check genotypes PKV NL-260 (LC) (7.59 g) and T-397 (NC) (5.75 g) in respect of test weight. Recorded observation are comparable with observation of Maurya *et al.* (2022) [13] observed that Increment in growth attributing characters were ultimately reflected in yield attributing characters. And Pande *et al.* (1970) [14] reported in field experiment of linseed, test weight slightly decreases in stressed condition.

Seed yield

The maximum seed yield plant^{-1}, plot^{-1} and hectare^{-1} were recorded in best check genotype PKV NL-260 (LC). The range in seed yield plant^{-1}, plot^{-1} and ha^{-1} was 1.77 g, 226.56 g and 472 kg in genotype NL-367 to 3.56 g, 502.34 g and 1046.73 kg in genotype PKV NL-260 (LC) respectively. Kumar *et al.* (2002) found that seed yield exhibited significant positive association with: harvest index, pods per plant, seeds per pod, biological yield per plant. Singh *et al.* (2002) [25] found that seed yield per plant, chlorophyll content and chlorophyll stability index. Seed yield is influenced by morpho-physiological parameters such as plant height, total dry matter production, leaf area, number of seeds and test weight which are considered as yield contributing parameters.

Harvest index (HI)

Significantly maximum harvest index was recorded in genotype NL-369 (34.17%) and minimum in NL-367 (24.59%). The range of harvest index was 24.59 to 34.17%.

Table 1: Plant height (cm), Number of leaves plant^{-1}, Total dry weight plant^{-1} (g), Leaf area plant^{-1} and Days to maturity

Genotypes	Morpho-physiological observations																	
	Plant height (cm)				Number of leaves plant^{-1}				Total dry weight plant^{-1} (g)				Leaf area plant^{-1} (dm^2)				Days to 50% flowering	Days to maturity
	30 DAS	45 DAS	60 DAS	90 DAS	30 DAS	45 DAS	60 DAS	90 DAS	30 DAS	45 DAS	60 DAS	90 DAS	30 DAS	45 DAS	60 DAS	90 DAS		
NL-339	13.67	22.00	42.67	54.67	63.33	90.67	175.67	115.00	1.50	2.17	3.86	6.80	1.49	2.14	4.14	2.71	50.00	115.33
NL-367	13.10	16.67	21.00	24.67	52.67	81.67	112.67	91.33	0.83	1.53	3.25	5.43	1.24	1.92	2.66	2.15	47.00	99.00
NL-369	13.67	21.67	38.67	55.67	58.67	111.00	227.00	167.67	0.93	2.27	4.80	6.70	1.38	2.62	5.35	3.95	49.00	117.00
NL-371	14.17	21.00	47.67	54.00	64.33	99.33	175.00	125.33	1.00	1.73	3.64	6.30	1.52	2.34	4.12	2.95	58.00	118.33
NL-407	14.50	18.67	40.00	53.67	51.67	94.67	230.00	201.33	0.90	2.17	4.87	8.00	1.22	2.23	5.42	4.75	56.00	119.00
NL-408	14.17	19.67	39.00	47.00	47.33	85.33	206.33	182.67	0.81	1.40	4.73	6.66	1.11	2.01	4.86	4.31	50.00	114.33
TL-99	11.83	19.67	39.00	45.00	54.33	66.00	146.67	108.00	0.70	1.47	2.62	5.80	1.28	1.56	3.46	2.55	45.00	106.00
LSL-93	13.83	19.00	24.67	32.07	74.33	99.33	187.33	154.67	1.10	1.80	3.46	7.13	1.75	2.34	4.41	3.64	47.00	109.00
PKV NL-260 (LC)	13.00	21.00	49.67	54.33	54.33	110.67	180.67	158.67	0.53	1.57	4.31	7.97	1.28	2.61	4.26	3.74	58.00	107.00
T-397 (NC)	11.33	19.33	48.67	52.33	54.67	102.00	200.67	176.00	0.40	1.13	4.36	6.50	1.29	2.41	4.73	4.15	58.00	109.67
SE (m) ±	1.02	1.32	2.13	2.33	4.13	6.98	10.02	9.01	0.06	0.10	0.22	0.35	0.10	0.16	0.24	0.21	0.53	2.57
CD at 5%	-	3.91	6.33	6.93	12.43	20.85	29.78	26.78	0.18	0.28	0.58	1.05	0.29	0.49	0.70	0.63	1.76	7.64

Table 2: Relative Growth Rate (g g^{-1} day^{-1}), Net Assimilation Rate (g dm^{-2} day^{-1}), Crop Growth Rate (g m^{-2} day^{-1})

Genotypes	Growth Analysis observations											
	Relative Growth Rate (g g^{-1} day^{-1})				Net Assimilation Rate (g dm^{-2} day^{-1})			Crop Growth Rate (g m^{-2} day^{-1})				
	30 DAS	45 DAS	60 DAS	90 DAS	30 DAS	45 DAS	60 DAS	90 DAS	30 DAS	45 DAS	60 DAS	90 DAS
NL-339	0.025	0.038	0.019	0.025	0.038	0.055	0.044	0.038	1.003	2.495	2.180	1.003
NL-367	0.041	0.050	0.017	0.041	0.046	0.075	0.045	0.046	1.037	2.538	1.620	1.037
NL-369	0.060	0.050	0.011	0.060	0.069	0.067	0.021	0.069	1.975	3.753	1.407	1.975
NL-371	0.037	0.049	0.018	0.037	0.039	0.060	0.038	0.039	1.086	2.825	1.970	1.086
NL-407	0.059	0.054	0.016	0.059	0.076	0.076	0.031	0.076	1.871	4.007	2.318	1.871
NL-408	0.040	0.081	0.012	0.040	0.039	0.104	0.021	0.039	0.869	4.939	1.429	0.869
TL-99	0.049	0.039	0.027	0.049	0.056	0.049	0.053	0.056	1.136	1.711	2.355	1.136
LSL-93	0.033	0.043	0.024	0.033	0.035	0.051	0.046	0.035	1.037	2.455	2.690	1.037
PKV NL-260 (LC)	0.073	0.067	0.021	0.073	0.055	0.081	0.046	0.055	1.531	4.069	2.706	1.531
T-397 (NC)	0.070	0.090	0.014	0.070	0.041	0.094	0.024	0.041	1.086	4.780	1.585	1.086
SE (m) ±	0.004	0.004	0.001	0.004	0.005	0.004	0.003	0.005	0.11	0.26	0.14	0.11
CD at 5%	0.013	0.013	0.004	0.013	0.015	0.013	0.008	0.015	0.32	0.77	0.42	0.32

Table 3: Relative water content (%), Germination stress index (%) and Dry matter stress index (%)

Genotypes	Drought tolerant observations					
	Relative water content (%)				Germination stress index (%)	Dry matter stress index (%)
	30 DAS	45 DAS	60 DAS	90 DAS		
NL-339	75.03	70.29	66.65	64.53	47.92	92.50
NL-367	76.30	67.45	64.45	51.66	36.67	72.93
NL-369	76.03	65.49	63.61	59.01	50.42	93.04
NL-371	76.49	64.27	61.67	59.14	49.71	92.56
NL-407	76.66	68.33	63.33	60.42	45.83	89.93
NL-408	75.66	64.50	62.57	58.81	40.83	75.95
TL-99	74.26	69.50	65.11	53.77	38.33	73.39
LSL-93	76.49	68.83	65.50	58.75	42.50	83.24
PKV NL-260 (LC)	74.92	72.50	68.77	57.99	51.67	94.43
T-397 (NC)	74.83	70.00	67.67	57.30	44.58	87.12
SE (m) ±	1.05	1.42	1.63	1.99	1.31	0.66
CD at 5%	-	4.22	4.84	5.92	3.79	1.92

Table 4: Test weight, Number of capsules $plant^{-1}$, Seed yield $plant^{-1}$ (g), Seed yield $plot^{-1}$ (kg), Seed yield ha^{-1} (q) and Harvest index (%).

Genotypes	Test weight (g)	Number of capsules $plant^{-1}$	Seed yield $plant^{-1}$ (g)	Seed yield $plot^{-1}$ (kg)	Seed yield ha^{-1} (q)	Harvest index (%)
NL-339	7.18	44.33	2.78	358.62	747.13	28.99
NL-367	7.52	29.00	1.77	226.56	472.00	24.59
NL-369	6.19	61.00	3.45	458.41	955.01	34.17
NL-371	6.51	53.67	3.22	441.14	919.04	33.81
NL-407	7.17	48.33	2.44	336.26	700.55	23.41
NL-408	6.15	50.33	2.26	305.55	636.56	25.38
TL-99	5.61	34.00	1.84	251.62	524.22	24.00
LSL-93	7.92	37.67	2.51	326.30	679.79	25.92
PKV NL-260 (LC)	7.59	57.67	3.56	502.43	1046.73	30.97
T-397 (NC)	5.75	61.67	2.31	328.02	683.38	26.17
SE (m) ±	0.09	2.79	0.18	24.04	50.09	1.63
CD at 5%	0.26	8.29	0.53	71.44	148.83	4.83

Conclusions

The genotypes of linseed in rainfed moisture stress condition showed significant variation in morpho-physiological parameters *viz*. number of leaves, total dry weight, leaf area, leaf area index, RGR, NAR and CGR were recorded significantly higher values in PKV NL-260 followed by NL-371 and NL-369 which are said to be drought tolerant genotypes. NL-339 and T-397 recorded moderately higher which moderately tolerant genotypes towards moisture stress. Genotypes NL-367 followed by TL-99, LSL-93, NL-408 and NL-407 recorded significantly lowest morpho-physiological traits mention above which are said to be drought susceptible genotypes.

None of the genotypes showed significant increment in yield attributing characters under rainfed moisture stress condition over best PKV NL-260 local check genotype. PKV NL-260 followed by NL-369 and NL-371 recorded significantly highest values for yield and yield attributing traits, *viz*., Yield and yield attributing characters (number of capsules $plant^{-1}$, number of grain $capsule^{-1}$, test weight, seed yield $plant^{-1}$, seed yield $plot^{-1}$ and seed yield $hectare^{-1}$), which are said to be drought tolerant genotypes. NL-339 and T-397 genotypes recorded moderately yield and yield attributing traits values by which are said to be moderately tolerance to drought. Genotypes NL-367 followed by TL-99, LSL-93, NL-408 and NL-407 recorded lowest yield and yield attributing traits which are said to be drought susceptible genotypes.

Genotypes PKV NL-260 (34.77%), NL-369 (28.48%), NL-371 (25.68%) and NL-339 (8.57%) recorded higher seed yield over national check variety T-397.

On the basis of stress indices like, GSI & DMSI respectively showed that NL-369(50.42%, 93.04%), NL-371(49.17%, 92.56%) and NL-339(47.92%, 92.50%) were found drought tolerant genotypes which were at par with PKV NL-260 (LC) (51.67%, 94.43%).

The genotype of linseed under rainfed moisture stress condition study, local check PKV NL-260 (LC) was significantly superior due to enhanced all morpho-physiological, chemical and biochemical and yield contributing characters. However, genotypes NL-369, NL-371 were also at par, which were said to be drought tolerant. Hence, these genotypes may be used for further linseed crop improvement programme. Genotypes NL-339 and T-397 recorded moderate values which are said to be moderate drought tolerant NL-367 followed by TL-99, LSL-93, NL-408 and NL-407 recorded lowest values which are said to be drought susceptible genotypes.

References

1. Abidoye TO. Effects of soil moisture content on growth and yield of cowpea (*Vigna unguiculata* (L) Walp). B. Agric. Dissertation, University of Ilorin, Nigeria; c2004.
2. Abayomi YA, Abidoye TO. Evaluation of cowpea genotypes for soil moisture stress tolerance under screen house conditions. African Journal of Plant Science. 2009;3(10):229-237.
3. Barrs HD, Weatherly PE. Physiological indices for high yield potential in wheat. Indian Journal of Plant Physiology. 1962;25:352-357.
4. Boyer Y. Preliminary studies of the mechanisms of accelerate development induced by temporary drought. Archives of Biochem and Biophysic. 1975;260(1):7283-86.
5. Bray EA, Bailey J, Weretilnykn E. Responses to abiotic stresses; In Biochemistry and molecular biology of plants eds. (B. Buchanau, W. Gruissem and R.L. Jones) Rockville, American Society of Pl physiologists App; c2000. p. 1158-1203.
6. Debez A, Hamed BK, Grignon C, Abdelly C. Salinity effects on germination, growth, and seed production of the halophyte Cakile maritime. Plant Soil. 2004;262:179-189.
7. Dharanguttikar VM, Bharud RW, Borkar VH. Physiological responses of chickpea genotypes for drought tolerance under induced moisture stress. Int J Scientific and Res Pub. 2015;5(9):1-11.
8. Fischer RA. Some remarks on the methods formulated in the recent article on the quantitative analysis of plant growth. Ann. appl. Bio. 1971;7:367-372.
9. George BW. High temperature seed dormancy in wheat (*Triticum aestivum* L.). Crop Sci. 1967;7:249-253.
10. Hiler EA, Van Babel CHM, Hossain MM, Jordan WR. Sensitivity of Southern Peas to Plant Water Deficit at Three Growth Stages 1. Agronomy Journal. 1972;64(1):60-64.
11. Jatoi WA, Baloch MJ, Kumbhar MB, Khan NU, Kerio MI. Effect of water stress on physiological and yield parameters at anthesis stage in elite spring wheat cultivars. Sarhad J Agric. 2011;27(1):59-65.
12. Kumar R, Sharma SK, Malik BPS, Dahiya A, Sharma A. Correlation studies in lentil (Lens culinaris Medik). Ann. Bio. Hisar. 2002;18(2):121-123.
13. Maurya SK, Kalhapure A, Singh N, Kumar A, Yadav P, Kumar M, *et al*. Growth and Yield Response of different Indian Mustard [*Brassica juncea* (L.)] varieties to Irrigation Scheduling. Biological Forum – An International Journal. 2022;14(3):434-439.
14. Pande RC, Singh M, Agrawal SK. Effect of different levels of irrigation, nitrogen and phosphorus on growth, yield and quality of linseed (*Linum usitatissimum* L.). Ind. J of Agronomy. 1970;15:125-130.
15. Panda BB, Shivay YS, Bandyopadhyay SK. Growth and development of Indian mustard (*Brassica juncea*) under different levels of irrigation and date of sowing. Ind. J of Plant Physiology. 2004;9(4):419-425.
16. Panse VG, Sukhatme PV. Statistical methods for Agricultural workers, I.C.A.R. Publication, New Delhi. 2nd Edn; c1954. p. 63-66.
17. Pinto C de M, Távora FJAF, Pinto OR de O. Water relations, gas exchange in peanuts, sesame and castor beans subjected to water deficit cycles. Technical Agriculture. 2014;35(1):31-40.
18. Rahimi N, Jalalian J, Pirzad A, Gholinezhad E. Evaluation of grain and oil yield changes of linseed (*Linum usitatissimum* L.) as affected by bio-fertilizers and supplementary irrigation. Pl. Ecophysiology (Arsanjan branch). 2020;12(41):41-52.
19. Rajput A, Rajput SS, Jha G. Physiological Parameters Leaf Area Index, Crop Growth Rate, Relative Growth Rate and Net Assimilation Rate of Different Varieties of Rice Grown Under Different Planting Geometries and Depths in SRI. Int. J Pure App. Biosci. 2017;5(1):362-367.
20. Sanap MM, Munge HB, Deshmukh DV. Growth and yield variation in chickpea for drought tolerance. J of Maha Agri Univer. 2004;29(2):143-145.
21. Sammar Raza MA, Saleem MF, Khan IH, Jamil M, Ijaz M, Khan MA. Evaluating the drought stress tolerance efficiency of wheat (*Triticum aestivum* L.) cultivars. Russian J of Agri and Socio-Economic Sci, No. 2012;12(12):41-46.
22. Seyni B, Diouf M, Cisse N. Need for water, growth and productivity of sesame (*Sesamum indicum* L.) in semiarid zone. Ceraas/Isra. 2010;22(2):139-147.
23. Shipley B. Net assimilation rate, specific leaf area and leaf mass ratio which is most closely correlated with relative growth rate A meta-analysis. Funct. Ecol. 2006;20:565-574.
24. Shikh F, Toorchi M, Valizadeh M, Shakiba MK, Islam BP. Drought resistance evaluation in spring rapeseed cultivars. Agricultural Sciences-Tabriz. 2005;15(1):163-174.
25. Singh B, Usha K. Salicylic acid induced physiological and biochemical changes in wheat seedlings under water stress. Plant Growth Regulation. 2002;39(2):137-141.
26. Son D, Compaore E, Bonkoungou S, Sangare S. Effect of water stress on sesame growth and production (*Sesamum indicum* L.). Journal of Applied Biosciences. 2011;37;2460-2467.
27. Sravanthi AL, Ratnakumar P, Reddy SN, Eswari KB, Pandey BB, Manikanta C, *et al*. Morpho-physiological, quality traits and their association with seed yield in sesame (*Sesamum indicum* L.) indigenous collection

under deficit moisture stress. Pl. Physio. Reports. 2022;27(1):132-142.
28. Wang Min, Zhang Cong Yu, Ma Tong Fu, Yao Weichuan. Studies of drought tolerance of soyabean cultivars at their seedling stage, Chinese J of Oil Crop Sci. 2004;26(3):29-32.
29. Watson DJ. The dependence of net assimilation rate on leaf-area index. Annals of Botany. 1958;22(1):37-54.
30. Williams RF. The physiology of plant growth with special references to the concept of net assimilation rate. Ann. Bot. 1946;10(1):41-42.
31. Karki U, Sravanti L. Excess Screen time-impact on childhood development and management: A Review. Journal of National Medical College. 2021 Jul 19;6(1):40-45.