*Biological Forum – An International Journal* **15(11): 483-488(2023)**

**ISSN No. (Print): 0975-1130**
**ISSN No. (Online): 2249-3239**

# Phenotypic Variability Analysis of Moth Bean (*Vigna aconitifolia*) Accessions under Drought and Heat Stress Conditions

***Monika Punia[1*], Lalit Kumar Rolaniya[1], Ram Lal Jat[1], Ashok Kumar Parihar[2] and Sudheer Kumar[1]***
*[1]ICAR-Indian Institute of Pulses Research, Regional Research Centre, Bikaner-334006 (Rajasthan), India.*
*[2]ICAR- Indian Institute of Pulses Research, Kanpur-208024 (Uttar Pradesh), India.*

*(Corresponding author: Monika Punia*)*
*(Received: 15 September 2023; Revised: 28 September 2023; Accepted: 12 October 2023; Published: 15 November 2023)*
*(Published by Research Trend)*

**ABSTRACT: The moth bean (*Vigna aconitifolia* (Jacq.) Maréchal) is a pulse crop of significant economic value in the arid regions of India, known for their harsh drought conditions and extremely hot summers. In a comprehensive evaluation of phenotypic diversity, this study analyzed 300 moth bean accessions, taking into account seven qualitative and eight quantitative traits. The study uncovered extensive variability within the quantitative traits, in contrast to the qualitative traits which presented limited diversity. Analysis of variance demonstrated highly significant differences among the accessions for all measured quantitative traits, with the exception of plant height. The traits displayed a strong correlation between phenotypic and genotypic coefficients of variation, suggesting minimal environmental influence on trait expression. Notably, most traits showed high heritability with significant genetic advance potential, a pattern not observed for plant height and the number of seeds per pod, indicating these traits may be more complex and influenced by environmental factors. This research underlines the vast phenotypic diversity present in moth bean accessions and suggests a promising direction for future breeding programs aimed at enhancing crop resilience and productivity in arid environments.**

**Keywords:** Drought, moth bean, quantitative traits, heritability and phenotypic diversity.

## INTRODUCTION

The moth bean (*Vigna aconitifolia*) is a hardy legume crop that thrives in arid and semi-arid regions, renowned for its drought resistance and ability to grow in marginal soils. It is a critical source of protein in diets for humans (Rani *et al*., 2023) and serves as a fodder crop, green manure, and cover crop, contributing to sustainable agricultural practices. The small, yellow-brown seeds of the moth bean are a staple in traditional dishes and are valued for their nutritional content, particularly high protein and essential amino acids

Studying the phenotypic variability within moth bean cultivars is crucial for crop improvement and resilience. It provides insights into the range of adaptation mechanisms the plant possesses, which can be harnessed to enhance yield and stress tolerance. As climate change intensifies, understanding this variability becomes vital for breeding programs aimed at securing food production in increasingly hostile environmental conditions. Climate change poses a formidable challenge to global agriculture, exacerbating the frequency and severity of drought and heat stress events (Abbass *et al.*, 2022). These environmental stressors critically undermine agricultural productivity by impairing plant growth, disrupting photosynthesis, and hastening senescence (Mareri *et al*., 2022). Drought stress limits water availability, leading to reduced leaf size, stunted growth, and ultimately, lower crop yields. Heat stress, often concurrent with drought, can cause denaturation of vital cellular proteins and enzymes, further diminishing a plant's physiological and metabolic functions.

The concurrent impact of these stresses can be particularly deleterious, as they not only diminish yield but also deteriorate the quality of agricultural produce. Nutrient composition, seed viability, and flavor profiles are adversely affected, reducing the marketability and nutritional value of the crops. For subsistence farmers and global food supplies, enhancing stress resistance in crops like the moth bean is not merely beneficial but essential for food security and agricultural sustainability.

Previous research on phenotypic and genetic variability in moth bean and related crops under stress conditions has provided valuable insights into the adaptability of these crops to challenging environments. The moderate to high heritabilities coupled with moderate expected genetic advance in moth bean were observed for plant height, pod length, number of branches per plant exhibited positive and significant association with seed yield (Vir and Singh 2015). The higher PCV and GCV was observed for harvest index (38.02%,36.06%) followed by seed yield per plant (34.18%, 33.82%) and number of pods per plant (23.97%,17.86%). Most of the characters possessed high heritability (Sahoo *et al*., 2019). These studies have focused on characterizing agro-morphological traits, including plant height, pod number, seed yield. These investigations have identified specific traits associated with stress tolerance and highlighted the potential for genetic improvement in moth bean. However, several knowledge gaps persist in this field. Firstly, while previous studies have identified traits associated with stress tolerance, there is a need for a comprehensive understanding of the relationships among these traits and their relative importance in contributing to overall crop performance. Additionally, the identification of specific accessions or genotypes with superior stress resistance and desirable agronomic traits remains an ongoing challenge.

This study aims to address these knowledge gaps by conducting a comprehensive analysis of agro-morphological traits in a diverse collection of moth bean accessions. By doing so, it aims to provide a more holistic understanding of the factors influencing crop performance under stress conditions and identify potential candidates for breeding programs.

## MATERIALS AND METHODS

The present investigation conducted at the ICAR-Indian Institute of Pulses Research in Bikaner, Rajasthan. This area is characterized by a hyper-arid climate with extreme temperatures and low annual rainfall of 263 mm. The soil is loamy sand with a slightly alkaline pH and low to medium levels of nutrients. The research involved 300 moth bean accessions planted in an augmented design with eight blocks, including four check varieties. The crop was sown on July 25, 2021, to coincide with the rainy season. Agronomic practices were followed to maintain a good plant population. Weather data from the experimental period showed that rainfall was 54% below the average monsoon season, with an uneven distribution from July to October. There was a long dry spell post-sowing, followed by more significant rainfall in mid-September to early October. Temperature and humidity varied widely during the crop growth period.

Based on the phenotypic frequencies of qualitative traits Shannon–Weaver diversity indices (H') as described by Jain *et al* (1975) and reported by Manyassa *et al*. (2008) was calculated following the formula:

$$H' = -\sum_{i=1}^{n} pi\ logpi$$

where pi is the proportion of the accessions in the $i^{th}$ class of an n-class character.

Data was collected on 15 traits from selected plants, following IPGRI and NBPGR descriptors. These included plant vigor, growth habit, leaf color, seed characteristics, and flowering time. Disease severity was also recorded. Statistical analysis was performed using descriptive statistics and ANOVA to calculate variation among the moth bean accessions. The analysis provided estimates of heritability, genetic advance, and coefficients of variance, which are crucial for assessing the effectiveness of selection in breeding programs.

## RESULT AND DISCUSSION

*A. Effect of drought and heat stress*

Abiotic stresses are mostly inescapable and are the most detrimental factor in crop development, particularly in arid regions. Drought and heat stresses are the major abiotic stresses and often occur in combination (Prasad, 2008). These stresses affect crop growth, development, and yield processes. In our experiment, there was a long dry spell just after sowing of the crop and the mean maximum temperature during that period was 40.5°C. The rainfall distribution from July to October was erratic, and the crop suffered soil moisture deficit with heat stress at the seedling and vegetative growth stages. As a result, out of 300 moth bean accessions, 17% were not germinated and 11.66% were not survived. These stresses alter the initiation and duration of developmental stages (Prasad *et al*., 2008).

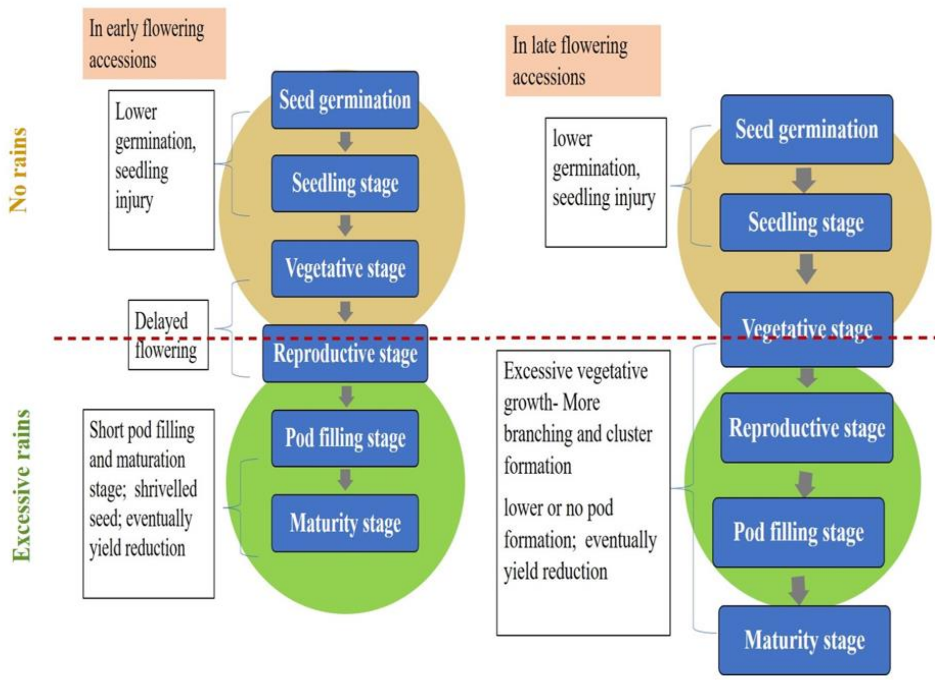


**Fig 1.** Effect of erratic rainfall on different growth stages of moth bean accessions.

In moth bean accessions, stress before flowering delayed the transition from the vegetative stage to the reproductive stage and plant remained vegetative until the stress was relieved. Thus, there was a 3 to 20 days delay in the onset of floral development; in sorghum, a similar finding was observed by Craufurd *et al*., 1993. Drought during flowering and anthesis may lead to failure of fertilisation because of decreasing pollen or ovule function, inhibits pollen development and causes sterility, shortening the pod development stage and the grain-filling duration leading to small and shrivelled seed with reduced yield (Wheeler *et al*., 2000; Prasad *et al*., 2006; Wardlaw and Willenbrink 2000). During September, there were more rainy days, and because of more rains, the inter-row space; was entirely covered by excessive vegetative growth of semi-erect and spreading type accessions which led to lower pod formation and eventually yield reduction.

*B. Variation in qualitative traits*

The frequency distribution of different classes within each qualitative character is depicted in Fig. 2. A prolonged dry weather lasted up to 37 days; the crop suffered from a lack of water during the early development stages. In the collection, the accessions analysed were generally less vigorous. Predominantly, 64.97% of the accessions had low early plant vigour, whereas only 9.67% were very good and 25.34 % attributed good plant vigour. The growth habit of the moth bean is indicated by the stem branching pattern, which may range from spreading to compact upright type. Three main classes of growth habits were observed in the collection: erect (3.39%), semi-erect (56.19) and spreading type plant growth habit (41.90%). Moth bean is cultivated as the sole crop and a component crop in different cropping systems; therefore, plant type is also an essential feature of this crop. Erect and determinate type plant types are suitable for sole cropping short growing season (58-65 days) as well as for intercropping. For sole cropping during the normal growing season (70-74 days), semi-erect type plants with indeterminate habit are suitable (Kumar, 2002).

Many accessions (87.38%) presented a drum shape, while 12.62% had oval type seed shape. It was observed that most accessions (80.84) had green leaf colour while 19.16% of accessions showed dark green leaf colour. The majority of accessions (48.58%) in the collection had a shallow type lobing of terminal leaflet followed by intermediate (27.83%) and deep (23.58%) lobing of terminal leaflet. Contrasting forms of this trait can be utilised as a morphological marker to identify hybrids in $F_1$. Other characters have limited genetic diversity for contrasting traits which can be easily identifiable. The variation observed in seed colour showed three classes in which the most represented was light brown (47.72%) followed by cream (28.97%) and dark brown (21.03%). The moth bean seed luster was also recorded, but all the accessions were non-lustrous (dull).

In qualitative traits, variability was calculated by Shannon–Weaver diversity indices (H') as described by Jain et al. (1975). The diversity index (H') ranged from 0.38 to 1.05 (Fig. 3), showing remarkably low phenotypic variability for contrasting forms of qualitative traits. Lobing of terminal leaflet was most diversified (1.05), followed by seed colour (1.03). In contrast, the seed shape exhibited the least diversity (0.38). Moth bean flower size is very small, so it is difficult to emasculate; therefore, hybridisation without emasculation is feasible and may produce 2-5 % hybrid seeds (Mahla *et al.,* 2022). Contrasting forms of traits could be utilised in order to cross desirable parents and to identify hybrid progeny.

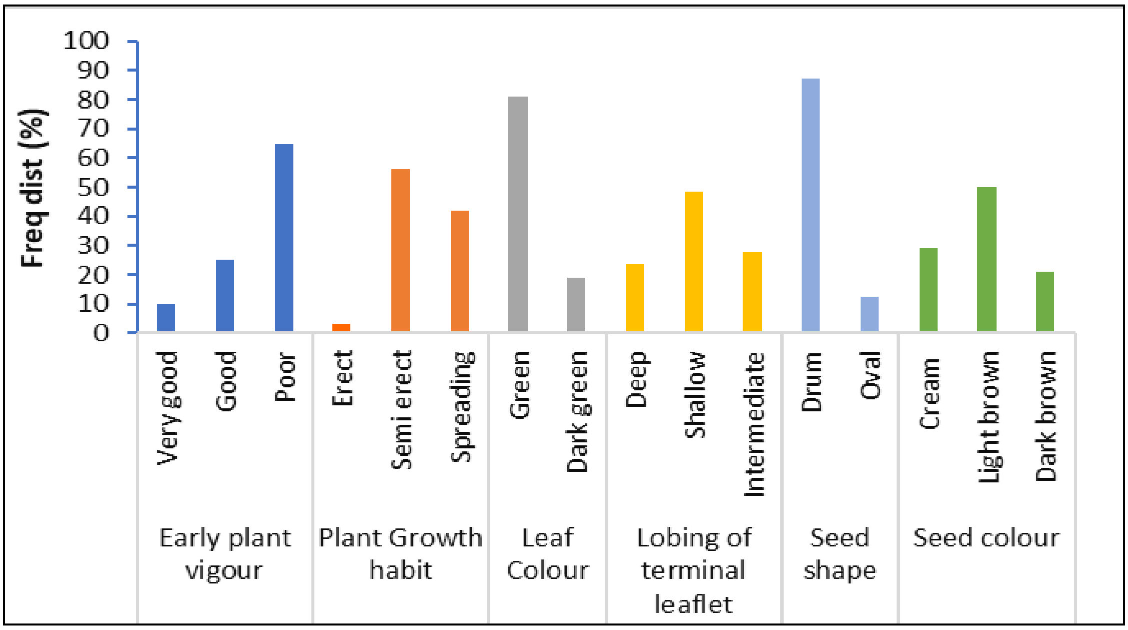


**Fig. 2.** Frequency distribution of different qualitative traits.

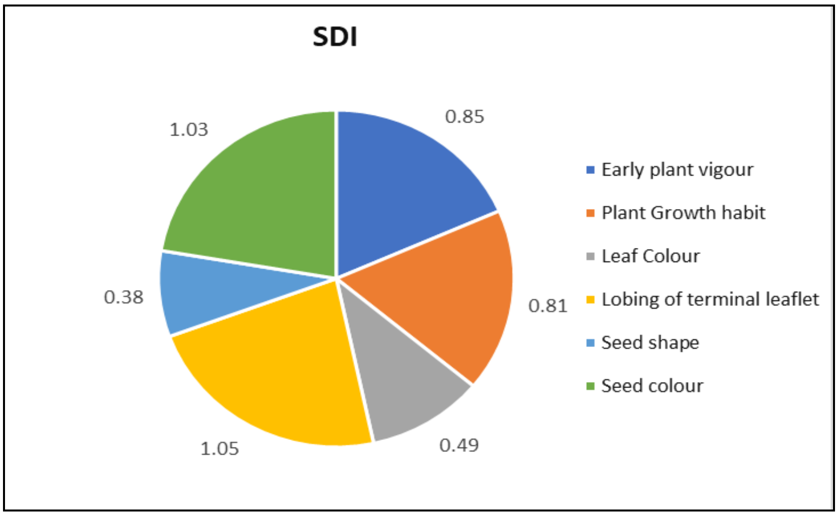


**Fig. 3.** Shannon–Weaver diversity indices (H') for various qualitative traits.

*C. Variation in quantitative traits*

**Phenotypic divergence in the collection.** The accessions studied for eight different quantitative traits were significantly different for a large number of quantitative traits measured. As revealed by the descriptive statistics and ANOVA results (Table 1), a significant variation existed in all the characters except plant height. Any breeding programme may get a good start when there is a substantial level of variability present among the accessions. In the case of the moth bean, several studies were conducted in the past to estimate the genetic diversity and a wide range of variability was recorded for yield and yield attributing traits (Vir and Singh 2015; Yogeesh *et al*., 2016; Meena *et al*., 2021).

**Table 1: Descriptive statistics for quantitative traits.**

| Sr. No. | Traits | Minimum | Maximum | Mean | SD | CV |
|---|---|---|---|---|---|---|
| **1.** | Days to 50% flowering | 35.00 | 69.00 | 53.28 | 6.38 | 11.97 |
| **2.** | Plant height (cm) | 20.00 | 48.00 | 36.07 | 5.67 | 15.72 |
| **3.** | Number of branches per plant | 1.40 | 21.60 | 7.12 | 5.65 | 79.36 |
| **4.** | Number of clusters per plant | 3.60 | 51.60 | 18.03 | 10.57 | 58.64 |
| **5.** | Number of pods per plant | 5.75 | 200.80 | 39.18 | 30.01 | 76.59 |
| **6.** | Number of seeds per pod | 3.60 | 6.80 | 5.08 | 0.45 | 8.90 |
| **7.** | Test weight (gm) | 1.01 | 2.73 | 2.28 | 0.30 | 13.04 |
| **8.** | Seed yield per plant (gm) | 0.28 | 17.07 | 2.82 | 2.50 | 88.69 |

Among all the quantitative traits seed yield per plant showed a highest coefficient of variation (CV = 88.69). Across all plots, it varied from 0.28 g to 17.07 g showing a wide range of variability in the germplasm for this trait. The number of branches per plant and number of pods per plant showed a high value of the coefficient of variation (CV) after yield per plant that was 79.36 and 76.59, respectively. Another trait which exhibited a high variability (CV = 58.64) in the germplasm was number of cluster per plant, and it varied from 3.6 to 51.6 pods per plant. The traits such as plant height, days to 50% flowering, number of seeds per pod and test weight showed low variation (CV < 20%). Similar results were observed by Sihag *et al*. (2004) and Patel *et al*. (2008). In contrast to this, Yaqoob and Najibullah (2005) reported high variability for plant height, days to 50% flowering and number of seeds per pod.

Out of eight quantitative traits the most significant quantitative traits for arid regions are days to 50% flowering and yield per plant. Early flowering genotypes escape the terminal drought situations, so in arid regions, the selection of promising genotypes should be based on early flowering rather than maturity (Kumar, 2002). IC-8851, IC-329051, IC-370508, IC-415116, IC-415127, IC-415134, IC-415138, C-120963 were identified early flowering types; therefore, these accessions can be used as a donor for the development of short-duration varieties. Accessions IC-11368, IC-34715, IC-39709, IC-39741, IC-35942, IC-11352, IC-52152, IC-39835, IC-39659, IC-10185, IC-10530, IC-11344, IC-11463, IC-10880 were identified high yielding over the check varieties.

Generally, moth bean pods have 4-5 seeds per pod in arid conditions, and 2-3 seeds can be increased, which may enhance yield by increasing the number of seeds per pod. Accessions IC-121065, IC-311396, IC-36616, IC-39816, IC-311450 were identified with > 6 seeds per pod; Therefore, these accessions with more seeds per pod can be utilised as a donor in the breeding programme.

*D. Components of phenotypic variance and estimation of genetic parameters*

The mean values of eight quantitative traits were used in a combined analysis of variance to estimate the different genetic variability parameters (genotypic variance, phenotypic variance and environmental variance). Based on these variance components, phenotypic and genotypic coefficient of variation, heritability and genetic advance were estimated and presented in Table 2. There was a close relationship between genotypic and phenotypic coefficients of variation for almost all the traits, although the phenotypic variance was higher than the corresponding genotypic values. This shows that traits are less influenced by the environment and direct selection for these traits should be used for their improvement. High phenotypic and genotypic coefficient of variation were estimated for yield per plant, number of pods per plant, number of branches per plant and number of cluster per plant in moth bean accessions. Similar results were also reported by Sihag *et al*. (2004). These results indicate that improvement through direct selection is easy and effective for these traits.

**Table 2: Variance components, heritability and genetic advance of different traits.**

| **Traits** | **Variance Components** | | | **Phenotypic and Genotypic coefficient of variation** | | **Heritability ($H^2$)** | **Genetic Advance (GA)** |
|---|---|---|---|---|---|---|---|
| | $\sigma^2P$ | $\sigma^2G$ | $\sigma^2E$ | PCV | GCV | | |
| Days to 50% flowering | 40.68 | 40.35 | 0.33 | 12.03 | 11.98 | 99.2 | 13.05 |
| Plant height | 32.13 | 12.89 | 19.24 | 15.74 | 9.97 | 40.12 | 4.69 |
| Number of branches /plant | 31.93 | 31.65 | 0.28 | 80.33 | 79.98 | 99.12 | 11.55 |
| Number of cluster/plant | 111.8 | 97.32 | 14.47 | 59.08 | 55.12 | 87.05 | 18.99 |
| Number of pods/plant | 900.54 | 667.63 | 232.91 | 76.78 | 66.11 | 74.14 | 45.9 |
| Number of seeds/pod | 0.2 | 0.17 | 0.03 | 8.91 | 8.13 | 83.09 | 0.77 |
| Test weight | 0.09 | 0.08 | 0.004 | 13.03 | 12.73 | 95.47 | 0.59 |
| Yield/plant | 6.25 | 4.34 | 1.91 | 88.72 | 73.94 | 69.46 | 3.58 |

The phenotypic coefficient of variation (PCV) varied from 88.72 (yield per plant) to 8.91 (seed per pod) whereas genotypic coefficient of variation (GCV) ranged from 79.98 for number of branches per plant to 8.13 for number of seeds per pod. The highest value of phenotypic and genotypic coefficients of variation was observed for yield per plant and number of branches per plant, respectively. Heritability estimates ranged from 40.12 to 99.2 and the genetic advance ranged from 0.59 to 48.6. Almost all traits exhibited high value of heritability. The highest value (99.2) was observed in days to 50% flowering, while plant height showed the lowest (40.12) value of heritability. Concerning genetic advance, the highest value was observed in (45.9) number of pods per plant and the lowest was observed for test weight (0.59).

High estimates of heritability coupled with high genetic advance were observed for all the traits except plant height and number of seeds per pod. Hence these traits are easy to improve through simple selection. Vir and Singh, 2015 and Yogeesh *et al*. (2016) also reported similar results in earlier studies.

## CONCLUSIONS

This study revealed that moth bean accessions comprised a wide range of variability for yield and yield attributing traits, which could be utilised to improve this valuable but neglected pulse crop. However, qualitative traits showed limited variability, but contrasting forms of some qualitative traits can be used to cross desirable parents and identify hybrid progeny. Accessions dominated the collection, with the semi-erect plant growth habit contributing 56.19 % of the total collection. Almost all the traits exhibited a close relationship between phenotypic and genotypic coefficients of variation, indicating that environment had little effect on their expression and direct selection can be done for improvement.

## FUTURE SCOPE

The study's findings are critical for developing strategies to combat abiotic stress and improve crop yields in arid and semi-arid regions.

**Acknowledgement.** Authors gratefully acknowledge the ICAR-Indian Institute of Pulses Research, Kanpur, India for support in this study.
**Conflict of interest.** None

## REFERENCES

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environ. Sci. Pollut. Res.*, *29*(28), 42539–42559.

Craufurd, P. Q., & Peacock, J. M. (1993). Effect of heat and drought stress on sorghum (*Sorghum bicolor*). II. Grain yield. *Exp. Agric., 29*, 77-86.

Jain, S. K., Qualset, C. O., Bhatt, G. M., & Wu, K. K. (1975). Geographical patterns of phenotypic diversity in a world collection of durum wheats. *Crop Sci.*,*15*(5), 700-704.

Kumar, D. (2002) New concept of moth bean improvement. Moth bean in India: 31-47.

Mahla, H. R., & Sharma, R. (2022). An easy method of artificial hybridisation in two arid legumes, guar (*Cyamopsis tetragonoloba* Taub.) and moth bean [*Vigna aconitifolia* (Jack.) Marechal]. *Indian J. Genet. Plant Breed*., *82*(1), 109-112.

Manyasa E. O., Silim S. N., Githiri S. M., & Christiansen J. L. (2008) Diversity in Tanzanian pigeonpea [*Cajanus cajan* (L.) Millsp.] landraces and their response to environments. *Genet Resour Crop Evol.*, *55*, 379–387.

Mareri, L., Parrotta, L., & Cai, G. (2022). Environmental Stress and Plants. *Int. J. Mol. Sci*., *23*(10), 5416.

Meena, S., Sharma, N.K., Sharma, A.K., Kumar, R., & Gour, G., (2021). Study of Genetic Variability Parameters for Seed Yield and Component Traits in Mothbean [*Vigna aconitifolia* (Jacq) Marechal] under Arid Environment. *Biological Forum – An International Journal*, *13*(3a), 180-183.

Patel, J. D., Desai, N. C., Intwala, C. G., & Kodappully, V. C. (2008). Genetic variability, correlation and path analysis in moth bean. *J. Food Legumes 21*, 158-160.

Prasad, P. V. V., Staggenborg, S. A., & Ristic, Z. (2008). Impacts of drought and/or heat stress on physiological, developmental, growth, and yield processes of crop plants." Response of crops to limited water: Understanding and modeling water stress effects on plant growth processes *1*, 301-355.

Prasad, P. V. 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. *Agric. For. Meteorol*., *139*(3-4), 237-251.

Rani, J., Dhull, S. B., Kinabo, J., Kidwai, M. K. & Sangwan, A. (2023). A narrative review on nutritional and health benefits of underutilized summer crop to address agriculture challenges: Moth bean (*Vigna aconitifolia* L.). *Legume Sci*., e204.

Sahoo, S., Sanadya, S. K., Kumari, N., & Baranda, B. (2019). Estimation of the various genetic variability parameters for seed yield and its component traits in Mothbean germplasm [*Vigna aconitifolia* (Jacq.) Marechal]. *J. Pharmacogn. Phytochem*., (SP3), 49-52.

Sihag, S. K., Khatri, R. S., & Joshi, U. N. (2004). Genetic variability and heritability for grain yield and its components in mothbean [*Vigna aconitifolia* (Jacq.) Marechal]." *Annals of Biology* (India).

Vir, O. & Singh, A. K. (2015). Moth bean [*Vigna aconitifolia* (Jacq.) Marechal] germplasm: Evaluation for genetic variability and inter characters relationship in hot arid climate of western Rajasthan, India. *Legume Res. - An International Journal*, *38*(6).

Wardlaw, I. F., & Willenbrink, J. (2000). Mobilisation of fructan reserves and changes in enzyme activities in wheat stems correlate with water stress during kernel filling. *New Phytol*., *148*(3), 413-422.

Wheeler, T. R., Craufurd, Peter. Q., Richard H. E, John, R., & Vara-Prasad, P, V. (2000). Temperature variability and the yield of annual crops. *Agric. Ecosyst. Environ. 82*(1), 159-167.

Yaqoob, M., Najibullah & Khaliq, P. (2005). Moth bean germplasm evaluation for yield and other important traits. *Indus J. Plant Sci*., *4*, 241-248.

Yogeesh, L. N., Viswanatha, K. P., Madhusudhan, R., & Gangaprasad, S. (2016). Morphological diversity and genetic variability in moth bean. *Int. J. Sci., Environ. Technol*. *5*, 1912-1924.

**How to cite this article:** Monika Punia, Lalit Kumar Rolaniya, Ram Lal Jat, Ashok Kumar Parihar and Sudheer Kumar (2023). Phenotypic Variability Analysis of Moth Bean (*Vigna aconitifolia*) Accessions under Drought and Heat Stress Conditions. *Biological Forum – An International Journal, 15*(11): 483-488.