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PHYSIOLOGICAL STUDIES ON DROUGHT TOLERANCE IN LEGUME CROP ARACHIS HYPOGAEA

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ABSTRACT
*Groundnut (*Arachis hypogaea *L.) is an important legume crop valued for its high oil (43–55%) and protein (25–28%) content, serving as a major source of income and nutrition for farmers in tropical and subtropical regions. Although moderately drought-tolerant, its yield is highly affected by irregular rainfall and water scarcity. This study investigates the physiological responses of groundnut under varying levels of drought stress during different growth stages. Key drought-adaptive traits such as dehydration avoidance, stomatal regulation, root system efficiency, and osmotic adjustment were analyzed to understand their contribution to yield stability under stress conditions. Results indicate that integrated physiological traits play a crucial role in enhancing drought tolerance and sustaining productivity. Strategies such as crop duration adjustment, soil moisture conservation, and nutrient optimization showed promising potential for improving recovery after drought. The findings suggest that targeted physiological approaches combined with agronomic management can significantly enhance the drought resilience of groundnut, ensuring stable yields in arid and semi-arid environments.*
Keywords: *Drought-resistant varieties, Drought stress, Drought-stress management, Environments, Groundnut (Arachis hypogea L.), Water use efficiency.*

INTRODUCTION

Oilseeds are among the most ancient agricultural crops and hold a crucial position in the Indian national economy. [1] They are crucial to human existence, ranking with dietary grains in fulfilling diverse human needs. They represent approximately 10% of the cultivated area and the value of all agricultural output. Long before the advent of kerosene and energy, vegetable oils were utilized as illuminants to illuminate human habitats. [2] Oilseeds significantly influence the community's standard of living, as their oils serve not only as edible products but are also essential for the production and formulation of soaps, toiletries, hair oils, paints, varnishes, and lubricants. [3] In the 1950s, groundnut and sesame oil were utilized for industrial uses and export; however, such usage has been prohibited since July 1964. [4] Oilseeds are thus classified as a multiproduct and multifunctional commodity, and their impact on the national economy should be assessed with appropriate consideration. The peanut (Arachis hypogaea) is a significant oilseed crop cultivated extensively across various continents, soils, and climates. [5] Drought and warmth are two primary abiotic variables resulting in significant declines in productivity and quality of peanuts globally. Over 90% of global peanut cultivation occurs in tropical and semi-arid areas, making the effects of drought particularly pronounced. [6] A recent estimate indicates that global peanut productivity suffered an annual decline of around 6 million tons, resulting in a financial loss of about $520 million alone due to drought. [7] Drought stress can be mitigated by the development of drought-resistant genotypes or through agronomic practices that reduce the detrimental impacts of drought. Breeding new peanut cultivars will offer a sustainable strategy to mitigate drought constraints in peanut cultivation. [8] The development of drought-tolerant genotypes should prioritize the enhancement of physiological activities in plants affected by drought. Consequently, potential genetic enhancement techniques in drought-stressed ecosystems should adopt a physio-genetic strategy to optimize yields. [9] Characteristics of cultivars, including early stomatal closure, leaf area for sustaining optimal photosynthetic rates with elevated water use efficiency (WUE), and enhanced root dynamics, can be utilized to generate drought-tolerant cultivars. Peanut plants exhibit alterations in morphological, [10] physiological, and agronomic traits in response to drought stress, which breeders might leverage to enhance drought resistance. Therefore, a deeper understanding of their survival in drought-affected situations will facilitate the advancement of drought-resistant genotypes. [11] Understanding how different environmental conditions affect plant photosynthetic rates (A) is essential for improving agricultural practices and enhancing crop resilience. A specific area of study is the impact of natural light intensities on the photosynthetic efficiency of various plant genotypes under differing water availability conditions. Drought generally lowers stomatal conductance to preserve water, thereby restricting CO_2 absorption and decreasing photosynthesis. [12].

Methodology

Study Area

This study carried out in the Waziristan Bannu region of Khyber Pakhtunkhwa (KPK), Pakistan, an area characterized by dry to semi-arid agro-climatic conditions. The region endures elevated temperatures, limited and variable precipitation, and recurrent droughts, rendering it an exemplary area for evaluating drought resilience in leguminous crops like Arachis hypogaea (peanut). Waziristan, situated on Pakistan's western border, is characterized by its rocky topography and arid climate, which profoundly affect local agriculture, especially rainfed crops. Bannu, neighboring Waziristan, functions as a transitional agro-ecological zone characterized by comparable meteorological difficulties although possessing more accessible agricultural terrain. Both regions depend significantly on seasonal precipitation, with inadequate irrigation infrastructure, rendering crops vulnerable to intermittent water shortages. Soil samples were obtained from peanut cultivation areas in both locations to represent indigenous growing conditions. Controlled greenhouse experiments were conducted to simulate the drought stress conditions typically encountered in Waziristan and Bannu. This localized emphasis improves the ecological validity of the research and offers insights into drought-adaptive characteristics pertinent to local agriculture.

1. Experimental Design and Plant Material

This study was conducted under controlled greenhouse conditions. Certified seeds of Arachis hypogaea (peanut) were obtained from a reputable agricultural research institute. Seeds were sown in plastic pots filled with a homogenized mixture of loamy soil, sand, and compost in a 2:1:1 ratio. The experiment followed a **completely randomized design (CRD)** with three replicates per treatment. Plants were grown under optimal conditions until the drought treatment was initiated at the vegetative growth stage.

2. Drought Stress Treatment

Drought stress was imposed by withholding water for a specific period to simulate water-deficit conditions. The control group was irrigated regularly to maintain field capacity, while drought-stressed groups received water at 50% and 25% of field capacity. Soil moisture content was monitored using a moisture meter. The drought stress period lasted for 10–14 days, after which physiological parameters were recorded.

3. Physiological Measurements

To assess drought tolerance, the following physiological parameters were measured:

Relative Water Content (RWC): Determined using fresh, turgid, and dry weights of leaves following standard protocols.

Chlorophyll Content: Measured using a SPAD meter or spectrophotometrically after acetone extraction.

Stomatal Conductance and Transpiration Rate: Measured using a portable leaf porometer.

Leaf Water Potential: Measured with a pressure chamber to estimate plant water status.

Proline Content and Antioxidant Enzyme Activity (optional): To evaluate biochemical responses under drought stress.

Result and Discussion

Results

To investigate drought tolerance in Arachis hypogaea, plants underwent three irrigation treatments: well-watered (control), moderate drought stress, and severe drought stress, adhering to a completely randomized design. Physiological measures, including Relative Water Content (RWC), Chlorophyll Content, Stomatal Conductance, and Proline Accumulation, were evaluated at the conclusion of the stress session. These characteristics were selected for their recognized use as biomarkers in evaluating plant responses to abiotic stress, especially drought. Statistical analysis demonstrated substantial treatment effects across all assessed parameters. Descriptive statistics, such as variance, standard error, range, and skewness, elucidated the degree of physiological disturbance in water-limited situations. The results indicated that drought stress significantly reduced water status and photosynthetic capability, while biochemical reactions, such as proline buildup, exhibited an upward trend with increasing stress severity. The subsequent tables encapsulate the variety in physiological features observed under each treatment setting, illustrating the plant's adaptation responses to water deficiency situations prevalent in semi-arid locations like as Waziristan and Bannu.

Table 4.1: Relative Water Content Percentage.

The table shows the effects of different drought treatments on variance, standard error, range, and skewness of the measured traits in **Arachis hypogaea**. As drought stress increased from control to severe, the variance and range also increased, indicating more variation in plant response. The standard error was also higher under stress conditions. The skewness values were slightly positive under control and moderate drought, while a negative value was observed under severe drought, showing a change in data distribution.

Treatment	Variance	Standard Error	Range	Skewness
Control	3.66	0.38	6.98	0.12
Moderate Drought	7.71	0.56	11.44	0.16
Severe Drought	15.59	0.79	16.74	-0.71

Figure 4.1. Effect of Drought Stress on Statistical parameters in Arachis hypogaea

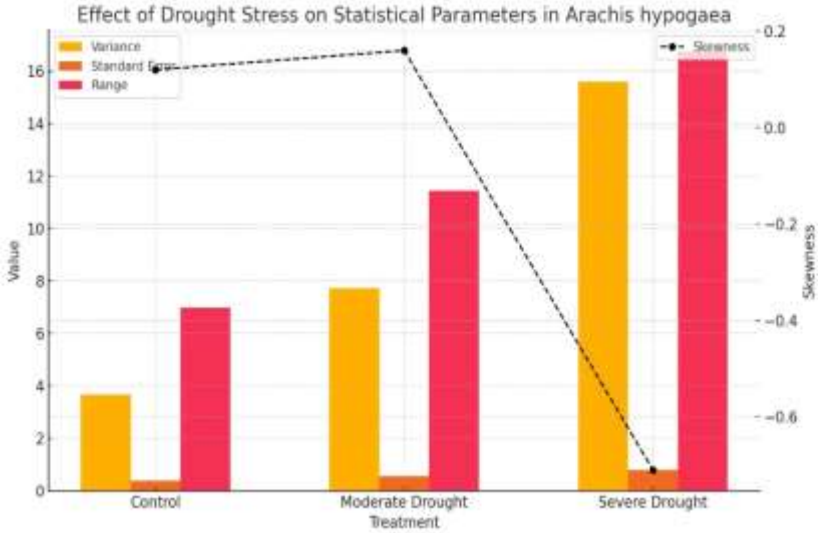


Table 4.2: Chlorophyll Content (SPAD)

The table summarizes the statistical characteristics of plant responses under different drought treatments in **Arachis hypogaea**. Variance, standard error, and range were lowest under control conditions, indicating more uniform plant behavior in the absence of stress. Both moderate and severe drought treatments showed increased variance and standard error, reflecting greater variability among plants under stress. Skewness was negative under control, indicating slightly lower values in the dataset, while moderate and severe drought conditions showed positive skewness, suggesting a shift towards higher values in plant response under drought.

Treatment	Variance	Standard Error	Range	Skewness
Control	0.57	0.15	3.47	-0.40
Moderate Drought	4.26	0.41	8.76	0.30
Severe Drought	4.09	0.40	7.60	0.43

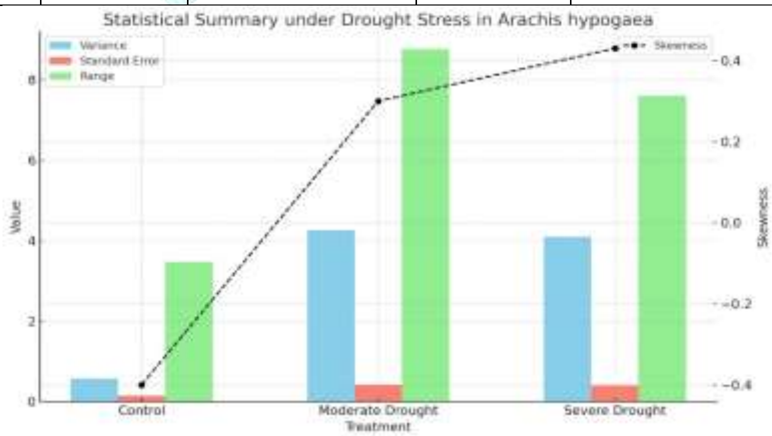


Figure 4.2.

Table 4.3: Stomatal Conductance (mmol m^{-2} s^{-1})

The data indicate a clear increase in the variability of stomatal conductance as drought stress intensifies. Under control conditions, the variance was relatively low (26.36) with a small standard error (1.03) and a narrow range (18.53), suggesting uniform stomatal behavior. In the moderate drought treatment, the variance increased to 43.66 and the range widened to 29.65, indicating more variability among plants. Under severe drought, the variance peaked at 94.76 with the widest range (45.76), showing substantial differences in plant response. Skewness remained positive across all treatments, with moderate (0.73) and severe drought (0.72) showing stronger right-skewed distributions, suggesting that more plants had lower conductance values while a few maintained higher levels.

Treatment	Variance	Standard Error	Range	Skewness
Control	26.36	1.03	18.53	0.30
Moderate Drought	43.66	1.32	29.65	0.73
Severe Drought	94.76	1.95	45.76	0.72

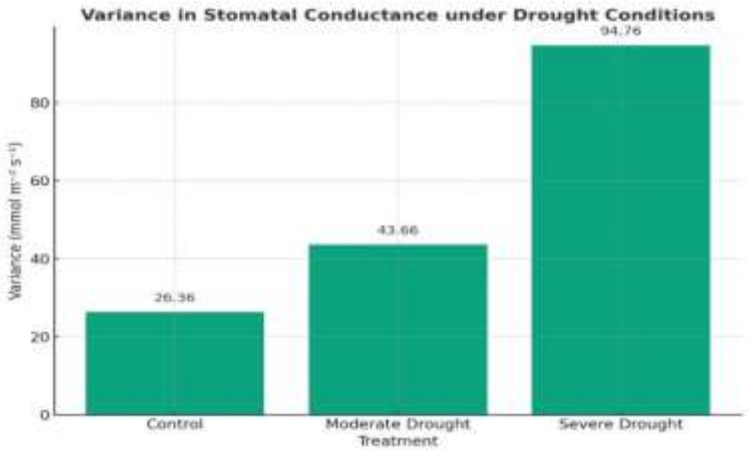
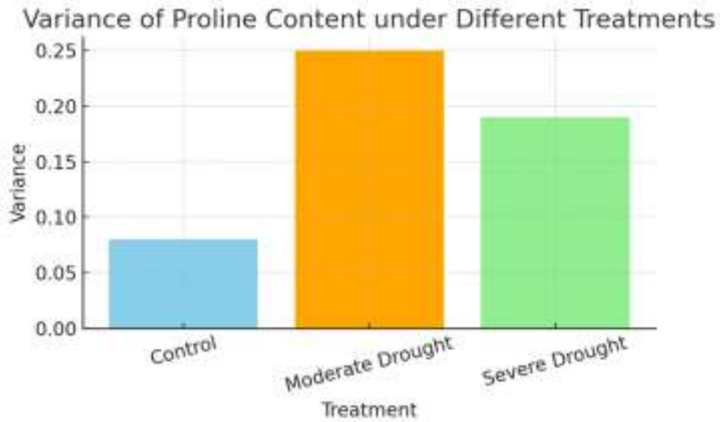


Figure 4.3.

Table 4.4: Proline Content (µmol g⁻¹ FW)

In the Table Proline content showed greater variation under drought conditions compared to the control. The variance and range increased under moderate and severe drought, indicating higher accumulation and variability among plants. Skewness values were close to zero, showing a relatively balanced distribution across all treatments.

Treatment	Variance	Standard Error	Range	Skewness
Control	0.08	0.06	1.25	0.27
Moderate Drought	0.25	0.10	2.15	-0.20
Severe Drought	0.19	0.09	2.04	-0.04



Discussion

This study examined the physiological responses of Arachis hypogaea (groundnut) under drought stress conditions. Drought constitutes a substantial abiotic factor that severely restricts groundnut yield, particularly in arid and semi-arid areas. The findings revealed that drought stress caused significant alterations in essential physiological characteristics, reflecting the crop's adaptive responses to water scarcity. Stomatal conductance exhibited a significant decline under both moderate and severe drought conditions. This response exemplifies a standard drought avoidance technique in which the plant occludes its stomata to minimize water loss via transpiration. Nonetheless, this behavior also constrains CO_2 absorption, potentially impacting photosynthesis and growth. The heightened diversity in stomatal conductance under drought, as evidenced by greater variance and range, implies varying adaptation capacity across individual plants. Proline accumulation was markedly elevated under drought stress relative to control conditions. Proline functions as a compatible solute, preserving osmotic equilibrium and safeguarding cellular membranes and proteins during dehydration stress. The findings indicate that Arachis hypogaea modifies its osmotic potential via proline production in response to drought, a typical physiological reaction observed in other legume crops. The examination of variability metrics, including variance, standard error, and skewness, further substantiates that physiological features are sensitive indicators of drought stress. Elevated variation and range values during drought signify a wide array of responses among genotypes, warranting further investigation for the selection of drought-tolerant lines. These findings correspond with prior research indicating that physiological characteristics, including stomatal control, relative water content, osmolyte buildup, and antioxidant responses, are fundamental to drought tolerance in groundnut. The findings underscore the necessity of incorporating physiological trait evaluations in drought screening initiatives for Arachis hypogaea. In conclusion, the study verifies that Arachis hypogaea has both drought avoidance and drought tolerance mechanisms at the physiological level. Assessing characteristics such as stomatal conductance, proline concentration, and water retention ability can act as dependable markers for recognizing drought-resistant cultivars. Future studies should focus on conducting extended field trials in water-scarce conditions to confirm these findings and improve drought management strategies for groundnut farming.

REFERENCES

Halilou, O., Hamidou, F., Taya, B. K., Mahamane, S., & Vadez, V. (2015). Water use, transpiration efficiency and yield in cowpea (Vigna unguiculata) and peanut (Arachis hypogaea) across water regimes. Crop and Pasture Science, 66(7), 715-728.

Reddy, T. Y., Reddy, V. R., & Anbumozhi, V. (2003). Physiological responses of groundnut (Arachis hypogea L.) to drought stress and its amelioration: a critical review. Plant growth regulation, 41(1), 75-88.

Prasad, P. V., Boote, K. J., & Allen Jr, L. H. (2006). Adverse high temperature effects on pollen viability, seed-set, seed yield and harvest index of grain-sorghum [Sorghum bicolor (L.) Moench] are more severe at elevated carbon dioxide due to higher tissue temperatures. Agricultural and forest meteorology, 139(3-4), 237-251.

Zaman-Allah, M., Jenkinson, D. M., & Vadez, V. (2011). A conservative pattern of water use, rather than deep or profuse rooting, is critical for the terminal drought tolerance of chickpea. Journal of Experimental Botany, 62(12), 4239-4252.

Kakani, V. G., & Reddy, K. R. (2007). Temperature response of C4 species big bluestem (Andropogon gerardii) is modified by growing carbon dioxide concentration. Environmental and experimental botany, 61(3), 281-290.

Vadez, V., Kholová, J., Hummel, G., Zhokhavets, U., Gupta, S. K., & Hash, C. T. (2015). LeasyScan: a novel concept combining 3D imaging and lysimetry for high-throughput phenotyping of traits controlling plant water budget. Journal of Experimental Botany, 66(18), 5581-5593.

Ndunguru, B. J., Ntare, B. R., Williams, J. H., & Greenberg, D. C. (1995). Assessment of groundnut cultivars for end-of-season drought tolerance in a Sahelian environment. The Journal of Agricultural Science, 125(1), 79-85.

Wright, G. C., Hubick, K. T., Farquhar, G. D., & Rao, R. N. (1993). Genetic and environmental variation in transpiration efficiency and its correlation with carbon isotope discrimination and specific leaf area in peanut. In Stable isotopes and plant carbon-water relations (pp. 247-267). Academic press.

Painawadee, M., Jogloy, S., Kesmala, T., Akkasaeng, C., & Patanothai, A. (2009). Heritability and correlation of drought resistance traits and agronomic traits in peanut (Arachis hypogaea L.).

Upadhyaya, H. D., Reddy, L. J., Gowda, C. L. L., & Singh, S. (2006). Identification of diverse groundnut germplasm: Sources of early maturity in a core collection. Field Crops Research, 97(2-3), 261-271.

Singh, A. L. (1999). Mineral nutrition of groundnut. Advances in plant physiology, 2, 161-200.

12. Songsri, P., Jogloy, S., Vorasoot, N., Akkasaeng, C., Patanothai, A., & Holbrook, C. C. (2008). Root distribution of drought-resistant peanut genotypes in response to drought. Journal of Agronomy and Crop Science, 194(2), 92-103