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Screening of sweet potato (*Ipomoea batatas* (L.) lam.) cultivars for drought tolerance using multi-index analysis

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Abstract
This study explores the drought response of sweet potato varieties through a comprehensive analysis of yield parameters and drought tolerance indices. Tuber weight and diameter were analyzed under two water regimes, 100% field capacity (FC) and 50% FC. Tuber weight and diameter assessments, conducted under different field capacities. Root development analysis underscores the adverse impact of drought on key physiological processes, aligning with established findings on sweet potato yield reduction under such conditions. Drought tolerance indices, including Yield Index (YI), Yield Stability Index (YSI), Mean Productivity Index (MPI), Geometric Mean Productivity (GMP), and Stress Tolerance Index (STI), were examined. Sree Kanaka consistently exhibits resilience across these indices, positioning it as a promising drought-tolerant cultivar. A correlation study between drought indices and yield refines the evaluation process, emphasizing the significance of MPI, STI, and GMP in discriminating between tolerant and susceptible genotypes. This research provides crucial insights for selecting resilient sweet potato cultivars under drought conditions, offering a robust methodology applicable to diverse crops, contributing to sustainable crop production in challenging environments.

Keywords: Drought indices, sweet potato, yield loss, drought tolerance, ranking method

1. Introduction

Sweet potato (*Ipomoea batatas*), a widely cultivated and nutritionally significant crop, plays a pivotal role in global food and nutritional security owing to its remarkable versatility and dietary value. It is a vital source of carbohydrates, vitamins, and dietary fiber for millions of people, especially in regions where there is limited arable land (Sapakhova *et al*., 2023) [34]. Sweet potato is known for its adaptability to different agro climatic conditions and relatively low water requirements compared to other major staple crops, making it as indispensable in bolstering food security, particularly in areas prone to environmental variability (Motsa *et al*., 2015) [27]. Beyond its role as a subsistence crop, sweet potato cultivation is economically significant, contributing to both smallholder and commercial farming enterprises. Its versatile utilization in various culinary traditions and its potential as a source of industrial raw materials further enhance its importance in the agricultural landscape (Gouveia *et al*., 2019) [14]. As a resilient and nutrient-rich crop, sweet potato holds promise in addressing the nutritional needs of vulnerable populations and mitigating the impacts of malnutrition. Furthermore, the sweet potato's global significance stems from its exceptional adaptability to a wide range of ecological conditions, encompassing tropical to temperate climates (Raji *et al*., 2021; Senthilkumar *et al*., 2023) [31, 36]. Its ability to thrive in diverse soil types positions it as a viable crop even in regions characterized by soil variability. With an efficient use of water resources and a relatively short growth cycle, sweet potato cultivation becomes feasible, especially in areas where access to irrigation is limited. This versatility not only solidifies its role as a cornerstone in ensuring food security but also highlights its potential as a vital component of sustainable agricultural systems.

In light of the sweet potato's pivotal role in global agriculture, the sustainable cultivation of this versatile crop in the face of increasing moisture stress has become an imperative. The challenges of water scarcity and erratic precipitation patterns, exacerbated by climate change, necessitate a comprehensive understanding of how various sweet potato varieties respond to moisture stress (Kivuva *et al*., 2015) [21].

Moreover, the rich genetic diversity within sweet potato cultivars holds promise for crop improvement endeavours (Laurie, 2014) [22]. Variations in traits such as drought tolerance, resistance to pests, and nutritional content offer valuable options for breeders working toward enhancing crop resilience and nutritional quality in the context of shifting environmental dynamics (Ricardo, 2011) [32]. Leveraging this diversity through comprehensive evaluation, as facilitated by drought indices, becomes essential in selecting the most promising cultivars to address both immediate and long-term challenges in modern agriculture (Saraswati, 2007) [35]. Additionally, it is essential to explore the physiological mechanisms and conventional breeding methods that can enhance sweet potato's drought tolerance (Placide *et al*., 2013; Velumani *et al*., 2020) [30, 38]. This holistic approach aligns with the overarching goal of enhancing the sustainability and adaptability of this vital crop within the global agricultural milieu.

In addition to sweet potato's nutritional significance and adaptability to diverse agroclimatic conditions, evaluating its drought tolerance through established indices such as the Yield Index (YI), Yield Stability Index (YSI), Mean Productivity Index (MPI), Geometric Mean Productivity (GMP), and Stress Tolerance Index (STI) is pivotal (Agili *et al*., 2012; Gitore *et al*., 2021; Atung *et al*., 2015) [2, 13, 4]. These indices provide quantifiable measures of crop performance, enabling nuanced assessments of how each cultivar responds to varying moisture regimes. Recent studies emphasize the importance of these indices in screening and selecting drought-tolerant sweet potato and rice genotypes, ultimately contributing to the development of more resilient and productive crop varieties (Kandel *et al*., 2022) [18]. As we delve into the performance evaluation of sweet potato varieties under moisture stress conditions, these indices become essential tools not only for addressing immediate challenges but also for enhancing the sustainability and adaptability of this vital crop.

The primary objective of this study is to assess the drought tolerance of five sweet potato varieties-Sree Bhadra, Sree Rethna, Sree Kanaka, Sree Varun, and Kanhangad local-under controlled moisture conditions. By subjecting these varieties to different field capacities (100% FC and 50% FC) within a factorial completely randomized design, we aim to calculate essential drought indices, including the Yield Index (YI), Yield Stability Index (YSI), Mean Productivity Index (MPI), Geometric Mean Productivity (GMP), and Stress Tolerance Index (STI). Through this evaluation, we seek to identify sweet potato cultivars that exhibit resilience and stability in response to moisture stress, contributing to the development of more drought-tolerant varieties.

2. Materials and Methods

Stem cuttings of the five sweet potato varieties, *viz*., Sree Bhadra, Sree Rethna, Sree Kanaka, Sree Varun, and *Kanhangad* local, were obtained from ICAR-CTCRI farm, Sreekaryam, Thiruvananthapuram, Kerala, India. The five varieties were grown in pots under controlled soil moisture regimes. The experiment, designed as a factorial experiment with a completely randomized block design, was conducted with four replications during 2021-2022. The location of the experiment was at the College of Agriculture, Vellayani, Thiruvananthapuram, positioned at the latitude of N 08025'49.6632", longitude of E 76059'24.954", and an altitude of 29 m above mean sea level.

2.1 Soil moisture regime description

To ensure the reliability and reproducibility of the experiment, rigorous measures were implemented to control and monitor the soil moisture levels. The two distinct soil moisture regimes were maintained at 100% field capacity (control) and 50% field capacity (stress) for the respective groups. Continuous monitoring of soil moisture levels was conducted using gravimetric moisture estimation at regular intervals, enabling precise adjustments to achieve and sustain the desired field capacities throughout the experimental duration.

2.2 Gravimetric methods

The gravimetric method, recommended by Topp (1993) [37], was employed to ascertain and regulate soil moisture content in the experimental pots. This involved systematic soil sampling, determination of moisture content and subsequent adjustments to maintain the targeted field capacities. In this study, soil samples were collected from experimental pots, ensuring uniformity in depth and location. The initial air-dry soil mass was determined by weighing each sample. Saturation was achieved by adding water to the samples, and the resulting mass was recorded to establish field capacity. The potting soil moisture content was adjusted to the desired field capacity using the gravimetric equation. Continuous monitoring of soil moisture levels was conducted with specific equipment, and adjustments were made to maintain the targeted field capacity. At the conclusion of the experiment, final soil mass was determined, and gravimetric soil moisture content was calculated. The formula (Mass of water/Mass of dry soil)×100 was utilized for the calculation. These steps were replicated for each experimental set, and statistical analysis was performed to ensure the robustness of the gravimetric soil moisture estimations.

2.3 Water calculation equation

In determining the amount of water required to attain field capacity, the equation Amount of water needed=moisture content at field capacity−moisture content in initial air-dry soil Amount of water needed=moisture content at field capacity−moisture content in initial air-dry soil was employed (Imakumbili, 2019) [17]. The specific values utilized in the equation were ascertained through accurate measurements to ensure transparency. The moisture content at field capacity and moisture content in initial air-dry soil were meticulously measured, yielding precise values essential for the calculation.

2.4 Estimation of drought tolerant indices

Drought-tolerant indices, encompassing YI (Yield Index), YSI (Yield Stability Index), MPI (Mean Productivity Index), GMP (Geometrical Mean Productivity), and STI (Stress Tolerance Index), were calculated based on the yield relationship under both drought stress (Ys) and control (Yn) conditions.

The drought-tolerant indices were calculated as follows

YI (Yield Index) (Gavuzzi *et al*. 1997; Lin *et al*. 1986) [12, 24].

$YI = Y_s/\hat{y}_s$

YSI (Yield Stability Index) (Bouslama and Schapaugh, 1984) [5].
$YSI = Y_s/Y_n$

MPI (Mean Productivity Index) (Rosielle and Hamblin 1981; Hossain *et al*., 1990; Adhikari *et al*., 2019) [33, 15, 1].
$MPI = (Y_n + Y_s)/2$

GMP (Geometrical mean productivity) (Fernandez, 1992; Adhikari *et al*., 2019) [10, 1].
$GMP = \sqrt{(Y_s \times Y_n)}$

STI (Stress Tolerance Index) (Fernandez 1992; Anwaar *et al*., 2020) [10, 3].
$STI = (Y_s \times Y_n)/(Y_n)^2$

Here, Ys represents yield under stress, Yn is yield under non-stress for each cultivar, and ŷs denotes yield mean in stress. These indices provide a nuanced evaluation of sweet potato varieties, offering insights into their performance under diverse conditions and contributing valuable information on drought tolerance for agricultural applications.

2.5 Statistical analysis
Statistical analysis involved the calculation of correlations among indices and tuber yields under both stress and non-stress conditions, utilizing the GRAPES software.

3. Results and Discussion

3.1 Assessing drought response based on yield parameters

The yield of sweet potato varieties is known to be highly responsive to environmental conditions (Luh *et al*., 1979) [25]. At Harvest, the tuber weight of plants grown at 100% FC ranges from 168.08g/plant (Sree Varun) to 360.1g/plant (Sree Kanaka). While at 50% FC, tuber weight ranged from 53 g/plant (*Kanhangad* Local) to 293.3 g/plant (Sree Kanaka) (Fig 1). Water deficit consistently reduces the yield of sweet potato varieties grown under drought stress (50% FC) compared to the control (100% FC). Under control conditions, Sree Kanaka (360.60 g/plant) recorded the highest tuber weight per plant, followed by *Kanhangad* Local (207.10 g/plant). Under stress conditions, *Kanhangad* Local (53 g/plant) recorded the lowest tuber weight, while Sree Kanaka (293.30g/plant) maintained the highest tuber weight compared to the rest of the studied varieties.
Watering to different field capacity had a significant effect on tuber diameter in all the varieties. Sree Kanaka recorded significantly highest tuber diameter 7.27 cm, 5.57 cm at both 100% FC and 50% FC, respectively. The lowest tuber diameter was observed in *Kanhangad* Local 3.50, 1.7 cm at both 100% FC and 50% FC, respectively. Significant difference in the mean tuber weight per plant and tuber diameter between drought and normal control conditions for all five varieties were shown in bubble graph (Fig 1).

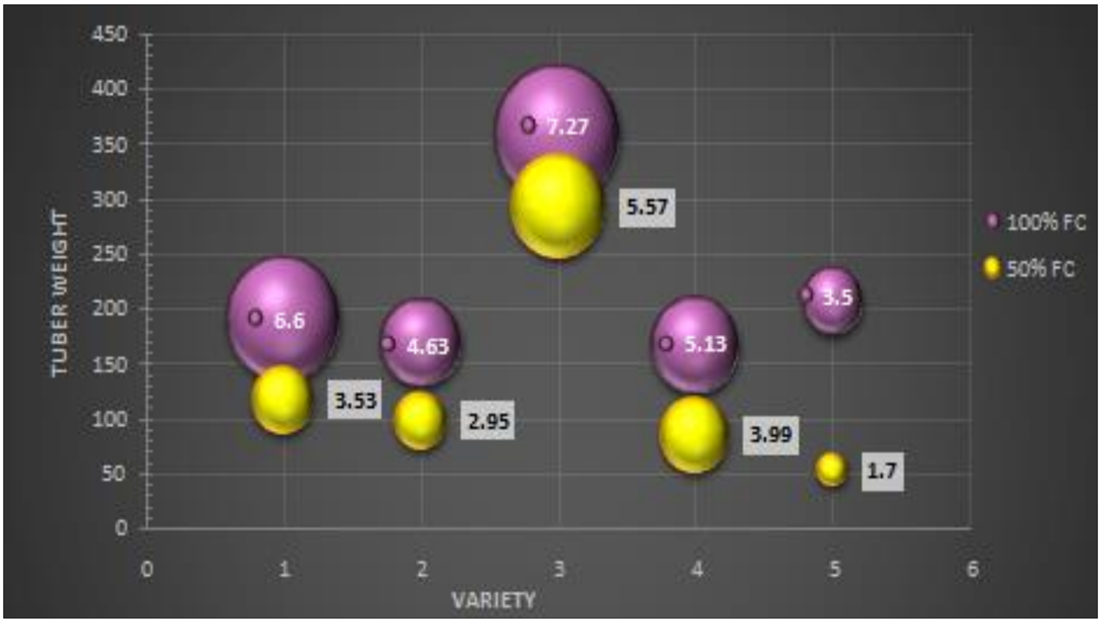


Fig 1: Effect of soil moisture content (100% FC and 50% FC on tuber diameter and tuber weight per plant of different sweet potato varieties. The size of the bubble indicates tuber diameter. X-axis – indicates varieties (1- Sree Rethna 2- Sree Bhadra 3- Sree Kanaka 4- Sree Varun5- Kanhangad Local)

Drought has two main effects on sweet potato root development, i.e. it declines the meristem activity and root elongation, which causes a negative effect on mineral and water uptake and suberization. This process further affects the dry matter production and disrupts the dry matter partitioning and its temporal distribution, resulting in reduced yield. Our experimental results also confirmed the results obtained by Lewthwaite and Triggs (2012) [23], Ekanayake and Collin (2004) [6] that there is a reduction in sweet potato yield under drought condition.

3.2 Screening of drought-tolerant sweet potato genotypes using drought-tolerant indices

Yield Index (YI): The genotypes that record high YI (more than one) are considered as drought tolerant, and those genotypes that showed values less than one are considered as susceptible to drought (Gitore *et al*., 2021) [13]. The variety Sree kanaka showed higher YI (1.6) and thus considered as tolerant variety. All other genotypes recorded less than one and so categorized as drought susceptible varieties. Similar result was also observed by Garg *et al.*

(2017) [11] in screening of rice varieties under drought condition.

Yield Stability Index (YSI)

Under both drought and control conditions, the genotypes with higher YSI are considered as stable and tolerant genotypes. Among the varieties studied, Sree Kanaka has shown the highest YSI value (0.81) and the lowest value was shown by *Kanhangad local* (0.26). All other varieties were found to show intermediate values. Similar findings have been reported in bread wheat (Farshadfar *et al*. 2012) [7], rice (Kandel *et al*., 2022) [18] and corn (Naghavi *et al*., 2013) [28].

3.2.1 Mean Productivity Index (MPI)

Under drought conditions, the varieties with higher MPI values are considered as tolerant. Among the varieties studied, Sree Kanaka has shown a higher MPI value and is considered as tolerant to drought, whilst the varieties *Kanhangad* local and Sree Varun have shown lower values and considered as sensitive to drought.

Geometric Mean Productivity (GMP)

The highest value of GMP was recorded in Sree Kanaka (324.99), followed by Sree Rethna (150.15). But relatively lower values were recorded in *Kanhangad* local (104.77), Sree Varun (120.34) and Sree Bhadra (129.36) indicating drought sensitivity.

3.2.2 Stress Tolerance Index (STI)

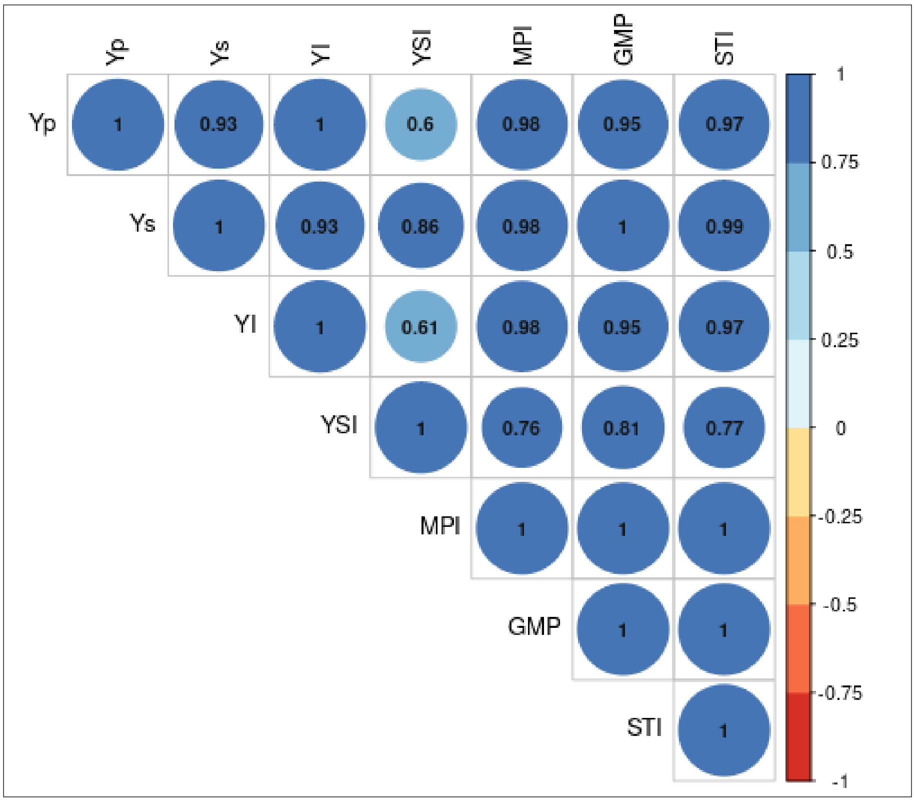
A higher STI value was recorded in Sree Kanaka (2.24), whereas the varieties *Kanhangad* local (0.23) and Sree Varun (0.31) recorded lower values. A high STI value indicates better tolerance to drought and the advantage of STI is its ability to separate group A from others (Farshadfar *et al*., 2012) [7].

3.3 Correlation study between drought indices and yield

Identifying the most drought tolerant and susceptible variety based on a single attribute is contradictory. In the present study, correlation coefficient between Yn and Ys and other drought indices were used to determine the most appropriate indices for the selection of tolerant and susceptible varieties under drought. The drought indices were calculated mathematically (Table 1) and correlation matrix (Fig 2) between variables were performed. According to Farshadfar *et al*. (2001) [8] the most suitable indices for the selection of drought-tolerant and susceptible cultivars are those indices which show relatively higher positive correlation with yield under both stress and non-stress conditions. The yield under both stress (Ys) and non-stress (Yn) conditions are significantly and positively correlated with MPI, STI and GMP, indicating that these indicators are able to discriminate tolerant and susceptible genotypes (Fig 2). However, a significant correlation was not observed in the case of YSI and YI. These observed correlations was consistent with numerous other studies.

Table 1: Drought tolerance indices calculated based on tuber yield per plant under non- stress (Yn) and stress (Ys) conditions (expressed in grams)

Variety	Yn	Ys	YI	YSI	MPI	GMP	STI
Sree Rethna	191.33	117.83	0.88	0.62	154.58	150.15	0.48
Sree Bhadra	169.83	98.53	0.78	0.58	134.18	129.36	0.35
Sree Kanaka	360.1	293.3	1.66	0.81	326.7	324.99	2.24
Sree Varun	168.07	86.17	0.77	0.51	127.12	120.34	0.31
Kanhangad local	207.1	53	0.95	0.26	130.05	104.77	0.23



*** Correlations is significant at 0.001 level (two tailed)

** Correlations is significant at 0.01 level (two tailed)

* Correlations is significant at 0.05 level (two tailed)

Fig 2: Correlation between drought indices of sweet potato

3.4 Ranks of varieties based on highly correlated drought indices

Different indices showed different varieties as drought tolerant. To determine the most desirable drought tolerant cultivar based on the indices mentioned above, the sum of ranks for each genotype was calculated. Based on these criteria, the most desirable drought-tolerant variety was identified. In the present study, considering highly and positively correlated drought indices to yield stress and non-stress, the variety Sree Kanaka showed the best sum of rank and hence identified as the most drought-tolerant cultivar. Whereas, the highest sum of ranks were showed by the varieties *Kanhangad* Local and Sree Varun which makes them the most drought sensitive varieties (Fig 3). Hence, this method of selecting tolerant and susceptible genotypes can also be adopted in drought studies in other crops (Khalili *et al*., 2012; Naghavi *et al*., 2013; Gitore *et al*., 2021) [19, 28, 13].

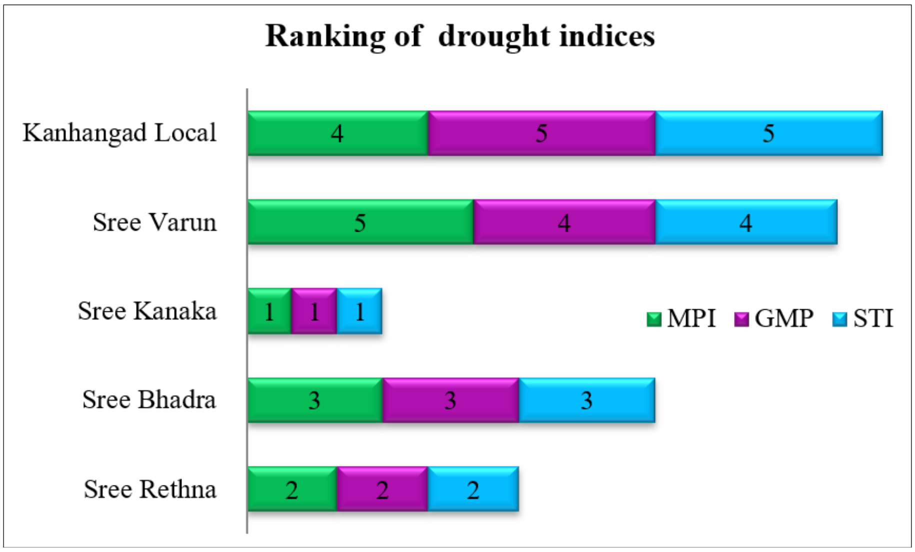


Fig 3: Sum of ranks of drought tolerant indices

4. Conclusion

Among the different drought indices evaluated, MPI, STI and GMP were found to have a higher correlation with tuber yield under drought and control conditions. So, these indices could be used to select tolerant and susceptible sweet potato genotypes under drought. The result obtained through correlation studies was followed by screening drought-tolerant genotypes using a ranking method that discriminated, Sree Kanaka as the tolerant variety with the best sum of ranks and the variety *Kanhangad* local as drought sensitive. Hence, these tolerant and sensitive varieties can be utilized in crop improvement programs for improvement of drought-tolerance in sweet potato.

5. Conflict of interest

Authors don't have any conflict of interest in publishing this article.

6. Acknowledgement

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7. References

1. Adhikari M, Adhikari NR, Sharma S, Gairhe J, Bhandari RR, Paudel S. Evaluation of drought tolerant rice cultivars using drought tolerant indices under water stress and irrigated condition. Am J Clim. Change. 2019 Apr 8;8(2):228-236.
2. Agili S, Nyende B, Ngamau K, Masinde P. Selection, yield evaluation, drought tolerance indices of orange-flesh sweet potato (*Ipomoea batatas* Lam) hybrid clone.
3. Anwaar HA, Perveen R, Mansha MZ, Abid M, Sarwar ZM, Aatif HM, *et al*. Assessment of grain yield indices in response to drought stress in wheat (*Triticum aestivum* L.). Saudi J Biol. Sci. 2020 Jul 1;27(7):1818-23.
4. Atung C, Guaf G, Komolong B. Screening sweetpotato (*Ipomoea batatas*) genotypes under soil moisture deficit condition using stress tolerance indices. Arch Appl. Sci. Res. 2015;7(11):23-29.
5. Bouslama M, Schapaugh Jr WT. Stress tolerance in soybeans. I. Evaluation of three screening techniques for heat and drought tolerance 1. Crop Sci. 1984 Sep;24(5):933-937.
6. Ekanayake IJ, Collins W. Effect of irrigation on sweet potato root carbohydrates and nitrogenous compounds. J Food Agric Environ. 2004 Jan 15;2:243-248.
7. Farshadfar E, Elyasi P. Screening quantitative indicators of drought tolerance in bread wheat (*Triticum aestivum* L.) landraces. Eur. J Exp. Biol. 2012;2(3):577-84.
8. Farshadfar E, Ghanadha, Sutka J, Zahravi M. Generation mean analysis of drought tolerance in wheat (*Triticum aestivum* L.). Acta Agron Hung. 2001 May 1;49(1):59-66.
9. Farshadfar E, Jamshidi B, Aghaee M. Biplot analysis of drought tolerance indicators in bread wheat landraces of Iran. Int. J Agric Crop Sci. 2012 Nov 7;4(5):226-33.
10. Fernandez GCZ. Effective selection criteria for assessing plant stress tolerance. In: Kus EG, editor. Adaptation of food crop temperature and water stress. Proceeding of 4th International Symposium. Shantana, Taiwan: Asian Vegetable and Research and Development Center; c1992. p. 257-270
11. Garg HS, Bhattacharya C. Drought tolerance indices for screening some of rice genotypes. IJABR. 2017;7(4):671-674.

12. Gavuzzi P, Rizza F, Palumbo M, Campanile RG, Ricciardi GL, Borghi B. Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Can J Plant Sci. 1997 Oct 1;77(4):523-31.
13. Gitore SA, Danga B, Henga S, Gurmu F. Evaluating Drought tolerance indices for selection of drought tolerant Orange Fleshed Sweet Potato (OFSP) genotypes in Ethiopia. Int. J Agric Sci. Food Technol. 2021;7(2):249-254.
14. Gouveia CS, Ganança JF, Nóbrega HG, Freitas JG, Lebot V, Carvalho MÂ. Drought avoidance and phenotypic flexibility of sweet potato (*Ipomoea batatas* (L.) Lam.) under water scarcity conditions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 2019;47(4):1037-1046.
15. Hossain AB, Sears RG, Cox TS, Paulsen GM. Desiccation tolerance and its relationship to assimilate partitioning in winter wheat. Crop Sci. 1990 May;30(3):622-7.
16. Ilker E, TATAR Ö, Tonk FA, Tosun M. Determination of tolerance level of some wheat genotypes to post-anthesis drought. Turk J Field Crops. 2011 Jan 1;16(1):59-63.
17. Imakumbili ML. Making water stress treatments in pot experiments: An illustrated step-by-step guide. Sokoine University of Agriculture: Morogoro, Tanzania, pp. 1–17.
18. Kandel BP, Joshi LP, Sharma S, Adhikari P, Koirala B, Shrestha K. Drought tolerance screening of rice genotypes in mid-hills of Nepal using various drought indices. Acta Agric Scand. Sect B Soil Plant Sci. 2022;72(1):744-750.
19. Khalili M, Naghavi MR, Aboughadareh AP, Talebzadeh SJ. Evaluating of drought stress tolerance based on selection indices in spring canola cultivars (*Brassica napus* L.). J Agric Sci. 2012 Nov 1;4(11):78.
20. Khalilzade GH, Karbalai-Khiavi H. In proc, of the 7th Iranian congress of crop scienc. Gilan, Iran, p. 563-564.
21. Kivuva BM, Githiri SM, Yencho GC, Sibiya J. Screening sweetpotato genotypes for tolerance to drought stress. Field Crops Res. 2015 Feb 1;171:11-22.
22. Laurie RN. Biochemical, physiological and agronomic response of various sweet potato cultivars/varieties to drought stress in rainout shelters and field conditions (*Doctoral dissertation*).
23. Lewthwaite SL, Triggs CM. Sweetpotato cultivar response to prolonged drought.42:1-10.
24. Lin CS, Binns MR, Lefkovitch LP. Stability analysis: where do we stand? 1. Crop Sci. 1986 Sep;26(5):894-900.
25. Luh CL, Moomaw JC, Belen EH, Villanueva M. Present and future outlook for sweet potato in Asia, research and development needs. In: 5th Symp. Int. Soc. Trop. Root Crops. Manila Philippines; c1979. p. 1-30.
26. Mohammadi R, Armioun M, Kahrizi D, Amri A. Efficiency of screening techniques for evaluating durum wheat genotypes under mild drought conditions. Int J Plant Prod. 2010;4(1):11-24.
27. Motsa NM, Modi AT, Mabhaudhi T. Sweet potato (*Ipomoea batatas* L.) as a drought tolerant and food security crop. South Afr J Sci. 2015 Dec;111(11-12):1-8.
28. Naghavi MR, Aboughadareh AP, Khalili M. Evaluation of drought tolerance indices for screening some of corn (*Zea mays* L.) cultivars under environmental conditions. Notulae Scientia Biologicae. 2013 Aug 1;5(3):388-393.
29. Patel JM, Patel AS, Patel CR, Mamrutha HM, Pradeep S, Pachchigar KP. Evaluation of selection indices in screening durum wheat genotypes combining drought tolerance and high yield potential. Int. J Curr Microbiol Appl Sci. 2019;8(4):1165-1178.
30. Placide R, Shimelis H, Laing M, Gahakwa D. Physiological mechanisms and conventional breeding of sweet potato (*Ipomoea batatas* (L.) Lam.) to drought-tolerance. Afr. J Agric. Res. 2013 May 16;8(18):1837-46.
31. Raji P, Shiny R, Byju G. Impact of climate change on the potential geographical suitability of cassava and sweet potato vs. rice and potato in India. Theor. Appl. Climatol. 2021 Nov;146:941-60.
32. Ricardo J. Screening Sweetpotato (*Ipomoea batatas* L.) for Drought Tolerance and High [beta]-carotene Content in Mozambique (Doctoral dissertation, University of KwaZulu-Natal, Pietermaritzburg).
33. Rosielle AA, Hamblin J. Theoretical aspects of selection for yield in stress and non-stress environment 1. Crop Sci. 1981 Nov;21(6):943-946.
34. Sapakhova Z, Raissova N, Daurov D, Zhapar K, Daurova A, Zhigailov A, *et al*. Sweet potato as a key crop for food security under the conditions of global climate change: A Review. Plants. 2023 Jun 30;12(13):2516.
35. Saraswati P. Physiological and growth responses of selected sweet potato (*Ipomoea batatas* (L.) Lam.) cultivars to water stress (Doctoral dissertation, James Cook University).
36. Senthilkumar KM, Raju S, Velumani R, Gutam S. Transcriptome analysis and identification of leaf, tuberous root and fibrous root tissue-specific high temperature stress-responsive genes in sweet potato (*Ipomoea batatas*).
37. Topp GC. Soil water content in soil sampling and methods of analysis. In: Carter MR, Gregorich EG, editors. Soil Sampling and Methods of Analysis. Lewish Publishers CRC Press; c1993. p. 541-557.
38. Velumani R, Muthusamy SK, Raju S, Chakrabarti SK. Analysis of molecular chaperones in differentiating storage root compared to non-tuber forming fibrous root of sweet potato (*Ipomoea batatas*). Curr Hort. 2020;8(2):51-56.