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RESEARCH ARTICLE

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Effect of Moisture Stress on Dry Matter Production, Dry Matter Partitioning and yield in Groundnut (*Arachis hypogea* L.) Genotypes

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ABSTRACT

Background: Drought is a leading abiotic factor limiting groundnut production globally. Therefore, the screening and development of moisture stress tolerant groundnut genotypes is a key issue towards sustainable agriculture.

Methods: An experiment was laid in a split plot design taking two conditions, control (T_1) and moisture stress (T_2) as main treatments and 7 genotypes of groundnut as sub treatments. Several morpho-physiological traits like dry matter production, dry matter partitioning, photosynthetic traits, relative water content, were measured after 10 days of stress imposition. Yield and yield attributes were also recorded at harvest along with drought tolerance index and principal component analysis.

Result: Results showed significant differences among the genotypes at moisture stress and control conditions. Significant decrease was observed in chlorophyll content, total dry matter production, dry matter partitioning efficiency, relative water content, photosynthetic traits, except specific leaf area among all the genotypes. TCGS-1694 have been identified as moisture stress-tolerant genotypes in principal component analysis with higher efficiency interms of total dry matter production, photosynthetic rate, dry matter partitioning to pods, stress tolerance index, yield and yield attributes while Kadiri-6 has been identified as susceptible genotype.

Key words: Dry matter partitioning efficiency, Principal component analysis, Stress tolerance index.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.,) is one of the world's most important legumes. Groundnut is from the *Fabaceae* family and it is grown worldwide on 49.9 million ha across 82 countries (Radhakrishnan *et al*., 2022). Drought stress (moisture stress) is a major threat to plant growth and productivity. Around 60% of the world's groundnut production fall under arid and semi-arid regions, where groundnut are frequently subjected to drought stress (Reddy *et al*., 2003). An annual estimated loss in groundnut production equivalent to over US$520 million is caused by drought (Kambiranda *et al*., 2011). Therefore, it is mandatory to take measures to improve plant's performance during drought conditions in order to sustain productivity in future.

Groundnut being relatively indeterminate in growth habit is particularly sensitive to drought stress during the vegetative and reproductive stages, *i.e*., peg formation and pod filling (Mateva, 2022). Drought has an adverse effect on groundnut growth, physiology, pod filling, number of pods, and pod yield. The partitioning of photosynthates into developing pods has been found to be the most significant physiological characteristic in yield determination, aside from the number of pods and the duration of the pod filling phase in groundnut, where vegetative and reproductive sinks work concurrently (Haro *et al*., 2022). The difference in the ability of genotypes to produce pods under drought conditions is ascribed to partitioning differences between genotypes. There are two distinct mechanisms for drought recovery, including the capacity to produce pods during drought stress conditions and the ability to recover from drought with greater pod yield (Wang *et al*., 2022). Therefore, it is necessary for promising genotypes to be tested for higher partitioning efficiency to pods and yield under both normal and drought stress. Studies carried out on groundnut genotypes showed that there exists genotypic variation in the degree of drought tolerance among different varieties (Abady *et al*., 2021, Sowmya and Nadaf, 2022). Therefore screening of groundnut genotypes drought tolerance is the research priority.

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MATERIALS AND METHODS

A field experiment was carried out at Regional Agricultural research station, Tirupati during *rabi*, 2020 and 2021 to

"Effect of moisture stress on dry matter production, dry matter partitioning and yield in groundnut (*Arachis hypogea* L.) genotypes". The experiment was laid in a split plot design taking two treatments *viz*. control (T_1), and moisture stress (T_2) as main treatments, and 7 genotypes as sub treatments. The genotypes are G_1: TCGS-1694, G_2: TCGS-1784, G_3: TCGS-1792, G_4: TCGS-1862, G_5: TCGS-2018, G_6: K-6, G_7: Kadiri 9.

Measurement of physiological parameters like SPAD Chlorophyll meter Reading (SCMR) using Minolta SPAD 502 m (Tokyo, Japan) was measured for the third fully expanded leaf from the top of the main stem. Total dry matter was measured at harvest. Then specific leaf area (SLA) was calculated using the formula

$$\text{SLA} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Leaf dry weight (g)}}$$

Relative water content (RWC) was recorded as described by Barrs and Weatherly (1962) using the formula

$$\text{RWC (\%)} = \frac{\text{(FW-DW)}}{\text{(TW-DW)}} \times 100$$

Where,
FW= Fresh weight.
DW= Dry weight.
TW= Turgid weight.

Dry matter partitioning was calculated by using of dry weights and following formula (Choyal *et al*., 2022).

Dry matter partitioning (%) =

$$\frac{\text{Dry weight of individual plant part (g)}}{\text{Total plant dry weight (g)}} \times 100$$

Measurement of photosynthetic gas exchange parameters was done portable photosynthesis system *i.e.*, InfraRed Gas Analyser (IRGA) (Model: Li-COR 3100).The automatic portable photosynthesis system recorded PAR, transpiration rate (E), net photosynthetic rate (PN) (µ mol CO_2 m^{-2} sec^{-1}), stomatal conductance (gs) (mole H, O m²/sec), Transpiration rate (E) (m. mole H, O m²/sec) and intercellular CO_2 concentration (Ci) (µmole CO, mole^{-1}) (Uni *et al*., 2021).

At the harvest of plants yield and yield attributes like hundred kernel weight (g), pod yield (Kg ha^{-1}), kernel yield (Kg ha^{-1}), shelling (%) and harvest index were recorded.

$$\frac{\text{Stress tolerance index (STI) values were calculated as yield under stress}}{\text{yield under control}} \times 100$$

The two years data was collected, pooled and was statistically analyzed following the analysis of variance (design split plot). Statistical significance was tested with an F test at the 5% level of probability and compared to the treatment means with critical difference. The multiple comparisons of mean values of different parameters in all cultivars performed by SPSS software. Principal component analysis (PCA) biplot was formulated using *fviz_pca* functions of the R statistical software.

RESULTS AND DISCUSSION

Total dry matter production and physiological parameters

Moisture stress has a major impact on plant physiological traits, which in turn reduces crop yields and total dry matter output (Hura *et al*., 2022). In the present study, moisture stress significantly inhibited the plant growth, in all groundnut genotypes significantly.

Under moisture stress condition, the SCMR was significantly higher in Kadiri-9 (47.00) and least by Kadiri-6 (30.22) (Fig 1A). The total dry matter production under moisture stress condition was significantly higher in TCGS-1694 (40.32 g/plant) and the genotype Kadiri-6 (28.26 g/plant) recorded lowest (Fig 1B). Moisture stress has been linked to a decrease in leaf chlorophyll due to the breakdown of pigments and there by reduction of photosynthates and dry matter production (Trifunovi *et al*., 2021). Similar inhibitions of growth and development induced by drought stress have been reported for barley (Istanbuli *et al*., 2021), tobacco (Xu *et al*., 2022), Wheat (Farid *et al*., 2021), millet (Kalagare *et al*., 2021) *etc*.,

A crucial functional characteristic and indicators for calculating plant responses to environmental change is specific leaf area (SLA) and Relative water content (RWC) (Chaimala *et al*., 2021). SLA and RWC reported a sharp decline in genotypes under moisture stress conditions over control conditions. Plants generally reduce SLA in response to moisture stress (Andivia *et al*., 2021). Under moisture stress conditions, genotype Kadiri-9 (62.50%) recorded significantly higher RWC and least by Kadiri-6 (40.56%) (Fig 1C). Genotype, TCGS-1694 (253.00) showed the highest SLA value and lowest in Kadiri-6 (188.60), (Fig 1D). Recent findings were also similar to results of the present study, where a drought-tolerant genotype had higher RWC than the susceptible genotypes (Khar *et al*., 2022).

Photosynthetic parameters

Photosynthesis and drought stress relationship is exceedingly complex. Photosynthetic attributes decreased significantly in moisture stress imposed plants. The photosynthetic attributes (Pn, gs, Ci and E) (Fig 2) were significantly higher in the genotype TCGS-1694 and the genotype Kadiri-6 recorded lowest. Under moisture stress, TCGS-1694 showed the highest Pn (24.56 µ mol CO_2 m^{-2} sec^{-1}), gs (0.40 mole H_2, O m²/sec), Ci (198.54 µmole CO_2, mole^{-1}) and E (4.42 m. mole H_2, O m²/sec) values, in contrast to Kadiri-6 (15.50 µ mol CO_2 m^{-2} sec^{-1}, 0.09 mole H_2, O m²/sec, 125.63 µmole CO_2, mole^{-1}, 1.22 m. mole H_2, O m²/sec respectively), in which the minimum were recorded. This effect has also been reported for drought stressed cotton (EL Sabagh *et al*., 2020), green gram (Amarapalli, 2022) and sugarcane (Misra *et al*., 2020).

Dry matter partitioning efficiency

Alongside of photosynthetic attributes, dry matter partitioning is the more important trait for the yield differences among the groundnut genotypes under control and moisture stress conditions. In the present study, mean data of 2 years regarding dry matter partitioning in the leaves, stem, roots and pods at 60, 80 days after sowing (DAS) and harvest for control and moistures stress conditions are depicted in Fig 3,4.

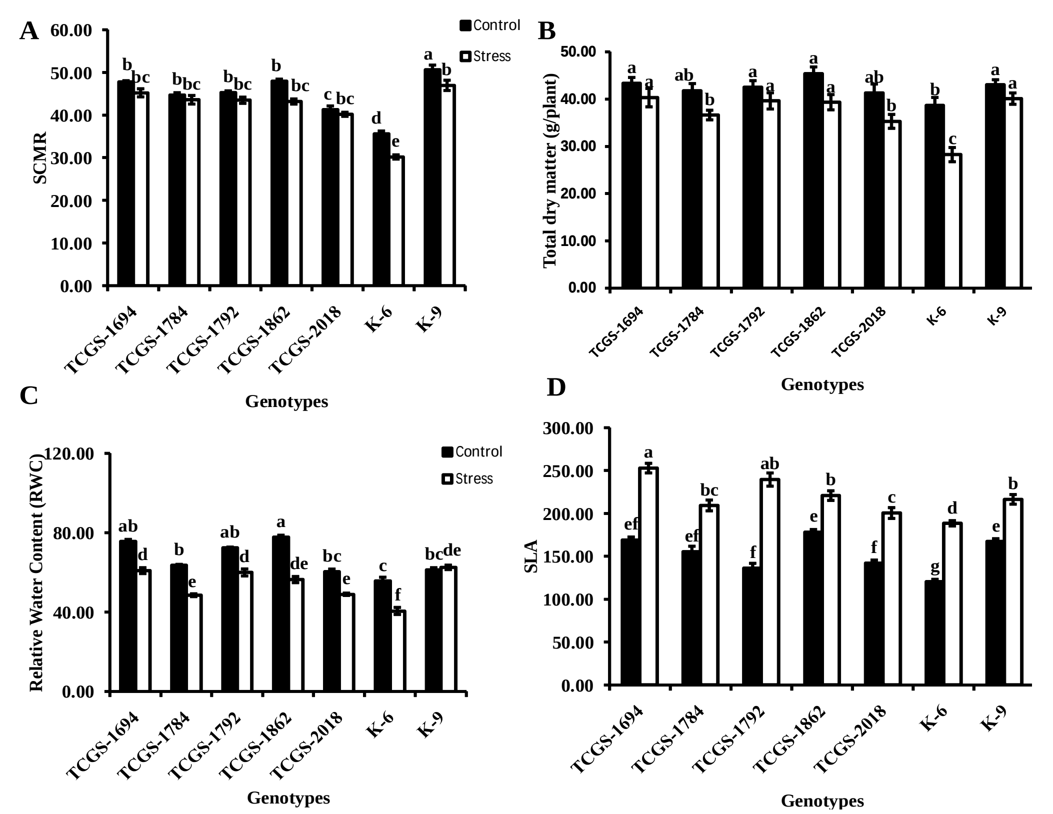
Under moisture stress conditions, at 60 DAS (Fig 4A) dry matter partitioning to leaves was significantly higher in the genotype, TCGS-1694 (60.69%). Groundnut genotype, TCGS-1694 with higher partitioning efficiency to leaf at 60 DAS representing more photosynthetic efficiency of the genotype. However, at 80 DAS (Fig 4B) and harvest (Fig 4C) dry matter partitioning to leaves was significantly higher in TCGS-2018 (39.81%). Genotype with higher partitioning from leaf to reproductive sinks coupled with better sink capacity is more important at 80 DAS under moisture stress conditions.

Both at 60 DAS and 80 DAS (Fig 4A,B) dry matter partitioning to stem was significantly higher in the Kadiri-6 (50% and 34.63%). Increased partitioning to stems result in lanky growth and lodging of plants. Both under control and stress conditions their no significant difference dry matter partitioing in roots at 60 DAS and 80 DAS respectively.

At 80 DAS and harvest (Fig 4 B and C) dry matter partitioning to pods was significantly higher in TCGS-1694 (54.97%). TCGS-1694 with higher Pn, total dry matter, dry partitioning to leaf resulted in higher dry matter partitioning to pods at grain filling phase. In plants, the reproductive sinks compete for dry matter with the vegetative organs thereby decreasing dry matter allocation to vegetative phase during seed development (Zhang *et al*., 2022). However, this phenomenon may be supplanted by translocation of stored assimilates produced prior to pod/kernel production in groundnut. On the same line, the Kadiri-6 with higher partition efficiency was observed to stem rather than sink. Such differential behaviour in total dry matter partitioning and its distribution among groundnut genotypes could also ascribe to genotypes' genetic characteristics (Salazar Licea, 2022).

Yield and yield parameters

Dry matter partitioning to pods may be a major cause of yield differences for groundnut genotypes. Under moisture stress conditions, TCGS-1694 recorded significantly higher pod yield (1316.70 kg/ha), harvest index (34.06), shelling percentage (62.99%), kernel yield (2674.95 kg/ha) and 100

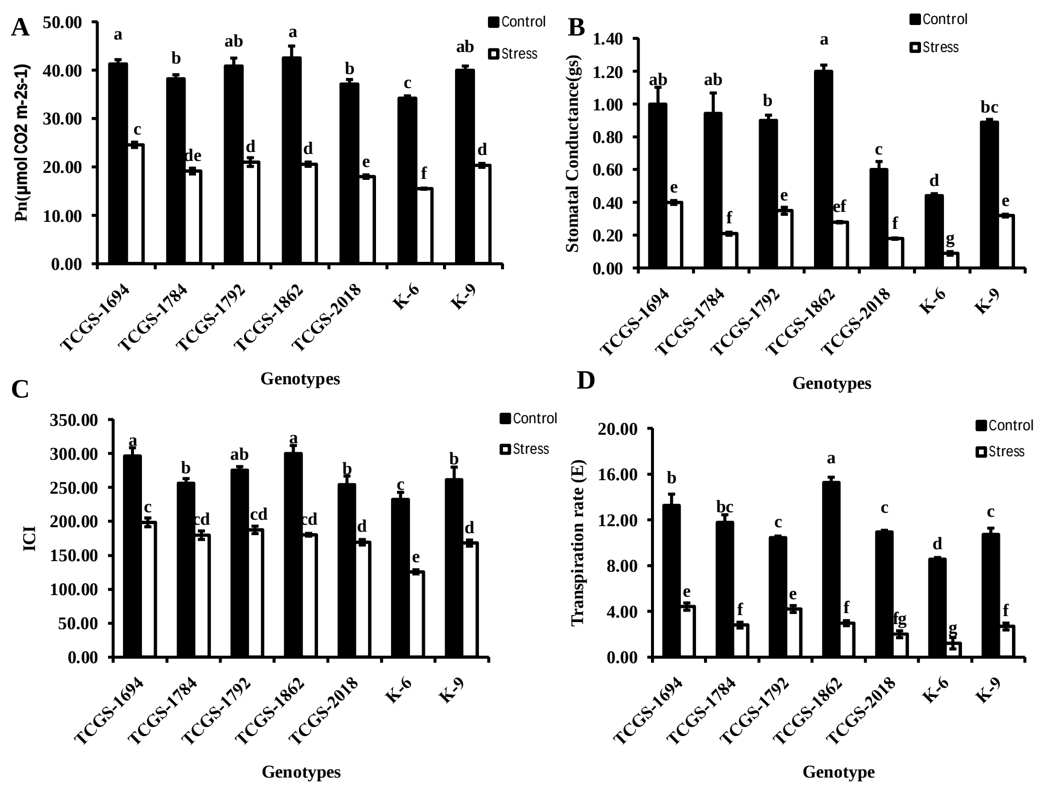


Foot notes: Values are represented in mean ± S.D. of 15 plants; Bars sharing the same superscript do not vary significantly from each other.

Fig 1: Effect of moisture stress on physiological parameters kernel weight (34.57 g) contrast to Kadiri-6 in which the lowest values (503.30 kg/ha, 20.66, 38.01%, 1324.10 kg/ha, 19.60 g respectively) were recorded (Table 1and2). Poorer dry matter partitioning observed in genotype Kadiri-6 may have contributed to its low yield despite the huge biomass partitioned to stem produced. Crop yield is increased by dry matter partitioned into sink (kernels). Genotype TCGS-1694 had significantly higher biomass coupled with higher partitioning efficiency to kernels in addition to high photosynthetic and harvest indices.

Variability of stress tolerance index (STI)

In the experiment, 7 genotypes of groundnut were subjected to evaluation at reproductive phase to moisture stress conditions (Table 2). Genotype TCGS-1694 recorded significantly higher stress tolerance index (63.71) and Kadiri-6 recorded lowest stress tolerance index (46.56). A high value of STI implies higher tolerance to stress. According to Kamrani *et al*. (2018) selection based on STI helps to determine high yielding genotypes.



Foot notes: Values are represented in mean ± S.D. of 15 plants; Bars sharing the same superscript do not vary significantly from each other.

Fig 2: Effect of moisture stress on photosynthetic parameters.

Table 1: Yield and yield attributes of groundnut genotypes as influenced by drought stress.

Genotype	Pod Yield (Kg ha^{-1})		Harvest Index		Shelling (%)	
	Control	Stress	Control	Stress	Control	Stress
TCGS-1694	2066.83±437.8^{ab}	1316.70±160.8^{a}	43.43±2.74^{b}	34.06±6.31^{a}	74.92±1.37^{ab}	62.99±26.79^{a}
TCGS-1784	2077.67±101.0^{ab}	1200.40±34.7^{b}	35.26±2.36^{c}	34.04±2.95^{a}	68.41±4.58^{ab}	58.70±20.34^{a}
TCGS-1792	2054.33±277.9^{ab}	1258.0±100.5^{ab}	42.47±3.97^{b}	33.13±4.01^{a}	75.47±5.68^{ab}	62.74±6.76^{a}
TCGS-1862	2108.57±176.4^{a}	1216.70±160.8^{a}	52.77±8.47^{a}	35.31±3.29^{a}	81.20±8.91^{a}	62.58±18.87^{a}
TCGS-2018	1789.25±83.5^{b}	938.30±143.7^{b}	27.67±3.06^{cd}	25.48±3.06^{ab}	66.52±2.63^{bc}	51.01±12.57^{ab}
K-6	1080.90±238.8^{c}	503.30±41.7^{c}	24.13±5.86^{cd}	20.66±6.82^{c}	52.64±1.52^{d}	38.01±12.57^{b}
K-9	1793.48±115.4^{b}	933.30±60.1^{b}	36.60±3.55^{c}	33.15±2.14^{a}	63.63±2.28^{bc}	62.17±18.65^{a}

Means with the same letters are not significantly different at 5% level of probability

Values Are Represented In Mean ± Standard Deviation; N = 15

Principal component analysis (PCA) biplot

The distribution of genotypes and traits in the PCA biplot explained the high variability of traits for principal components. PCA biplot for photosynthetic and yield traits depicted the 86.4% (control conditions) (Fig 5) and 88.3% (stress conditions) (Fig 6) of variability in the raw data (Fig 1). In PCA of all 7 genotypes, TCGS-1694 and TCGS-1792 genotypes had a significantly higher response for photosynthetic traits, specific leaf area and yield traits, while TCGS-1784, TCGS-1862, Kadiri-9 genotypes had a higher response for relative water content, total dry matter, SCMR, harvest index and shelling percentage in both control and stress conditions. However, under control conditions TCGS-1862 had higher response for photosynthetic traits and pod

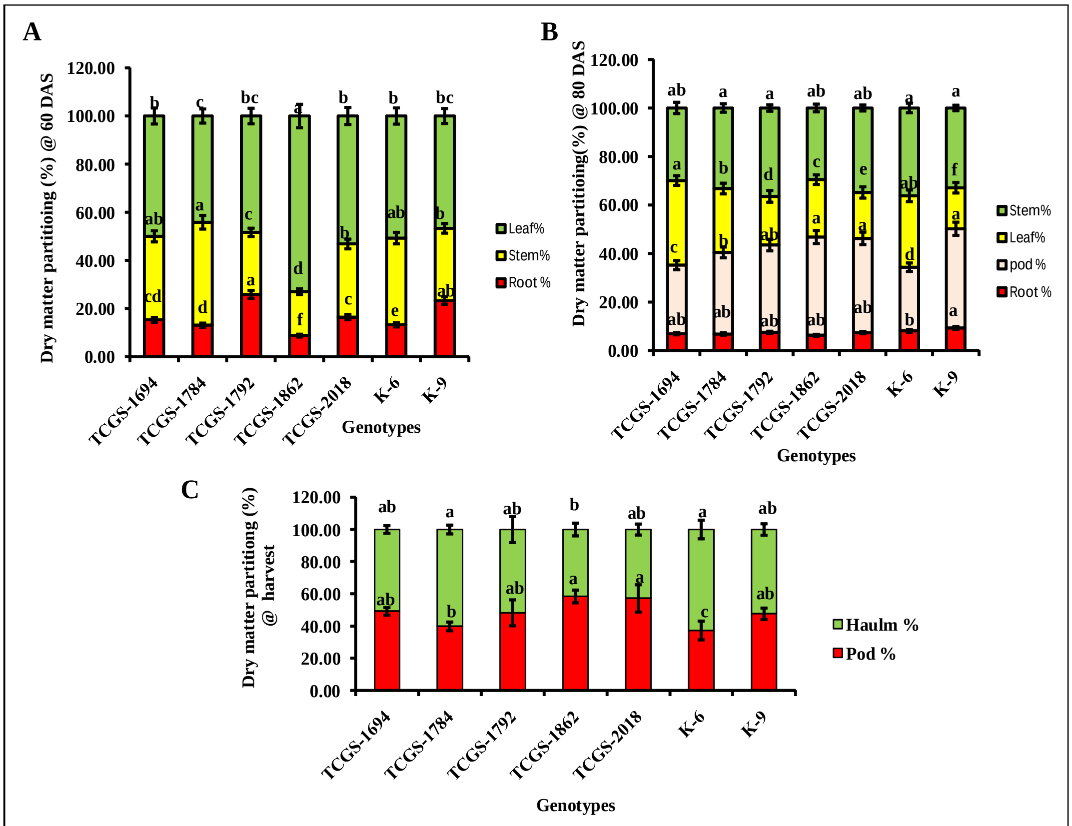
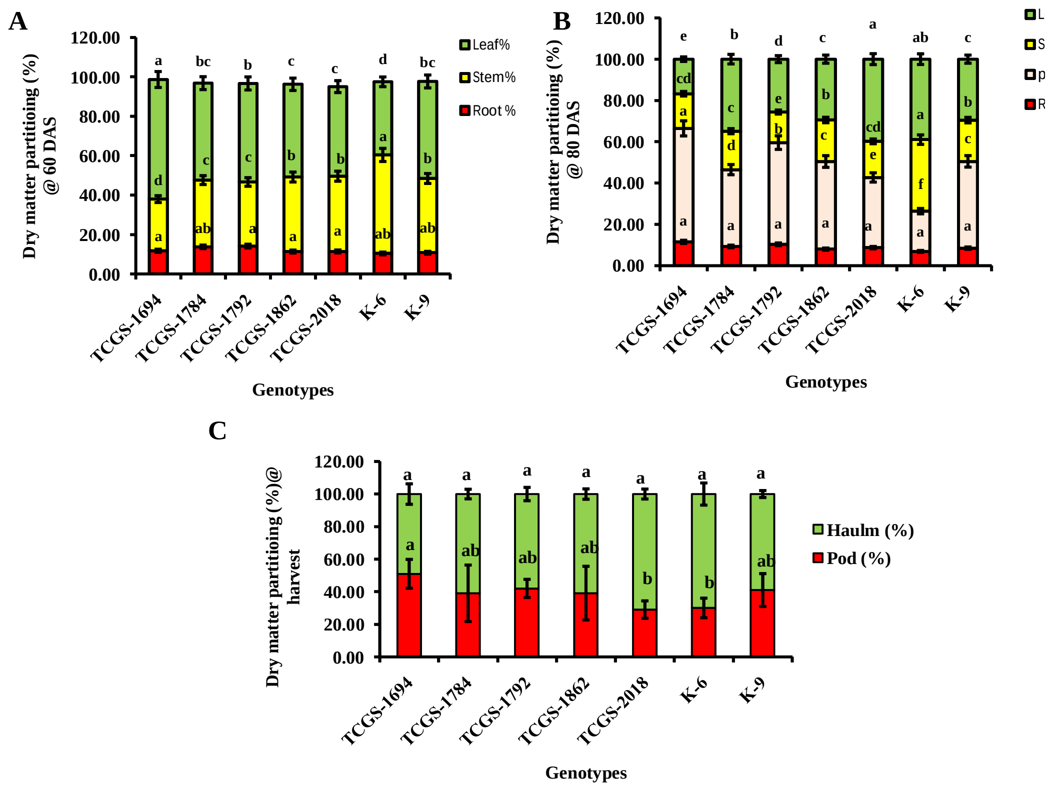


Fig 3: Effect of moisture stress on dry matter partitioning under control conditions.

Table 2: Yield and yield attributes of groundnut genotypes as influenced by drought stress.

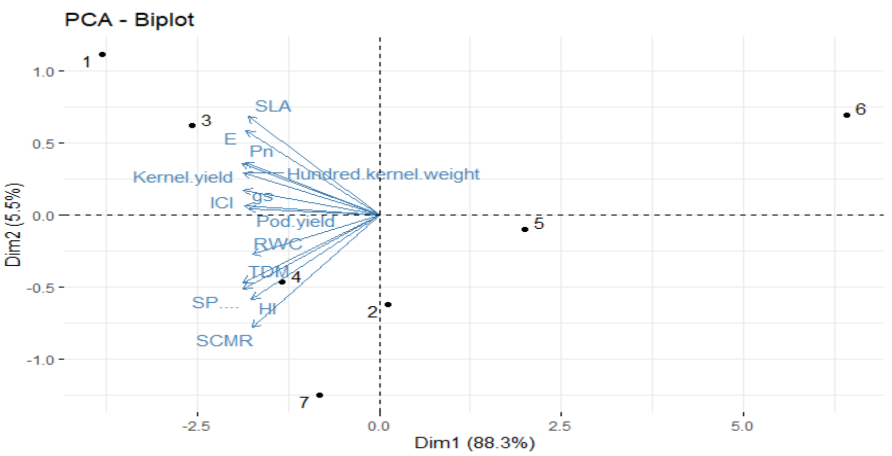
Genotype	Kernel yield (Kg ha^{-1})		Hundred kernel weight		Stress tolerance
	Control	Stress	Control	Stress	Index (STI)
TCGS-1694	3258.66±30.47^{b}	2674.95±58.37^{a}	46.03±8.47^{a}	34.57±2.59^{a}	63.71±2.3^{a}
TCGS-1784	3237.16±13.42^{b}	2019.99±40.50^{c}	44.50±4.95^{a}	28.57±3.66^{b}	57.78±2.8^{b}
TCGS-1792	3252.43±99.75^{b}	2469.55±22.08^{ab}	46.07±6.58^{a}	34.50±2.78^{a}	61.24±3.2^{a}
TCGS-1862	3581.95±43.83^{a}	2197.08±10.18^{b}	48.97±10.77^{a}	32.43±1.91^{a}	57.71±2.5^{b}
TCGS-2018	2877.21±16.1^{c}	1995.68±94.69^{d}	34.27±0.31^{b}	26.57±0.95^{c}	52.54±2.6^{c}
K-6	1429.03±50.19^{d}	1324.10±40.39^{e}	24.63±4.16^{c}	19.60±0.36^{d}	46.56±3.2^{d}
K-9	2818.80±68.98^{c}	2057.85±13.95^{c}	41.50±3.22^{a}	27.37±0.32^{b}	52.04±3.1^{c}

Means with the same letters are not significantly different at 5% level of probability.
Values Are Represented In Mean ± Standard Deviation; N = 15.



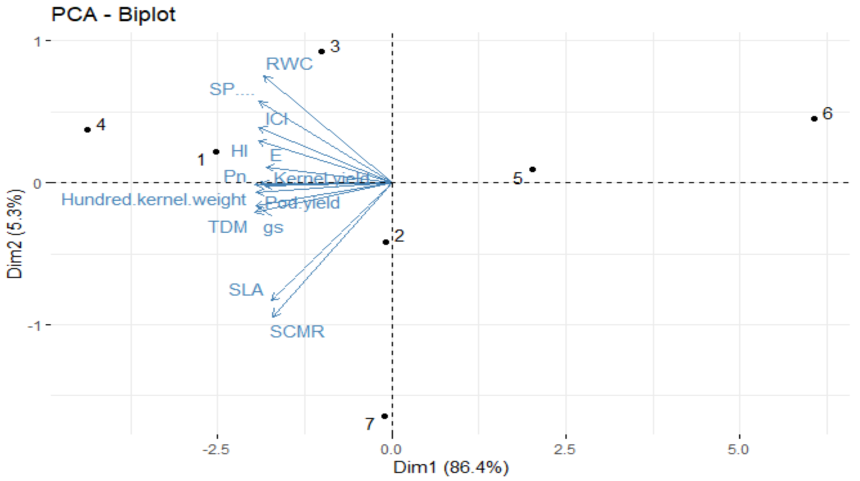
Foot notes: Values are represented in mean ± S.D. of 15 plants; Bars sharing the same superscript do not vary significantly from each other.

Fig 4: Effect of moisture stress on dry matter partitioning under moisture conditions.



Foot notes: Physiological traits and genotype numbers are represented in principal component analysis (PCA) biplot viz., Physiological traits are SLA (specific leaf area), E (transpiration rate), Pn (photosynthetic rate), gs (stomatal conductance), Ci (Inter cellular carbon dioxide), relative water content (RWC), TDM (total dry matter), SP (Shelling percentage) and SCMR (SPAD chlorophyll meter reading) genotypes are 1: TCGS-1694, 2: TCGS-1784, 3: TCGS-1792, 4: TCGS-1862, 5: TCGS-2018, 6: K-6, 7: K-9.

Fig 5: Principal component analysis (PCA) biplot of genotypes and traits under control conditions.



Foot notes: Physiological traits and genotype numbers are represented principal component analysis (PCA) biplot viz., Physiological traits are SLA (specific leaf area), E (transpiration rate), Pn (photosynthetic rate), gs (stomatal conductance), Ci (Inter cellular carbon dioxide), relative water content (RWC), TDM (total dry matter), SP (Shelling percentage) and SCMR (SPAD chlorophyll meter reading) genotypes are 1: TCGS-1694, 2: TCGS-1784, 3: TCGS-1792, 4: TCGS-1862, 5: TCGS-2018, 6: K-6, 7: K-9.

Fig 6: Principal component analysis (PCA) biplot of genotypes and traits under moisture stress conditions.

yield. Genotypes TCGS-1694 and TCGS-1792 have been identified as drought-tolerant genotypes, while Kadiri-6 has been identified as susceptible genotype.

CONCLUSION

The present study showed, on the one hand, a significant environmental effect on genotypic performance: moisture stress is the main factor reducing growth and pod yield groundnut. On the other hand, dry matter partitioning and photosynthetic traits served as helpful tools to screen moisture stress-tolerant genotypes. Our results revealed TCGS-1694 and TCGS-1792 genotypes were the most moisture stress tolerant genotypes, attaining higher dry matter partitioning to pods, higher pod yield under moisture stress conditions. TCGS-1862 reported higher dry matter partitioning to pods and pod yield under control conditions. However, Kadiri-6 is susceptible genotypes.

Conflict of interest: None.

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