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Morpho-physio characterization of greengram (*Vigna radiata* L.) genotypes under water deficit stress

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Abstract

The present investigation, titled "Morpho-physiological Characterization of Greengram (*Vigna radiata* L.) Genotypes under Water Deficit Stress." was conducted at the Department of Botany, VNMKV, Parbhani during the *khari* season of 2023-24 to evaluate drought tolerance in twenty-five greengram genotypes. The experiment was laid out in a Randomized Block Design with three replications under controlled and water deficit conditions. Morphological, physiological, and phenological traits such as plant height, leaf number, days to 50% flowering, dry weight, pod traits, seed index, harvest index, relative water content (RWC), chlorophyll content and germination rate were recorded. Significant variability was observed among genotypes in response to water stress. Genotypes PHULE CHETAK, BM-2002-1, AKM-4, BPMR-145, KOPARGAON, and BM-2003-2 exhibited superior drought tolerance by maintaining higher RWC, chlorophyll content, and stable yield attributes under stress conditions. In contrast, genotypes BWMD-6-53-1-1-3-1, BWMD-6-13-17-1-5-1, and BWMD-6-13-20-1-1-1 were highly susceptible, showing marked reductions in growth and yield parameters along with delayed flowering and reduced physiological efficiency. Results indicated that RWC and SCMR are reliable indicators of drought tolerance. The study concludes that identifying and utilizing tolerant genotypes can support breeding programs aimed at improving drought resilience and ensuring stable greengram productivity in water-limited environments.

Keywords: Greengram, Relative water content (RWC), Spad chlorophyll meter reading (SCMR), Drought tolerance, Water deficit conditions

Introduction

Greengram (*Vigna radiata* (L.) Wilczek), a diploid member of the family Leguminosae ($2n=2x=22$), is a premier pulse crop with global economic significance, particularly in tropical and subtropical regions. In India, it is the third most vital grain legume, spanning approximately 3.44 million hectares (Dhunde *et al.*, 2021) ^[5]. Often termed the "poor man's meat," it serves as a primary protein source (approx. 25%) for vegetarian populations, offering high concentrations of essential amino acids like lysine and phenylalanine (Rao *et al.*, 2020) ^[17]. Its rapid growth cycle and wide adaptability make it a cornerstone of food security in the Indo-Burma-Thailand regions of Asia.

Greengram (*Vigna radiata* L.) is the third most important grain legume after chickpea and pigeon pea, and is widely grown in the Asian countries. It has a wider adaptability and low input requirement and is grown mainly in rain-fed conditions at relatively high temperature (27-30 °C), with low humidity and moderate rainfall ranging from 60 to 80 cm (Bangar *et al.* 2019) ^[2]. It is a self-pollinating, fast-growing, short-duration crop that contributes to increased cropping intensity (Singh *et al.* 2016) ^[20]. It also improves soil fertility and productivity by fixing atmospheric nitrogen into the soil via symbiosis with rhizobium. Despite an economically important crop, the productivity of greengram is stagnant due to various biotic and abiotic stresses (Pratap *et al.* 2019) ^[14]. The global food supply is 71 million tons, with 79 million hectares dedicated to pulses (Anonymous, 2021). Greengram has a global area of roughly 7.3 million ha and a global production of approximately 5.3 million tons. Greengram is a well-known crop in Asian countries and India is the world's largest producer and consumer of pulses, accounting for 30% of global output.

Greengram is an important short-duration pulse crop reaching 0.3 to 1.4 m in height, characterized by branched stems, trifoliate leaves, yellow flowers, and short hairy pods (Lee *et al.*, 2021) ^[10] valued for its high nutritional and agronomic significance. It is a major source of easily digestible protein, especially for vegetarian populations. It is widely consumed as both whole and split pulse and forms a key component of cereal-based diets in Asia (Rao *et al.*, 2020) ^[17]. Its nutritional quality improves when combined with cereals due to complementary amino acids. In addition to its dietary importance, greengram plays a crucial role in sustainable agriculture by fixing atmospheric nitrogen, improving soil fertility, and fitting well into crop rotation and intercropping systems, particularly under dryland conditions.

Despite its economic importance, its productivity is significantly affected by various abiotic and biotic stresses. Among these, drought is the most critical factor, severely limiting plant growth and yield by disrupting water availability and increasing transpiration stress. With changing climate conditions and declining water resources, drought stress is expected to further reduce greengram productivity, making stress management essential for sustaining food production.

Plant water deficits may occur as a consequence of a seasonal decline in soil water availability, developing in the long term or may result from drought spells. Plant strategies to control water status and resist drought are numerous. In general, genotypes native from climates with marked seasonality are able to acclimate to the fluctuating environmental conditions. In the case of slowly developing water deficits, plants may also escape dehydration by shortening their life cycles. In case of rapid dehydration, oxidative stress developing as a secondary effect is potentially very damaging to the photosynthetic machinery. The capacity for energy dissipation and metabolic protection (induced or constitutive) against the damaging effects of reactive oxygen species is a key element for the success of plants under drought (Chaves and Oliveira *et al.*, 2004) ^[4]

Drought is one of the most harmful abiotic stresses, particularly in the Mediterranean basin, where arid climate causes water scarcity and high evapotranspiration. Severe droughts may directly reduce or eliminate yields, leading to a decline in crop productivity by up to 50-70%, which may affect 40% of the 4 global population. Moreover, according to the World Health Organization, drought stress affects the livelihood of approximately 55 million people worldwide annually, and it is estimated that around 700 million people are at risk of displacement by 2030 because of droughts. Hence, better understanding the plants' responses to environmental stresses is a key prerequisite for the improvement of their drought tolerance and yield under water deficit.

Drought causes an array of morphological, physiological, biochemical, and molecular changes in plants. Greengram being known as an essential tropical grain legume and an important cash crop with high protein content and high nitrogen fixing capability brings into focus the research it needs. In contrast, with erratic rainfall, the production of greengram is continuously threatened with the expanding

water deficit stressed zones. This encourages researchers to know more about greengram water deficit stress tolerance which thereby necessitates a detailed screening of the morphological and physiological characterizations.

Materials and method

A total of twenty five genotypes of greengram were selected for their comparative analysis under drought stress including both tolerant and susceptible traits. The experiment is laid out in randomized block design (RBD). Plants were allowed to grow normally for 30 days after sowing, until flowering began in all genotypes. At the time of flowering drought stress was introduced by covering plot B with a white polythene sheet of 200 micron UV polythene sheet with side wall opening and supported by a temporary framework. (D.Chatti *et al.* 2017) The field experiment was conducted at Department of Agricultural Botany, Vasant Naik Marathwada Krishi Vidyapeeth (VNMKV), Parbhani (MH), during the kharif season of 2023-24. The field is situated at a latitude of 19° 16' N, a longitude of 26° 47' E, and an altitude of 409 meters above sea level.

The soil at the site was medium black with a moderate capacity for moisture retention. The experiment was conducted on land with a uniform topography.

Sowing done by using the dibbling method at a depth of 3 cm. Two seeds were placed per hill, with a row spacing of 45 cm and a plant-to-plant distance of 10 cm. Germination counts were recorded 5 days after emergence, and plant populations were maintained through gap filling as needed. Drought stress was imposed during the flowering and pod-filling stages by covering the plants with a white polythene sheet. The control field, which was not covered with the sheet, received rainfall and one irrigation during its growth cycle. Five plants per plot were randomly selected for recording biometric observations at respective stages. Data were collected on various morphological and physiological parameters in response to drought treatment.

Result and discussion

A. Morphological parameters

1) Field Emergence (%)

The statistical analysis of twenty-five greengram genotypes reveals significant genetic variability in field emergence, with values ranging from a minimum of 85% to a maximum of 98%. The highest performance was observed in a cluster of BWMD genotypes, specifically BWMD-6-10-1-1-5-1 and BWMD-6-13-17-1-5-1, which performed at par with elite checks like PHULE CHETAK and BM-2002-1. While several lines maintained a stable and high profile around 95-96%, the genotypes BWMD-6-53-1-1-3-1 and BWMD-6-61-33-1-3-1 recorded the lowest emergence rates. This significant performance gap underscores that field emergence is a genotype-specific trait and a vital indicator of seed vigor. As emphasized by Paul D *et al.* (2022) ^[13], high initial emergence is a critical prerequisite for drought tolerance; it facilitates rapid root development, allowing the plant to "escape" soil moisture depletion. Consequently, genotypes with superior emergence ensure successful crop establishment and resource competition, whereas susceptible lines struggle with yield stability under water deficit stress.

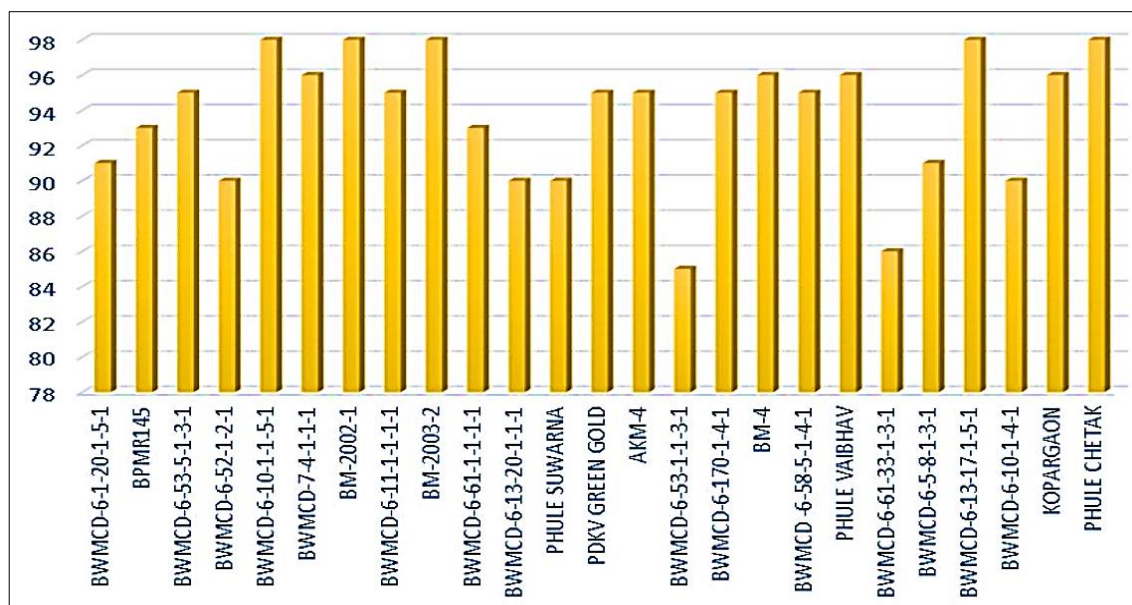


Fig 1: Field emergence (%)

2) Plant Height at Flowering Stage (cm)

Statistical analysis of twenty-five genotypes demonstrates that water deficit stress consistently reduces plant height, with values shifting from a control range of 29.8-41.8 cm down to 27.8-39.8 cm. PHULE CHETAK proved superior by maintaining the maximum height under both conditions, whereas BWMCD-6-10-1-1-5-1 consistently recorded the minimum growth. While genotypes like BWMCD-6-61-1-1-1-1 showed high resilience with a negligible reduction of only 0.6 cm, others such as BWMCD-7-4-1-1-1 and BM-

2003-2 were highly susceptible, experiencing a sharp decline of 5.9 cm. Ultimately, PDKV GREEN GOLD, PHULE CHETAK, and AKM-4 displayed the strongest adaptive capacity for drought-prone environments. These findings align with research by Hossain *et al.* (2010) [8], Rahbarian *et al.* (2011), Zare *et al.* (2013) [24], and Baroowa *et al.* (2016) [3], who concluded that drought-tolerant genotypes maintain greater height because moisture stress typically stunts growth by inhibiting cell elongation and disrupting mitosis.

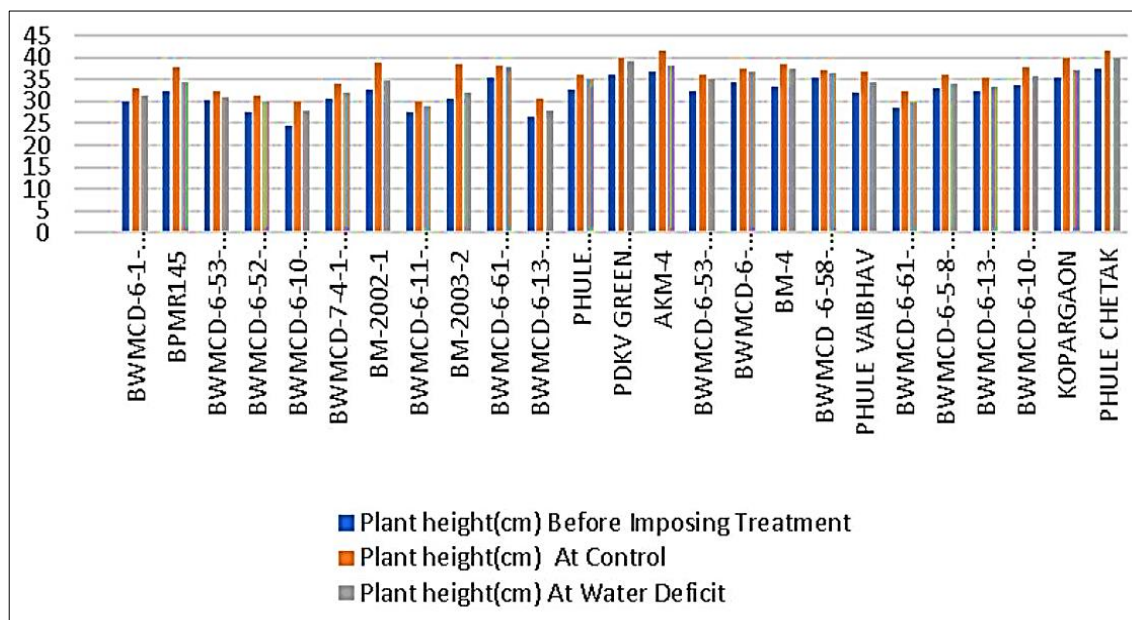


Fig 2: Plant height (cm)

3) Number of Leaves per Plant at Flowering Stage

Analysis of twenty-five genotypes at the flowering stage revealed that water deficit significantly reduces the number of leaves per plant, with counts dropping to a range of 19-32 compared to the control's 21-36. PHULE CHETAK emerged as the most resilient genotype, maintaining the highest leaf count (32) under stress, whereas BWMCD-6-10-1-1-5-1, BWMCD-6-61-1-1-1-1, and BWMCD-6-53-1-1-3-1 were the most susceptible, recording the minimum of

19 leaves. While genotypes like KOPARGAON and AKM-4 showed marked decreases, BWMCD-6-13-17-1-5-1 and BWMCD-6-61-33-1-3-1 exhibited tolerance through minor reductions. These results align with findings by Hussain *et al.* (2011) [9], Farooq *et al.* (2009) [6], Zhang *et al.* (2023) [7], Mittler *et al.* (2002), Baroowa and Gogoi (2016) [3], and Ranawake *et al.* (2011) [16], who concluded that leaf count is a critical indicator of drought resilience, as water stress typically inhibits cell division and leaf expansion.

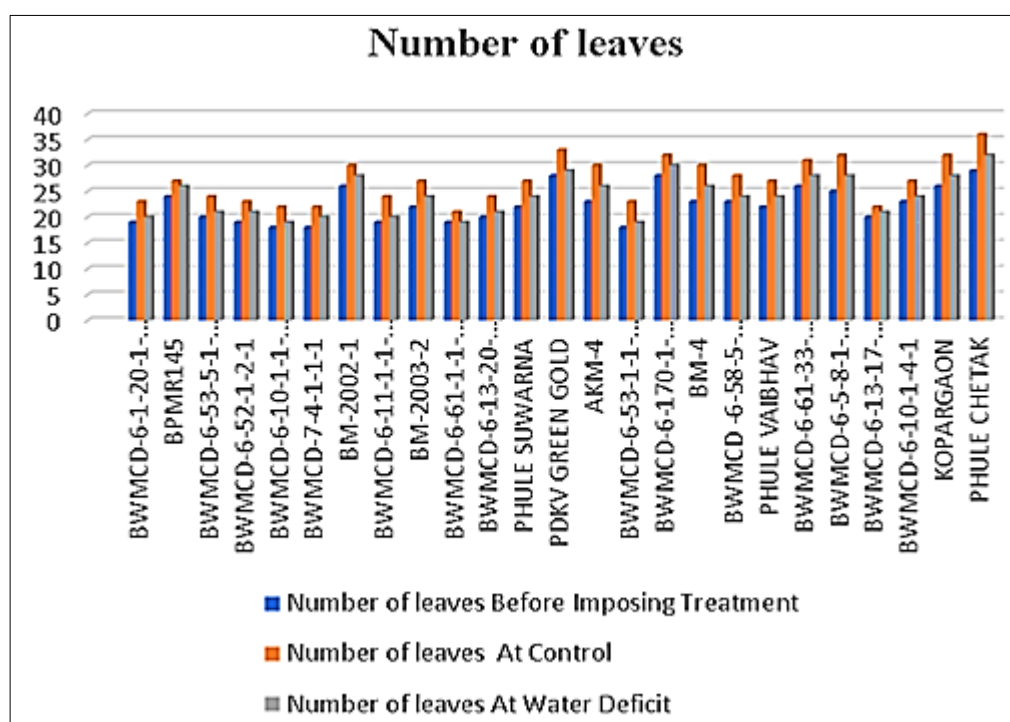


Fig 3: Number of leaves

4) Dry Weight per Plant at Flowering Stage (g/plant)

Analysis of twenty-five genotypes showed that plant dry weight declined under water deficit, with values ranging from 2.48g to 4.43g compared to the control range of 2.60g to 4.79g. BM-4 emerged as the most resilient genotype, maintaining the maximum dry weight under both conditions, while BWMCD-6-13-17-1-5-1 and BWMCD-6-13-20-1-1-1 recorded the minimum weights, highlighting their

vulnerability. These results align with research by Sinha *et al.* (2006), Ahmad *et al.* (2008) [1], Devi *et al.*, and Nair *et al.*, who concluded that dry weight reduction correlates with physiological stress, including reduced photosynthesis and altered nutrient uptake. Ultimately, genotypes like BM-4 demonstrate superior adaptability through efficient water-use and metabolic mechanisms.

Dry Weight

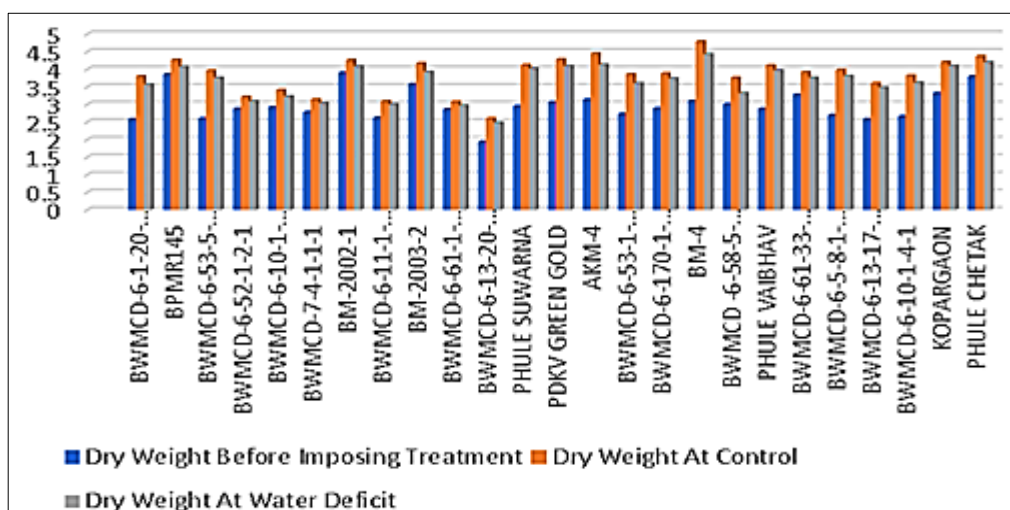


Fig 4: Dry weight

5) Final Plant Stand (%)

Significant difference recorded in genotypes among both conditions. Under control condition, minimum percentage recorded in genotype BWMCD-6-61-33-1-3-1 (75%) and maximum percentage was recorded in genotypes PHULE CHETAK (95%). Under water deficit condition, minimum plant stand was recorded in genotype BWMCD-7-4-1-1-1

(76%) and maximum plant stand was recorded in genotype PHULE VAIBHAV (88%), BWMCD-6-1-20-1-5-1 (85%) and this was found at par with genotypes BPMR145 (85%), BWMCD-6-53-5-1-3-1 (86%), BWMCD-6-52-1-2-1 (83%), BWMCD-6-53-1-1-3-1 (81%), BM-4 (83%), BWMCD-6-58-5-1-4-1 (85%), PHULE CHETAK (83%).

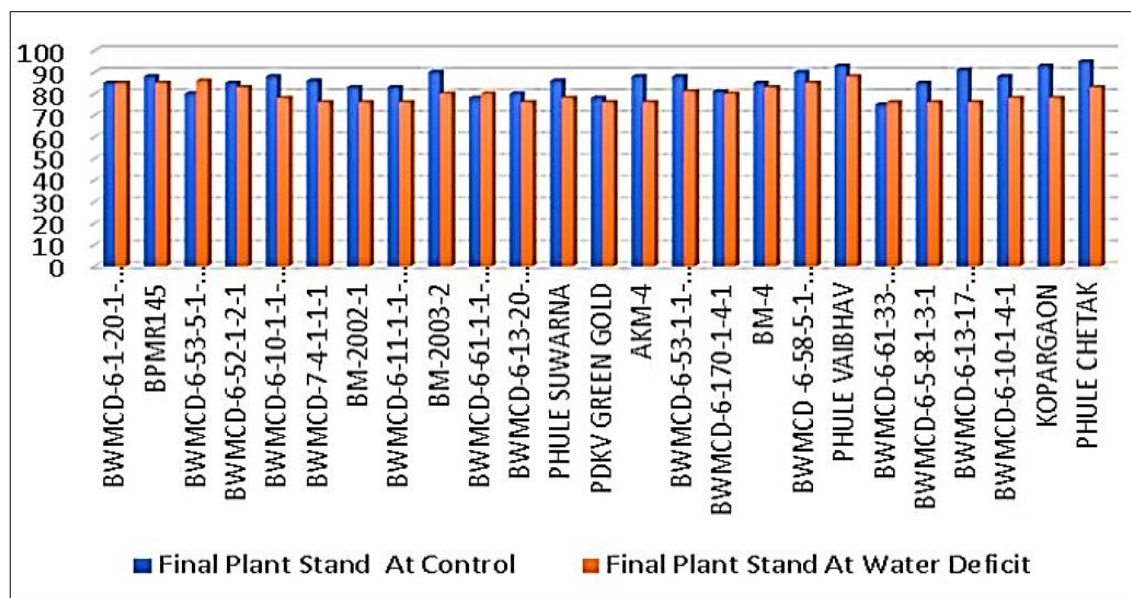


Fig 5: Final plant stand

B. Physiological parameters

1) Relative Leaf Water Content (%) at Flowering Stage

The statistical analysis of relative water content (RWC) across twenty-five genotypes revealed significant variability, with values ranging from 74.13% to 83.47% under control conditions and 72.2% to 81.47% under water deficit. Genotype BM-2002-1 exhibited remarkable resilience, maintaining the highest RWC (81.47%) with a minimal reduction of only 2.00% from control levels. PHULE CHETAK and AKM-4 also demonstrated superior water retention capabilities, indicating effective physiological adaptation to moisture stress. Conversely,

genotypes BWMCD-6-13-17-1-5-1 and BWMCD-6-61-1-1-1 recorded the lowest RWC under stress, highlighting their susceptibility. These results are in agreement with Saini *et al.* (2024) ^[18], Guo.Y. *et al.* (2023) ^[7], Kumar *et al.* (2013) ^[26], and Ashraf *et al.* (2012) ^[1], who observed that drought-tolerant genotypes minimize the decline in RWC to maintain turgor pressure and essential metabolic functions. The findings suggest that high water retention in tolerant lines serves as a critical mechanism to mitigate oxidative stress and prevent the loss of photosynthetic efficiency during water scarcity.

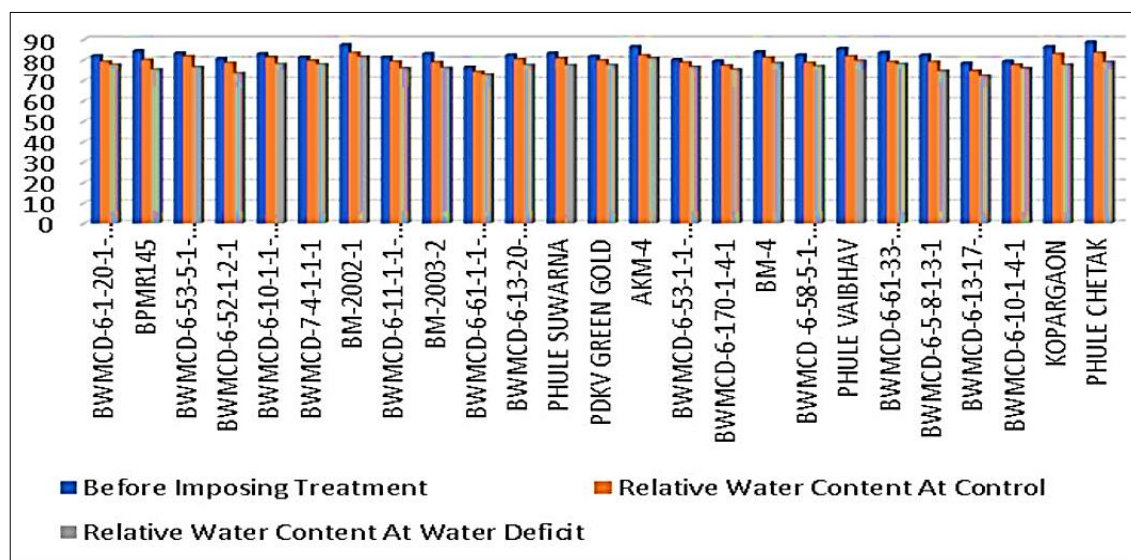


Fig 6: Relative water content

2) SCMR Value at Flowering Stage

Across the twenty-five genotypes, SCMR values ranged from 33.3 to 49.3, with a general decline observed under water deficit stress. BM-2002-1 and AKM-4 maintained the highest SCMR values, indicating superior chlorophyll retention and photosynthetic resilience, while BWMCD-6-5-8-1-3-1 and BWMCD-6-61-33-1-3-1 recorded the lowest. Among breeding lines, BWMCD-6-170-1-4-1 and

BWCD-7-4-1-1-1 demonstrated the highest stability under stress. These results align with Singh *et al.* (2016) ^[20], Nair *et al.*, Arunyanak *et al.*, Hayatu *et al.*, and Songsri *et al.* (2009) ^[32], who concluded that drought-tolerant genotypes utilize higher chlorophyll density to maintain metabolic efficiency and pigment synthesis despite moisture limitations.

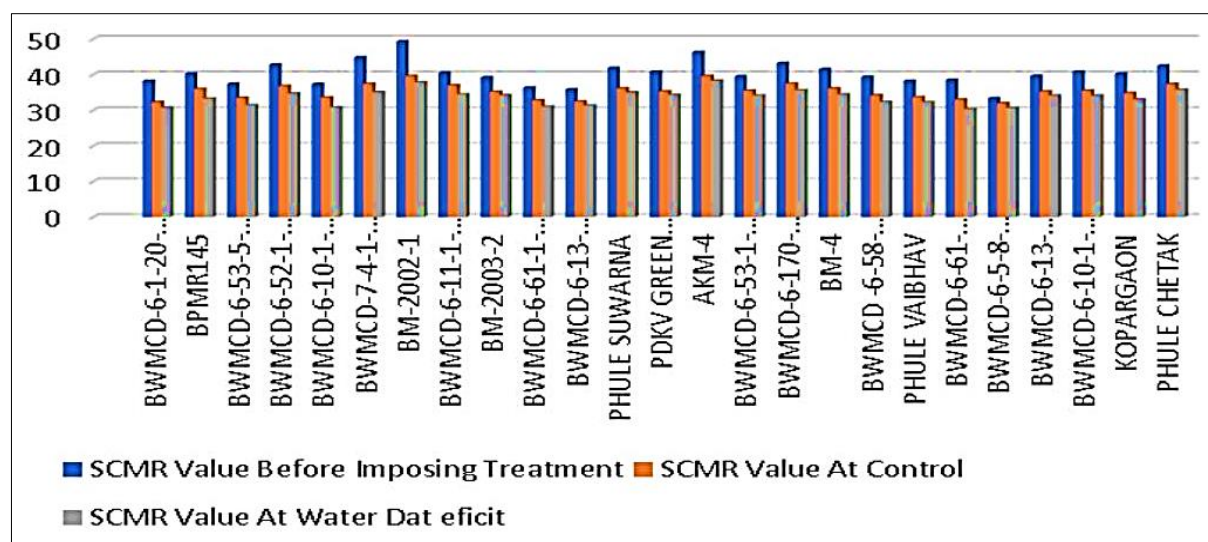


Fig 7: SCMR Value

3) RGR (Relative Growth Rate) (g/ g/ day)

Relative Growth Rate (RGR) exhibited significant variation across genotypes, ranging from 0.11 to 0.57. BM-4 and AKM-4 emerged as the most resilient, maintaining the highest RGR under both control (0.42) and water deficit (0.39) conditions. Among breeding lines, BWMCD-6-170-1-4-1 and BWMCD-6-10-1-1-5-1 showed superior tolerance, whereas BWMCD-6-11-1-1-1-1 and BWMCD-6-

5-8-1-3-1 recorded the lowest growth rates. These findings are supported by Singh *et al.* (2016) ^[20], Kumar *et al.* (2014) ^[26], and Nageswara Rao *et al.* (2020) ^[17], who noted that while RGR naturally peaks under optimal conditions, drought-tolerant genotypes mitigate reductions caused by stomatal limitations and decreased carbon assimilation to maintain biomass production

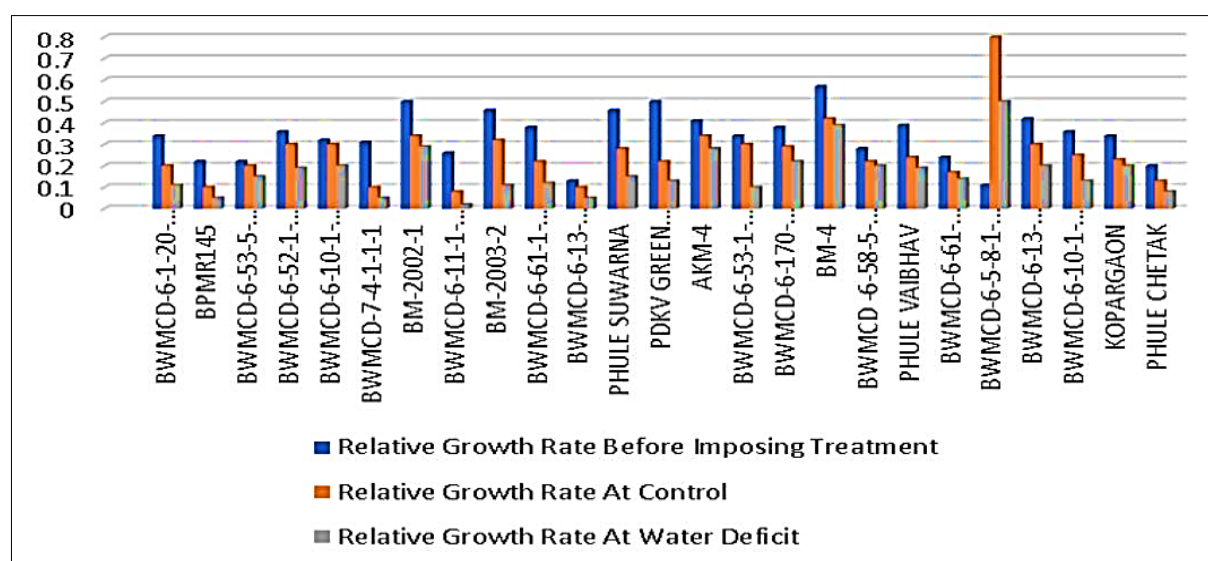


Fig 8: Relative growth rate

4) Absolute Growth Rate (g/day)

The analysis of Absolute Growth Rate (AGR) revealed significant genetic diversity, with initial values ranging from 0.02 to 0.15. Under control conditions, BM-4 recorded the highest AGR (0.16), a performance it sustained under water deficit (0.13), indicating superior growth stability. Among breeding lines, BWMCD-6-53-5-1-3-1 and BWMCD-6-5-8-1-3-1 maintained relatively high AGR (0.11) under stress,

while BWMCD-6-170-1-4-1 showed the most notable resilience with minimal decline. In contrast, BM-2002-1 and BWMCD-6-13-20- 1-1-1 were identified as more sensitive to moisture limitations. These results emphasize that maintaining AGR under moisture stress is a genotype-specific trait, making consistent performers like BM-4 and specific resilient breeding lines critical candidates for drought prone cultivation.

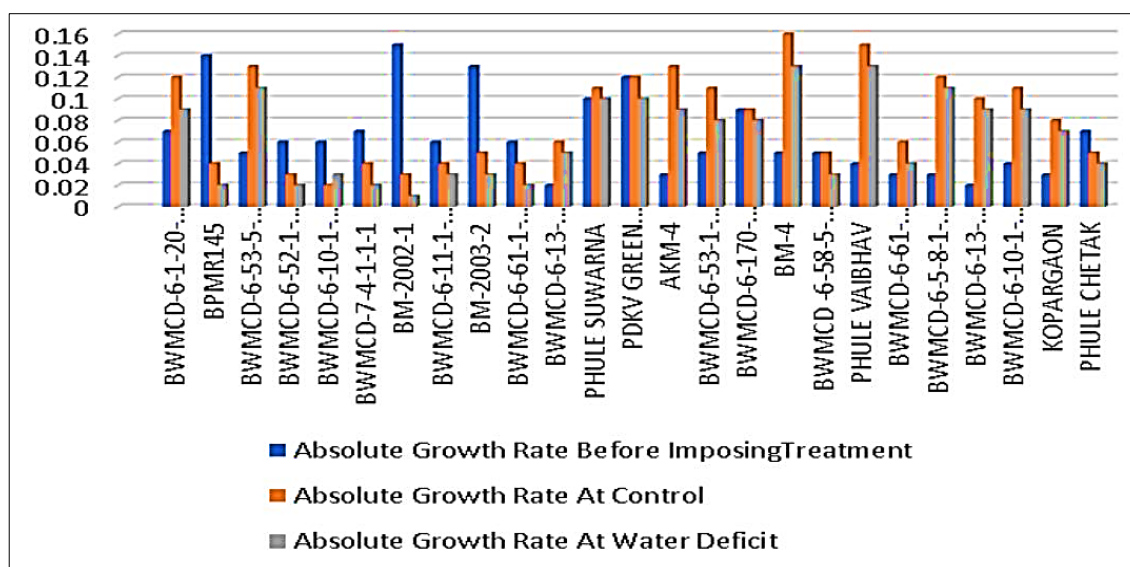


Fig 9: Absolute growth rate

5) Days to 50% Flowering (Days)

Significant variation in days to 50% flowering was observed, with durations ranging from 33-38 days under control and 34-40 days under water deficit. Drought stress generally delayed flowering, particularly in BPMR145 and PHULE VAIBHAV (40 days), while genotypes such as BWMCD-6-10-1-1-5-1 and BWMCD-6-13-17-1-5-1

exhibited resilience through earlier flowering (34-35 days). These findings align with Singh *et al.*, Sivakumar *et al.*, and Nageswara Rao *et al.* (2020) [17], who noted that water deficit disrupts physiological processes and reproductive efficiency. The results suggest that genotypes capable of maintaining stable flowering and high grain retention under stress are critical for developing drought-resilient varieties.

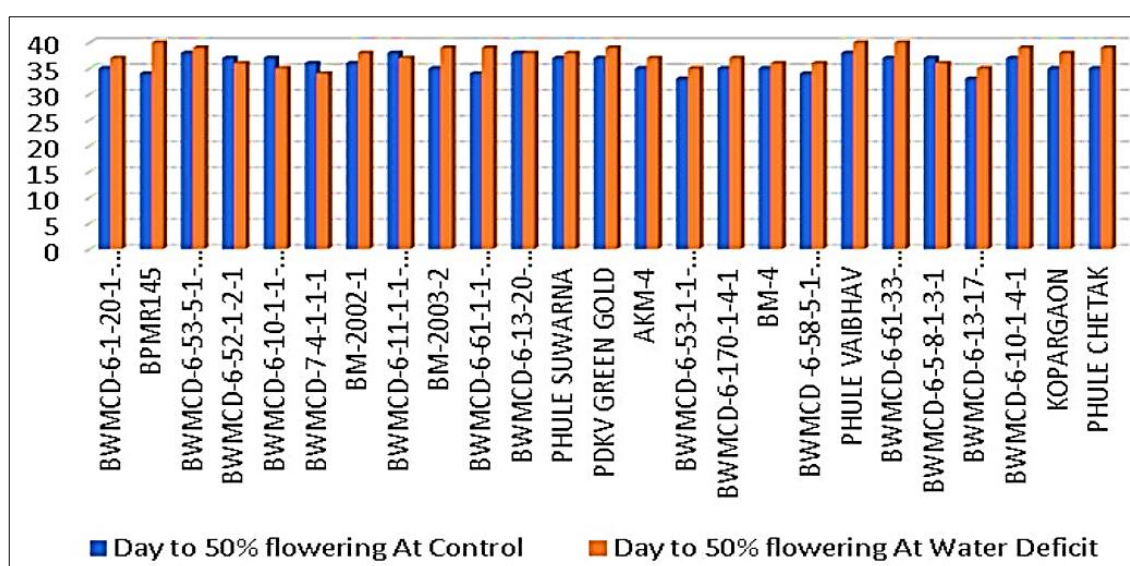


Fig 10: dry to 50% flowering

C. Yield Parameters

1) Number of Grains per Pod

The analysis of grains per pod revealed significant genetic variation, with values ranging from 11-18 under control conditions and 10-16 under water deficit. PHULE CHETAK consistently outperformed all genotypes, maintaining the maximum grain count in both environments, followed closely by BM-2002-1 and BM-2003-2. Among the breeding lines, BWMCD-6-61-1-1-1-1 and BWMCD-6-170-1-4-1 demonstrated notable stability under stress,

whereas BWMCD-6-1-20-1-5-1 recorded the minimum productivity. These findings are corroborated by Pandey *et al.* (2015) [25], Sharma *et al.* (2015) [36], Khazaei *et al.*, Gowda *et al.*, Farooq *et al.* (2009) [6], Singh *et al.* (2016) [20], Sivakumar *et al.*, and Nageswara Rao *et al.*, who concluded that moisture stress during the reproductive phase severely limits grain filling. The reduction is attributed to impaired pollination, reduced photosynthetic rates, and hormonal imbalances, marking high grain retention as a critical trait for drought resilient selection.

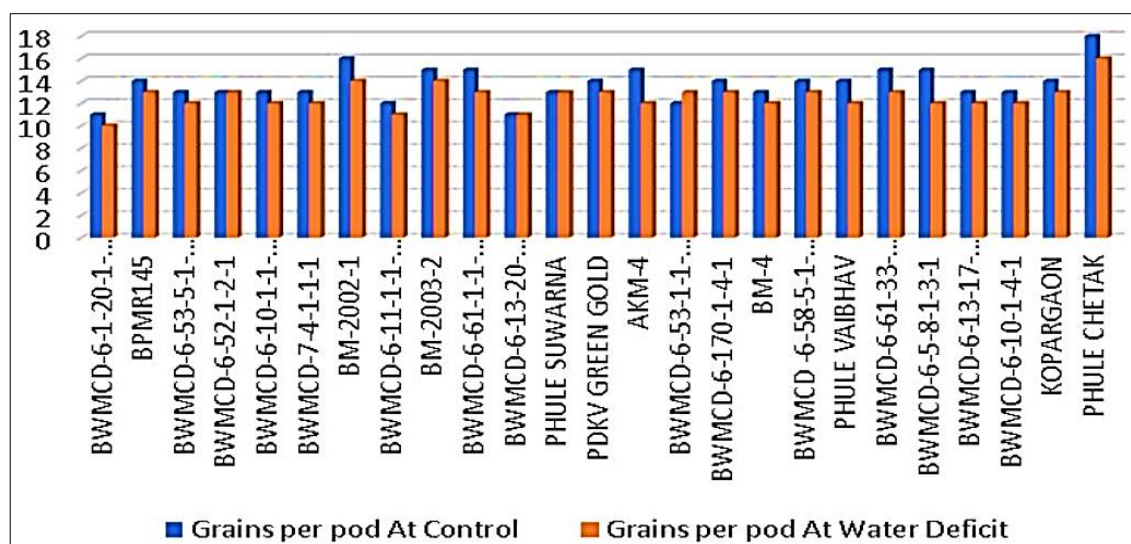


Fig 11: Grain per pod

2) Pod Weight (gm)

The analysis of pod weight revealed significant genotypic variation, with values ranging from 1.10-1.73 g under control conditions and 1.05-1.67 g under water deficit. PHULE CHETAK consistently recorded the highest pod weight in both environments, demonstrating superior reproductive stability. Among the breeding lines, BWMCD-6-58-5-1-4-1 and BWMCD-6-5-8-1-3-1 exhibited high resilience, while BWMCD-6-13-20-1-1-1 was identified as

the most sensitive, recording the minimum weight. These observations are consistent with the findings of Singh *et al.* (2016) [20], Pandey and Shukla (2015) [25], Kumar *et al.* (2014) [26], and Hamidou *et al.* (2013) [27], who concluded that water deficit impairs photosynthesis and assimilate translocation. The results emphasize that maintaining pod weight through efficient grain filling despite moisture limitations is a critical indicator of drought tolerance in greengram genotypes.

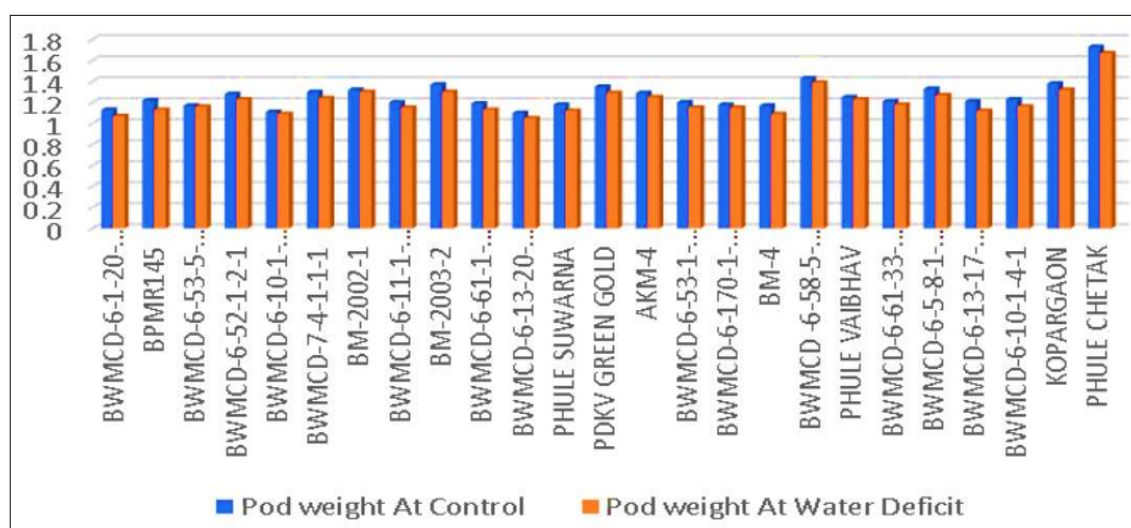


Fig 12: Pod weight

3) Pod Length (cm)

The analysis of pod length demonstrated significant genetic variation, with values ranging from 6.47-13.60 cm under control conditions and 6.10-13.23 cm under water deficit. PHULE CHETAK consistently achieved the maximum pod length across both environments, while BWMCD-6-58-5-1-4-1 and BWMCD-6-170-1-4-1 emerged as the most resilient breeding lines. Conversely, BWMCD-6-13-20-1-1-1

recorded the minimum values, highlighting its sensitivity to moisture stress. These results align with Rosales *et al.* (2004), who observed that water deficit negatively impacts pod elongation by limiting photosynthesis and altering hormonal regulation. The findings suggest that genotypes capable of maintaining pod length under stress possess superior physiological mechanisms for sustaining reproductive growth despite restricted water availability.

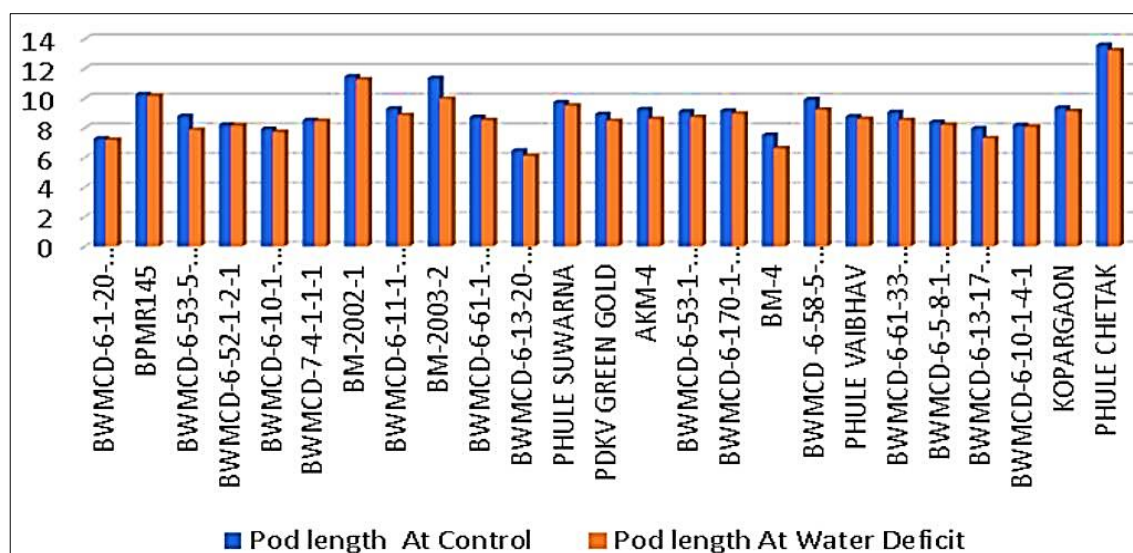


Fig 13: Pod length

4) Seed Index (gm)

The study of 100-seed weight (seed index) revealed significant genotypic variation and a general decline under water deficit stress, with values shifting from a control range of 3.8-5.6 g to a stress range of 3.3-5.4 g. PHULE CHETAK demonstrated superior performance by maintaining the highest seed index in both environments, while KOPARGAON and breeding lines BWMCD-6-11-1-1-1-1 and BWMCD-6-170-1-4-1 also exhibited high resilience. In contrast, BWMCD-6-13-20-1-1-1 consistently recorded the

minimum values, marking it as highly susceptible to drought. These findings align with research by Chandra *et al.* (2020) ^[29], Sathi *et al.* (2022) ^[30], and Linkemer *et al.* (1998) ^[31], who concluded that moisture stress reduces seed size by impairing translocation capacity during the critical pod-filling stage. The results suggest that the ability to maintain seed index under stress is a vital trait for identifying genotypes with efficient assimilate partitioning and yield stability.

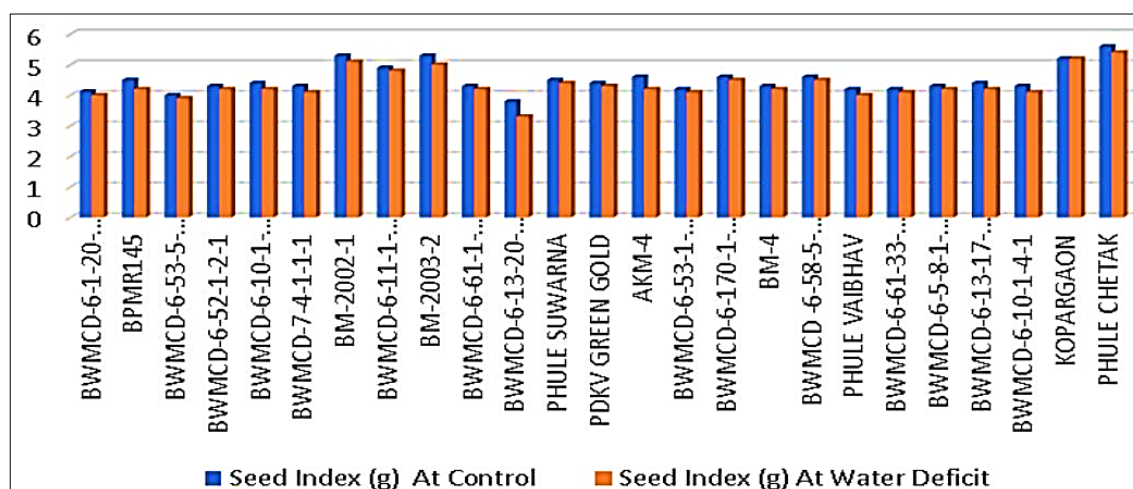


Fig 14: Seed Index (g)

5) Harvest Index (%)

The analysis of harvest index (HI) revealed significant genotypic variation, with values ranging from 27.5% to 37% under control conditions and 26.6% to 35.7% under water deficit. BPMR-145 consistently recorded the highest HI across both environments, followed by AKM-4 and PHULE CHETAK, demonstrating superior partitioning efficiency. Conversely, genotypes such as BWMCD-6-61-33-1-3-1 and BWMCD-6-1-20-1-5-1 exhibited lower values, highlighting

their sensitivity to stress. These findings align with Songsri *et al.* (2009) ^[32], Pushpavalli *et al.* (2014) ^[33], and Gholinezhad *et al.* (2009) ^[34], who concluded that drought stress at the reproductive stage severely disrupts the allocation of carbohydrates to the grains. The results suggest that the ability to maintain a stable harvest index under moisture limitations is a key physiological indicator of drought tolerance and efficient dry matter partitioning.

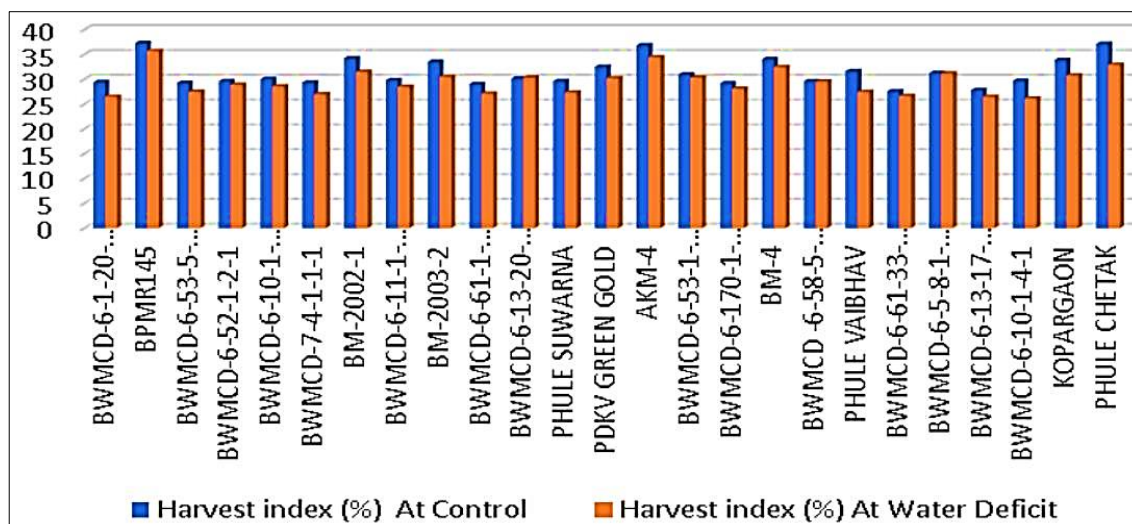


Fig 15: Harvest index (%)

D. Seed Quality Parameter

1) Germination Percentage (%)

The germination percentage showed significant variation among genotypes under control and water deficit conditions, ranging from 0 to 100%. Under control conditions, PHULE VAIBHAV recorded the highest germination (100%), followed by BPMR145 (96%), BM-2002-1 and BM-2003-2 (92%), while BWMCD-6-61-33-1-3-1 also showed high germination (94%). Among breeding lines, lower values were observed in BWMCD-6-13-17-1-5-1 (10%) and BWMCD-6-1-20-1-5-1 (24%), while some genotypes

showed no germination (BWMCD-6-53-1-1-3-1). Under water deficit conditions, germination decreased overall (0-92.67%), with BWMCD-6-61-33-1-3-1 maintaining the highest value (86.67%), while several lines such as BWMCD-6-13-17-1-5-1 (6%) and BWMCD-6-53-1-1-3-1 (0%) showed very poor performance. Overall, drought stress reduced germination due to physiological and hormonal constraints, consistent with previous reports by Kumar *et al.* (2012)^[35], Sharma *et al.* (2015)^[36], and Farooq *et al.* (2009)^[6].

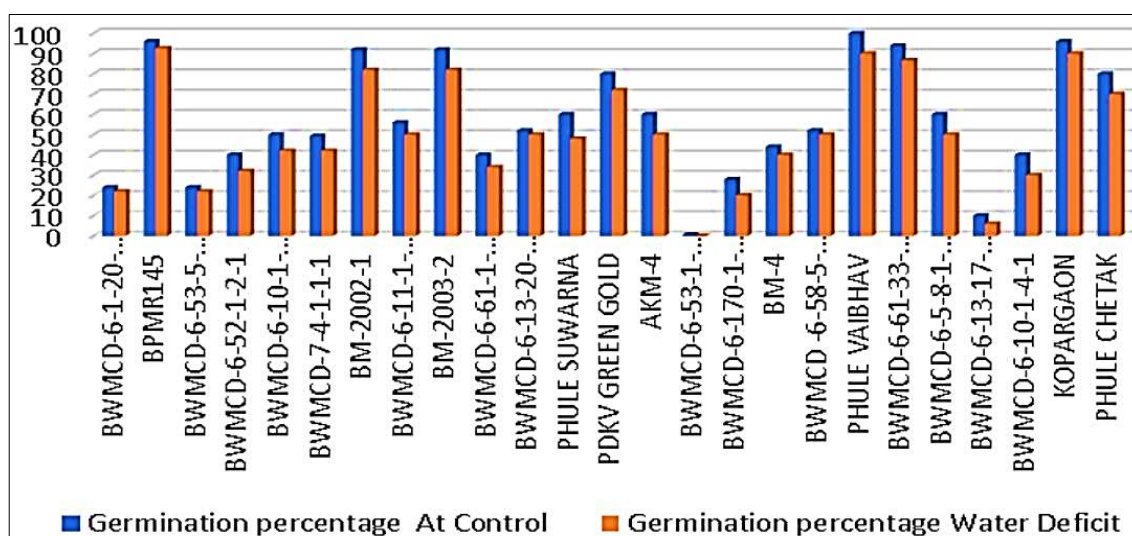


Fig 16: Germination percentage

2) Vigour Index I

The vigour index I showed a strong positive association with germination percentage and varied significantly among genotypes under control and water deficit conditions. Under control conditions, it ranged widely, with the highest values recorded in KOPARGAON (1839.8), followed by PHULE CHETAK, BPMR-145, BM-2002-1, and PHULE VAIBHAV, while among breeding lines BWMCD-6-61-33-1-3-1 showed the highest value (1618.4). The lowest vigour

index was observed in BWMCD-6-53-1-1-3-1. Under water deficit conditions, vigour index I decreased markedly, with PHULE CHETAK (1593.6) and BWMCD-6-61-33-1-3-1 (1467.4) performing best among breeding lines, while BWMCD-6-53-1-1-3-1 recorded zero vigour index due to no germination. Overall, drought stress significantly reduced vigour index I by lowering both germination percentage and seedling growth, indicating reduced seedling establishment potential under water deficit conditions.

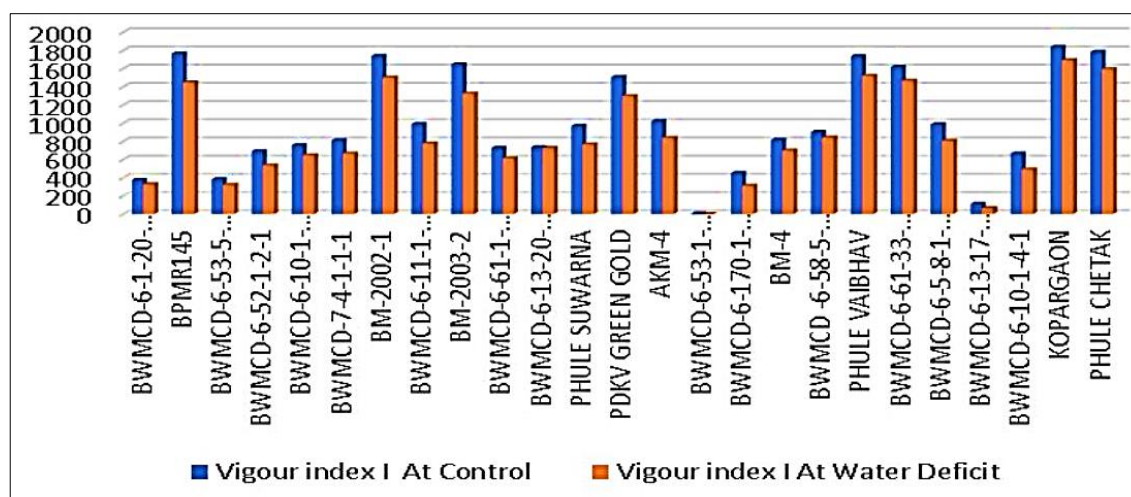


Fig 17: Vigour index I

3) Vigour Index II: The vigour index II showed significant variation among genotypes under control and water deficit conditions, with a strong influence of drought stress. Under control conditions, it ranged widely, with maximum values recorded in KOPARGAON (138.58) and PHULE CHETAK (129.84), while among breeding lines BWMCD-6- 61-33-1-3-1 showed the highest value (115.34). The lowest values were observed in BWMCD-6-13-17-1-5-1 (12.0) and BWMCD-6-1-20-1-5-1 (27.16), with BWMCD-6-53-1-1-3-1 showing no vigour index II due to poor or absent seedling growth. Under water deficit conditions, vigour index II

declined further across all genotypes, with BWMCD-6-61-33-1-3-1 (106.01) performing best among breeding lines, followed by BWMCD-6-5-8-1-3-1 (58.35) and BWMCD-6-58-5-1-4-1 (58.34), while BWMCD-6-13-17-1-5-1 (7.10) and others showed very low values. Overall, drought stress significantly reduced seedling dry weight and vigour index II due to reduced water and nutrient uptake, lower photosynthetic activity, and hormonal imbalance (increased ABA and reduced GA), as also supported by Sehrawat *et al.* (2023) [37], Nazran *et al.* (2019) [38], and Nadeem *et al.* (2019) [39].

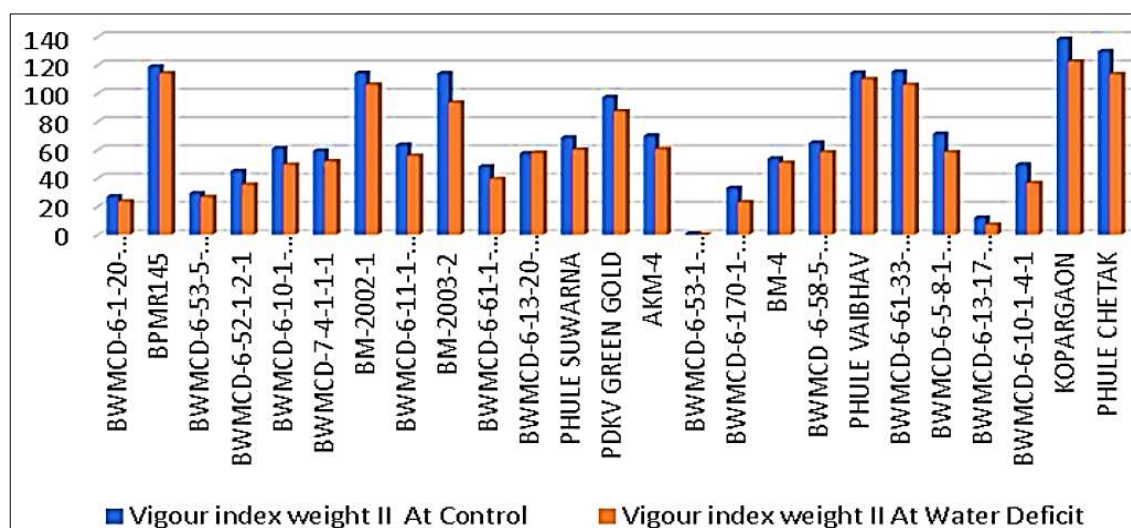


Fig 18: Vigour index weight III

Conclusion

The investigation “Morpho-physiological Characterization of Greengram (*Vigna radiata* L.) Genotypes under Water Deficit Stress” concludes that drought tolerance in greengram is a trait-specific phenomenon rather than a universal response. The study demonstrates that a genotype’s resilience depends entirely on its ability to maintain specific physiological, morphological, and yield-related functions under moisture limitations. Physiologically, genotypes like BM-2002-1 and AKM-4 proved superior by maintaining high Relative Water Content (RWC) and SCMR (Chlorophyll content), which preserved metabolic efficiency and prevented oxidative damage. Morphologically, PHULE CHETAK and BM-4 exhibited

high plasticity, sustaining plant height, leaf count, and robust Relative Growth Rates (RGR) despite water scarcity. From an agronomic perspective, the ultimate measure of tolerance was identified as efficient assimilate partitioning. Genotypes PHULE CHETAK, AKM-4, and BPMR-145 successfully translocated carbohydrates to grains, maintaining stable Harvest Indices (HI) and pod traits where susceptible lines like BWMCD-6-13-20-1-1-1 failed. Additionally, early-stage vigor in genotypes like KOPARGAON ensured successful crop establishment under erratic conditions. Ultimately, the study confirms that drought tolerance is dependent on the specific traits prioritized during selection. Based on this integrated characterization, PHULE CHETAK, BM-2002-1, BM-

2003-2, BM-4, AKM-4, and BPMR-145, BWMCD-6-61-33-1-3-1, BWMCD-6-58-5-1-4-1, BWMCD-6-5-8-1-3-1, BWMCD-6-13-17-1-5-1, BWMCD-6-10-1-4-1, BWMCD-7-4-1-1-1 are recommended as the most robust genotypes for future breeding programs aimed at enhancing climate resilience in greengram.

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