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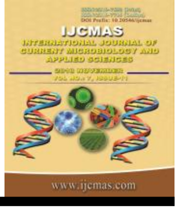

**Original Research Article**

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# Stability of Grain Nutrient Concentrations in White Finger Millet

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## ABSTRACT

**Keywords**

Finger millet, Genotype × environment, Stability parameters

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Grain calcium, iron and zinc are important micronutrients for human health for which deficiency occurs widespread in the world. Knowledge on genotype × environment interaction of these nutrients in the grains is expected to contribute to better understand the magnitude of this interaction and the potential identification of stable genotypes for these traits. The present investigation was carried out during *kharif* 2013 and 2014 in the experimental farm of Zonal Agricultural Research Station (ZARS), Bengaluru and ZARS V. C Farm Mandya to identify stable genotypes southern dry zone. The fourteen genotypes were evaluated at two locations to assess the genetic variability, detect genotype ×environment interaction and identification of genotypes which are stable across the two locations for grain nutrient content. Analysis of variance for individual environment for grain nutrient content revealed highly significant differences among the genotypes. Genotypes JWM-1 and VR-1034 for calcium content; OUAT-2, TNEC-1234 and GPU-71 for iron content and OUAT-2, TNEC-1234, VR-1034, GPU-71 and VR-936 for zinc content were identified. Pooled analysis of variance showed significant genotype × environment effects were observed for grain Calcium, iron and zinc contents. Eberhart and Russel stability parameters indicated the genotypes OUAT-2, VR-1034, GPU-71, GE-728 and JWM-1 were consistently adapted across the environments whereas, TNEC-1234, VR-936, GE-6834-1, VL-384, WFM-10, KMR-344, DHWFM 11-3, DHWFM 2-3 and GPU-67 were poorly adapted across the environments for their grain calcium content. Genotypes VR-1034, GPU-71, DHWFM 11-3, OUAT-2 and JWM-1were consistently stable across the environments whereas VR-936, GE-728, GE-6834-1, WFM-10, KMR-344, DHWFM 2-3 and GPU-67 were poorly adapted across the environments for their grain iron content. The genotypes TNEC-1234, VR-936, and GPU-71 were consistently stable whereas OUAT-2, GE-728, GE-6834-1, VL-384, JWM-1, KMR-344, DHWFM 2-3, GPU-67 poorly stable across the environment for their grain zinc content. It is observed that genotype GPU-71 is stable for iron, calcium and zinc contents across the two locations and two years. This genotype could be used as a parent for hybridization to improve micronutrient content.

## Introduction

Finger millet (*Eleusine coracana* L. Gaertn.) sub species coracana belongs to family Poaceae. *Eleusine* is a generic term named after the Greek goddess of the cereals. Common name “finger millet” is derived from the finger like branching of the panicle. The cultivated *Eleusine coracana* is an allotetraploid with chromosome number 2n=4x=36. There is considerable polymorphism for grain colour in finger millet. Traditionally brown coloured grains are predominant and preferred by the consumers. Of late, white grains are preferred by the food processing industries because of their high protein, low tannins and increased consumer acceptability (Sharathbabu *et al.*, 2008).

Finger millet is a nutritious food grain crop with a fair amount of protein (7.3g 100 $g^{-1}$) (Malleshi and Klopfenstein, 1998), dietary fibre (15-20%), (Chethan and Malleshi, 2007) and rich source of calcium (344 mg $100g^{-1}$) (Gopalan *et al.,* 2002). Wider adoptability (Uphadhayaya *et al.*, 2007) and higher nutritional quality, higher multiplication rate and longer shelf life under ambient conditions (Iyengar *et al.*, 1945), makes finger millet an ideal crop for use as a staple food and famine reserve. The most cost effective approach for mitigating micronutrient and protein malnutrition is to introduce finger millet varieties selected and/or bred for increased iron, zinc and protein contents through plant breeding. Attempts to breed finger millet for enhanced grain micro nutrient and protein contents are still in its infancy. As finger millet is a staple food crop of resource poor users and consumed in large quantities on daily basis, developing nutrient rich finger millet cultivars will contribute to reduced micro nutrient malnutrition.

## Materials and Methods

The material for present investigation was obtained from Project Coordinating Unit (Small millets), Bengaluru under All India Coordinated Small Millets Improvement Project. Material consisted of fourteen genotypes of finger millet including one white finger millet and one brown finger millet check. List of genotypes used for the investigation is shown in table 1. Experimental material was evaluated over two locations *viz.*, Bengaluru, Mandya and two seasons Kharif 2013 and 2014. The experiment was laid out in simple Randomised Complete Block Design with three replications. The plot size at each location was 3 m length comprising of 10 rows and planting was done at a spacing of 22.5 cm between rows and 10 cm between two hills in a row maintaining one healthy and vigorous seedling per hill. Fertilizers were applied at recommended dose of 50:40:25 NPK kg per ha. Nitrogen was given in two splits 50 per cent as basal and 50 per cent as top dressing. Inter cultivation practices were followed in both the locations.

## Determination of grain nutrient concentrations

The seeds of fourteen genotypes were thoroughly cleaned to remove foreign particles, samples were prepared from bulk, powdered, sieved through 40 mesh size and were used for estimation of grain nutrient content. The Protein content of the dried powder was estimated as per cent total nitrogen by micro Kjeldhal procedure and converted to per cent protein. Fat, fibre, Ash, Carbohydrate and total energy are determined according to AOAC, 1980 method. Mineral concentrations were determined by atomic absorption spectrophotometry (Perkin-Elmer 560), in an acetylene–air flame at the following wavelengths: 285 nm (Ca), 248 nm (Fe) and 214 nm (Zn).

## Statistical analysis

The statistical analysis of the data on the individual character was carried out on the mean value of five randomly selected plants on each genotype from each of the three replications. The analysis of variance for different Characters was carried out for each location separately in order to partition the variability due to different sources following the method given by Pense and Sukhatme (1964).

The stability model proposed by Eberhart and Russell (1966) was adopted to analyze the data over four environments.

The model involves the estimation of three parameters, mean (X), regression coefficient ($b_i$) and deviation from regression ($S^2d_i$), which are defined by the following mathematical formula.

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

Where,

$Y_{ij}$: Mean of the $i^{th}$ genotype at the $j^{th}$ location

(i = 1, 2, 3, 4, 5….19, j = 1, 2, 3)

$\mu_I$: The mean of $i^{th}$ genotype over all the location

$\beta_I$: The regression coefficient that measures the response of $i^{th}$ genotype to varying location

$\delta_{ij}$: The deviation from regression of the $i^{th}$ genotype of $j^{th}$ location

$I_j$: The location index obtained as the deviation from the mean of all the genotypes at the $j^{th}$ environment from the grand mean.

Mean ($\mu_i$), regression coefficient ($b_i$) and mean square deviation from linear regression line ($S^2d_i$) are the three stability parameters proposed by Eberhart and Russell (1966) in their stability model. These parameters were computed by using the following formulae.

Additive Main Effects and Multiplicative interaction effects (AMMI) model of analysis of variance for stability was followed for working out the variance for stability. The mathematical model for AMMI is

$$Y_{ger} = \mu + \alpha_g + \beta_e + \Sigma\, \lambda_n \gamma_{gn} \delta_{en} + \rho_{ge} + \varepsilon_{ger}$$

g = Genotypes

e = Environments

r= replications

Y = character of genotype g in environment e

$\mu$ = Grand mean

$\alpha_g$= Mean of the $g^{th}$ genotype minus the grand mean

$\beta_e$= Mean of the $e^{th}$ genotype minus the grand mean

n = Number of ICPAs (Interaction Principal Component axis) retained in the model.

$\lambda_n$ = Singular value or square root of the Eigen value of the PCA axis n

$\gamma_{gn}$= principal component score for PCA axis of the $g^{th}$ genotype

$\delta_{en}$ = Principal component score for PCA axis 'n' of the $e^{th}$ environment

$\varepsilon_{ger}$= Residual

## Results and Discussion

The mean protein content of the genotypes was comparable in all environments (Table 2). The protein content was highest (11.547%) and least (6.69%) in seeds of GE-6834-1 and GPU-67, respectively across the four environments (Fig. 1). The genotypes VR-1034 (9.69%), GE-728 (9.58%), VL-384(10.07%) and KMR-344 (9.02%) had higher protein content than the experimental mean (8.95%). However the check GPU-67(6.69 %) had lower grain protein content in all environments. A wide range of protein content (6.6% to 11.6%) was observed among the genotypes. The estimates of PCV and

GCV were moderate across the environments whereas, higher heritability was noticed across the environments. Narrower differences were observed between PCV and GCV for protein content across the environments (Table 3).

The seeds of JWM-1 (422.35mg/100g) had higher calcium content while those of DHWFM 2-3 had lowest calcium content (168.41 mg/100g) (Fig. 2). Seven genotypes had higher calcium content than brown grained check (239.26mg/100g) (Fig 2). A wide range (164mg/100g to 424mg/100g) of calcium content was observed among the genotypes. The estimates of PCV and GCV were high for all environments. Genotypes exhibited higher heritability across the environments except during *kharif* 2014 at Mandya (56.92%). Narrower differences were observed between PCV and GCV for calcium content across the environments (Table 3).

The seeds of genotype OUAT-2 had highest (10.13 mg/100g) iron content followed by GPU-71 (9.87mg/100g) and TNEC-1234 (9.29 mg/100g) and lowest was observed in GE-728 (2.90 mg/100g) (Fig. 2). A wide range (2.9 mg/100g to 10.4 mg/100g) of iron content was noticed among the genotypes. The estimates of PCV and GCV were high whereas heritability was high across the environments. Difference between PCV and GCV were narrow for iron content across the environments (Table 3).

The seeds of genotype OUAT-2 (6.64 mg/100g) had highest zinc content followed by TNEC-1234 (5.82 mg/100g) and VR-1034 (5.71 mg/100g). Except VR-1034 and GE-6834-1, the other genotypes have not exhibited variation for location and season (Fig. 3). Zinc content of the genotypes ranged from 2.55mg/100g to 6.88mg/100g. The estimates of genetic parameters PCV and GCV were high across the locations and seasons. Zinc content of genotypes registered high heritability across the environments. Difference between PCV and GCV were narrow for zinc content across the environments (Table 3).

None of the genotypes were superior for all the traits. Nevertheless, the genotype OUAT-2 had higher iron and zinc content.

Substantial variability for all grain nutrients observed in the fourteen finger millet genotypes. The genotypes differed significantly for protein, calcium, iron and zinc content. Grain nutrient content among the genotypes were comparable across the environments. Genotypes *viz.*, GE-6834-1, VL-384, VR-1034 and GE-728are promising for protein; JWM-1 and VR-1034 were promising for high calcium content.

White finger millet check OUAT-2 has a highest iron and zinc content among the fourteen genotypes. These genotypes can be utilized in hybridization with agronomically superior accessions/breeding lines to combine grain nutrients with farmer/consumer preferred traits. Similar findings have been reported in finger millet germplasm lines by Uphadhayaya *et al.,* (2011a).

The estimates of PCV and GCV were high for calcium, iron and zinc content in all the environments indicating the low effects of environments and greater role of genetic factors on the expression of a the character which offer scope for direct selection. Similar findings were reported in calcium (Vadivoo *et al.,* 1998), iron (Samak *et al.,* 2011 in rice; Govindraj, 2011 in pearl millet) and zinc (Samak *et al.,* 2011 in rice; Berhanu Dagnaw *et al.,* 2013 in rice).Moderate PCV and GCV were recorded for the grain protein content and indicated fairly large extent of variation for this trait. This is in accordance with the findings of the Vadivoo *et al.,* (1998) and Govindraj (2011).

**Fig.1** Mean performance of finger millet genotypes for grain calcium content across the four environments

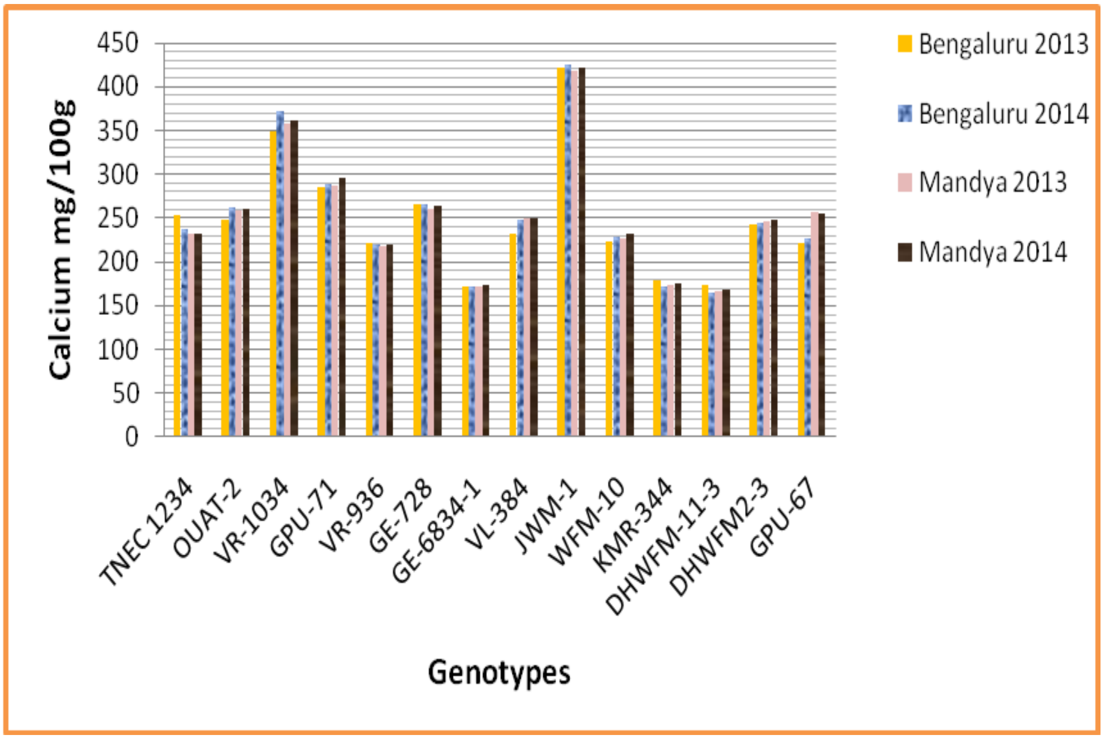

**Fig.2** Mean performance of finger millet genotypes for grain iron content across the four environments

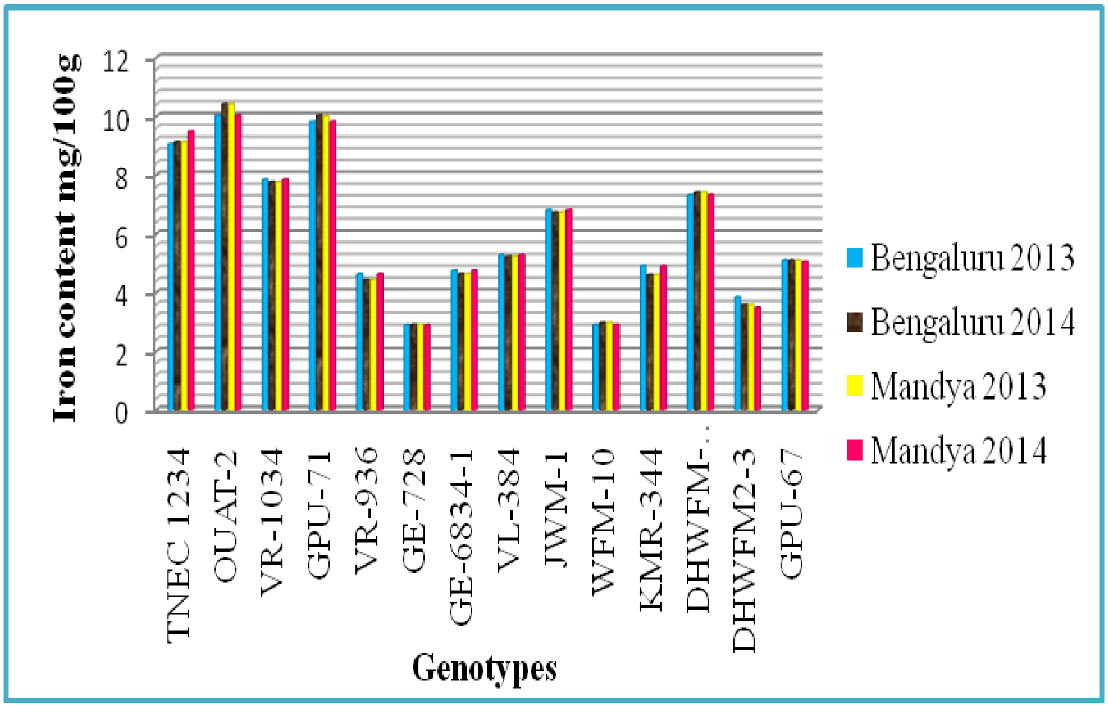

**Fig.3** Mean performance of finger millet genotypes for grain zinc content across the four environments

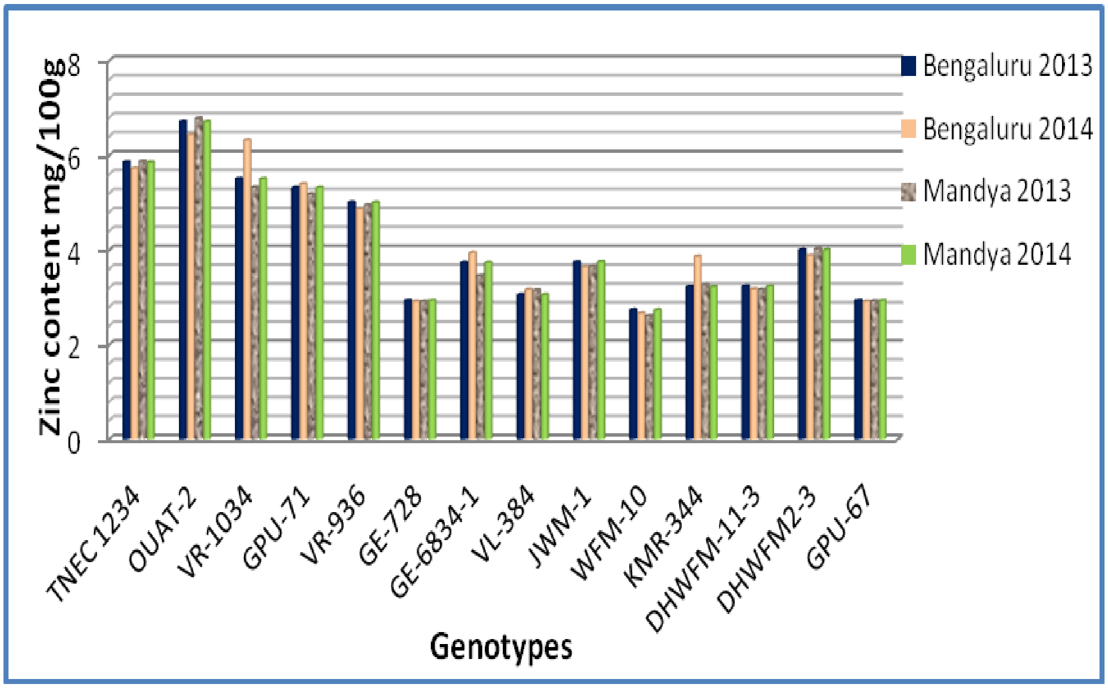

**Fig.4** AMMI biplot of main effects and G x E interaction of white finger millet genotypes for grain calcium content over locations and year

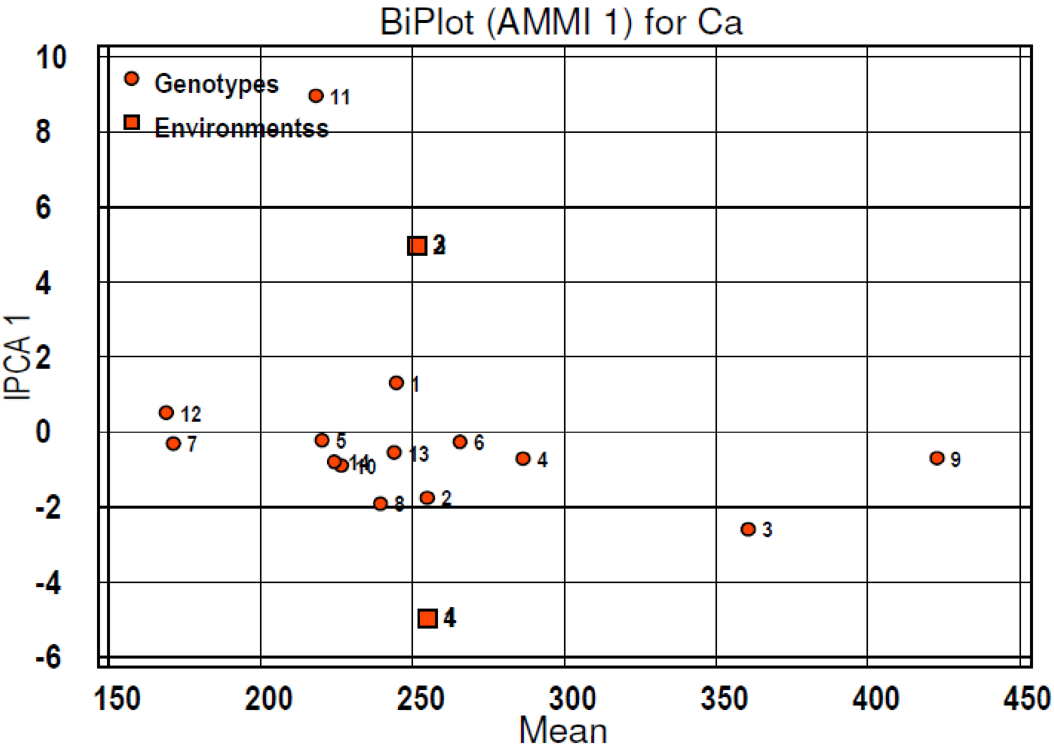

**Fig.5** AMMI biplot of main effects and G x E interaction of white finger millet genotypes for grain iron content over locations and years

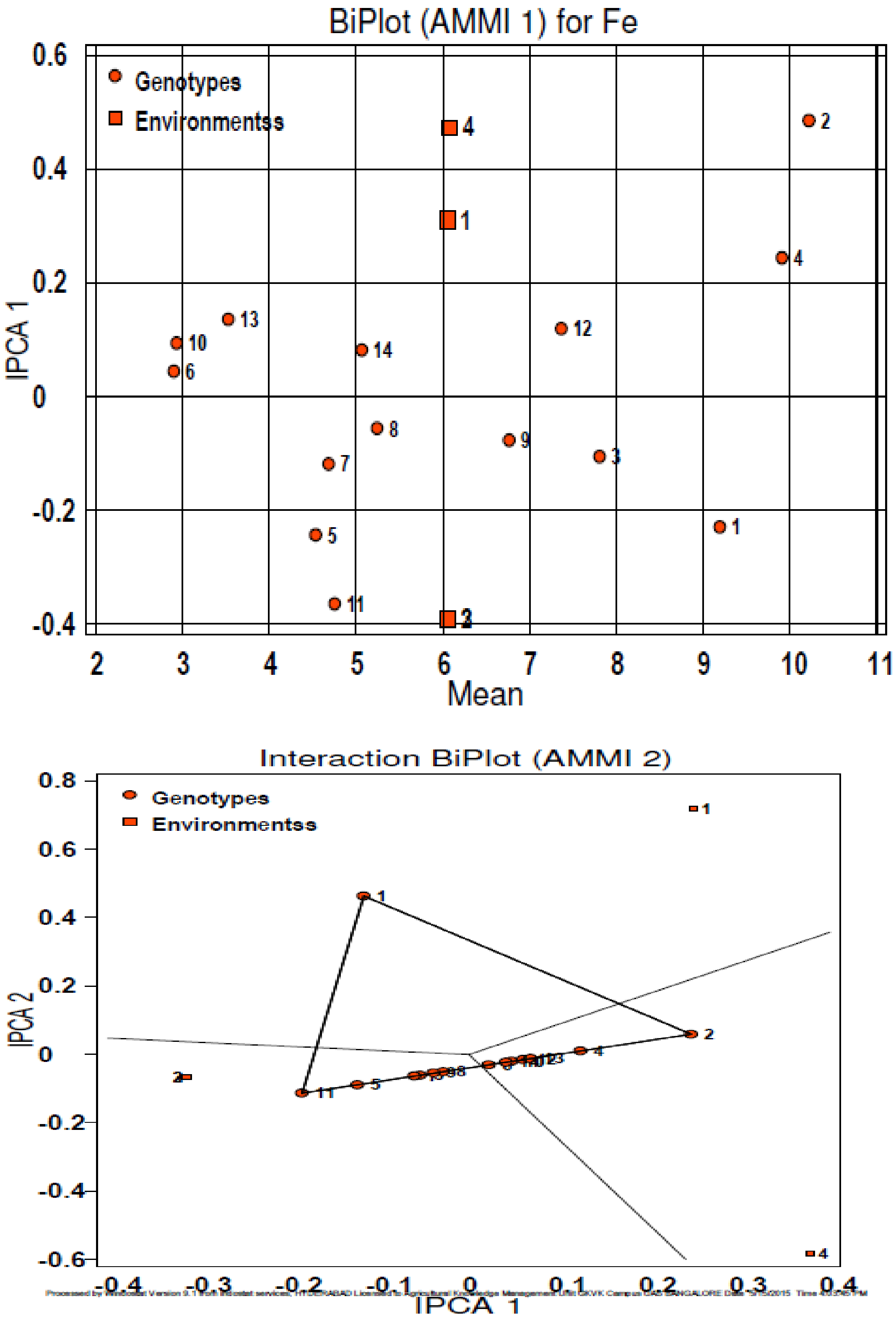

**Fig.6** AMMI biplot of main effects and G x E interaction of white finger millet genotypes for grain zinc content over locations and years

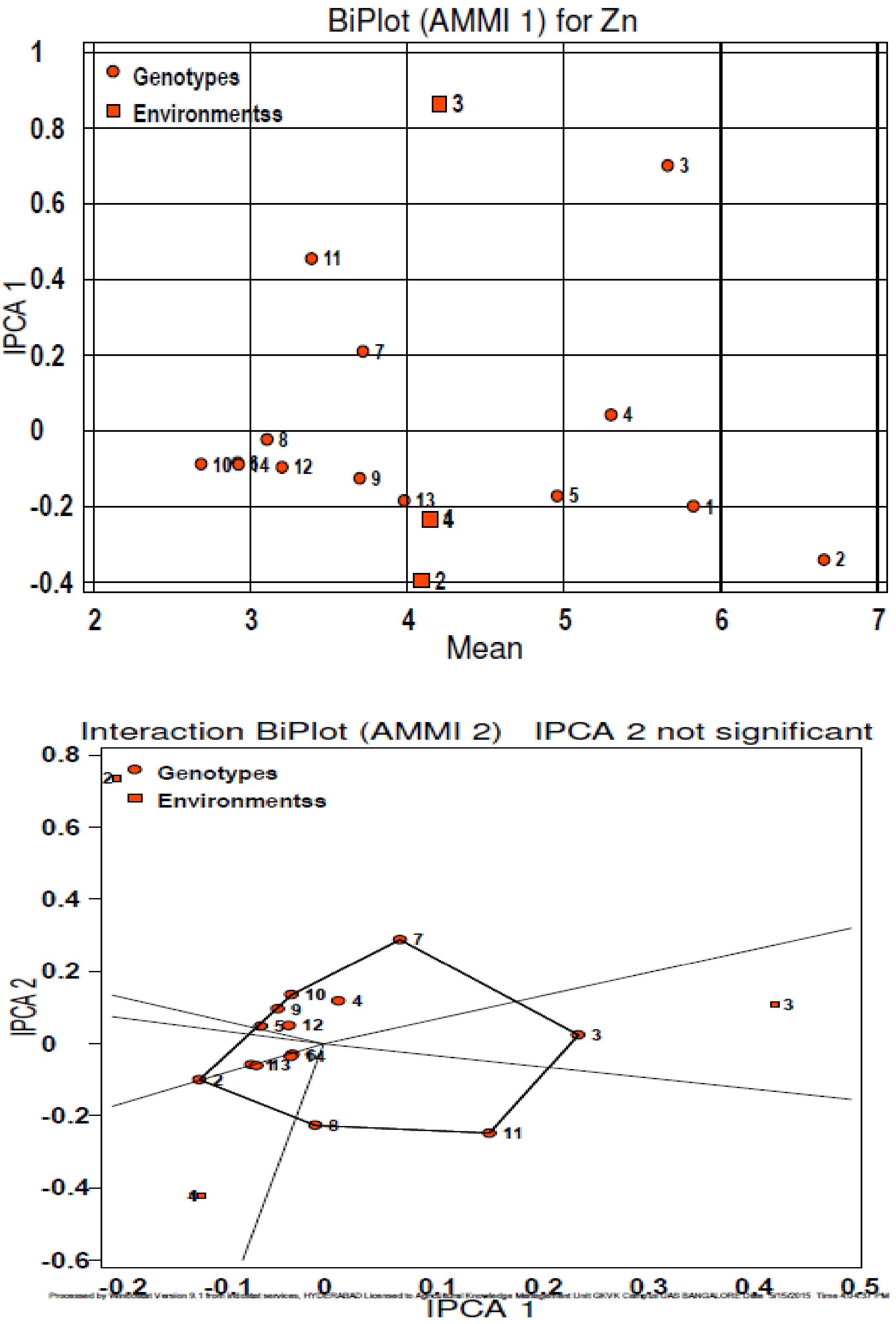

**Table.1** List of genotypes and their pedigree

| Varieties | Pedigree | Origin |
|---|---|---|
| **TNEC-1234** | Co-9 x GE-47 | Coimbatore, Tamil nadu |
| **OUAT-2 (Suvra)** | Selection from Co-9 | Berhampur, Odisha |
| **VR-1034** | Unknown | Vizianagaram, A.P |
| **GPU-71** | GE-4971 x VL 147 | Bangalore, Karnataka |
| **VR-936 (Hima)** | IE 2695 x Godavari (PR-202) | Vizianagaram, A.P |
| **GE-728** | Germplasm line | Unknown |
| **GE-6834-1** | Germplasm line | Unknown |
| **VL-384** | OUAT 2 x GEC-450 | Almora, Uttarkhand |
| **JWM-1** | Unknown | Jagdalpur, Chattisgarh |
| **WFM-10** | Pureline selection derived from GPU-28 x GE-4985 | Bangalore, Karnataka |
| **KMR-344** | WRC-1 x Indaf-11 | Mandya, Karnataka |
| **DHWFM 11-3** | Pureline selection from WFM-11 | Hanumanamatti, Karnataka |
| **DHWFM 2-3** | Pureline selection from WFM-2 | Hanumanamatti, Karnataka |
| **GPU-67*** | Selection from GE-5331 | Bangalore, Karnataka |

**Table.2** Mean performances of white finger millet genotypes for grain nutrient content across two locations and two years

| Genotype | Protein (%) | | | | | | | Calcium (mg/100g) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bengaluru | | Mean | Mandya | | Mean | Grand mean | Bengaluru | | Mean | Mandya | | Mean | Grand mean |
| | 2013 | 2014 | | 2013 | 2014 | | | 2013 | 2014 | | 2013 | 2014 | | |
| **TNEC-1234** | 7.86 | 7.847 | 7.86 | 7.847 | 7.87 | 7.86 | 7.857 | 253.02 | 236.60 | 244.81 | 231.21 | 232.03 | 231.62 | 238.42 |
| **OUAT-2** | 8.97 | 8.967 | 8.97 | 8.967 | 8.96 | 8.97 | 8.968 | 247.82 | 262.00 | 254.91 | 258.03 | 260.65 | 259.34 | 257.78 |
| **VR-1034** | 9.72 | 9.66 | 9.69 | 9.66 | 9.77 | 9.69 | 9.693 | 349.42 | 371.91 | 360.67 | 357.53 | 362.12 | 359.83 | 361.39 |
| **GPU-71** | 8.82 | 8.853 | 8.84 | 8.853 | 8.82 | 8.84 | 8.837 | 284.54 | 288.31 | 286.43 | 287.69 | 296.11 | 291.90 | 291.27 |
| **VR-936** | 7.817 | 7.877 | 7.85 | 7.877 | 7.87 | 7.85 | 7.847 | 220.87 | 219.68 | 220.28 | 217.21 | 219.41 | 218.31 | 219.84 |
| **GE-728** | 9.587 | 9.557 | 9.57 | 9.577 | 9.57 | 9.58 | 9.582 | 266.11 | 265.45 | 265.78 | 260.49 | 264.87 | 262.68 | 265.33 |
| **GE-6834-1** | 11.54 | 11.647 | 11.60 | 11.447 | 11.54 | 11.50 | 11.547 | 171.42 | 171.19 | 171.31 | 172.10 | 172.80 | 172.45 | 172.05 |
| **VL-384** | 10.04 | 10.097 | 10.07 | 10.097 | 10.47 | 10.07 | 10.072 | 231.78 | 247.47 | 239.63 | 249.69 | 249.77 | 249.73 | 244.70 |
| **JWM-1** | 8.57 | 8.56 | 8.57 | 8.56 | 8.47 | 8.57 | 8.565 | 420.91 | 424.55 | 422.73 | 417.81 | 421.96 | 419.89 | 422.35 |
| **WFM-10** | 8.94 | 8.86 | 8.90 | 8.86 | 8.84 | 8.90 | 8.9 | 223.81 | 229.37 | 226.59 | 226.67 | 231.68 | 229.18 | 229.14 |
| **KMR-344** | 9.023 | 9 | 9.01 | 9 | 9.23 | 9.01 | 9.02 | 264.47 | 171.95 | 218.21 | 173.69 | 174.51 | 174.10 | 196.36 |
| **DHWFM 11-3** | 8.933 | 8.947 | 8.94 | 8.947 | 8.9 | 8.94 | 8.94 | 173.27 | 164.74 | 169.01 | 166.22 | 167.82 | 167.02 | 168.41 |
| **DHWFM 2-3** | 8.833 | 8.9 | 8.87 | 8.9 | 8.83 | 8.87 | 8.867 | 242.96 | 245.04 | 244.00 | 245.97 | 248.63 | 247.30 | 246.32 |
| **GPU-67** | 6.63 | 6.763 | 6.70 | 6.763 | 6.63 | 6.70 | 6.697 | 221.94 | 226.53 | 224.24 | 256.80 | 254.28 | 255.54 | 239.26 |

| Genotype | Iron (mg/100g) | | | | | | | Zinc (mg/100g) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bengaluru | | Mean | Mandya | | Mean | Grand mean | Bengaluru | | Mean | Mandya | | Mean | Grand mean |
| | 2013 | 2014 | | 2013 | 2014 | | | 2013 | 2014 | | 2013 | 2014 | | |
| **TNEC-1234** | 9.05 | 9.12 | 9.09 | 9.12 | 9.49 | 9.31 | 9.29 | 5.85 | 5.72 | 5.79 | 5.87 | 5.85 | 5.86 | 5.82 |
| **OUAT-2** | 10.03 | 10.41 | 10.22 | 10.41 | 10.03 | 10.22 | 10.13 | 6.71 | 6.43 | 6.57 | 6.78 | 6.71 | 6.75 | 6.64 |
| **VR-1034** | 7.85 | 7.76 | 7.81 | 7.76 | 7.85 | 7.81 | 7.83 | 5.5 | 6.32 | 5.91 | 5.32 | 5.5 | 5.41 | 5.71 |
| **GPU-71** | 9.81 | 10.03 | 9.92 | 10 | 9.81 | 9.91 | 9.87 | 5.31 | 5.39 | 5.35 | 5.18 | 5.31 | 5.25 | 5.33 |
| **VR-936** | 4.63 | 4.43 | 4.53 | 4.43 | 4.63 | 4.53 | 4.58 | 5 | 4.86 | 4.93 | 4.95 | 5 | 4.98 | 4.97 |
| **GE-728** | 2.89 | 2.91 | 2.90 | 2.91 | 2.89 | 2.90 | 2.90 | 2.93 | 2.91 | 2.92 | 2.91 | 2.93 | 2.92 | 2.93 |
| **GE-6834-1** | 4.74 | 4.63 | 4.69 | 4.63 | 4.74 | 4.69 | 4.71 | 3.73 | 3.94 | 3.84 | 3.46 | 3.73 | 3.60 | 3.78 |
| **VL-384** | 5.27 | 5.22 | 5.25 | 5.22 | 5.27 | 5.25 | 5.26 | 3.05 | 3.16 | 3.11 | 3.15 | 3.05 | 3.10 | 3.08 |
| **JWM-1** | 6.8 | 6.73 | 6.77 | 6.73 | 6.8 | 6.77 | 6.78 | 3.74 | 3.64 | 3.69 | 3.65 | 3.75 | 3.70 | 3.72 |
| **WFM-10** | 2.9 | 2.97 | 2.94 | 2.97 | 2.9 | 2.94 | 2.92 | 2.73 | 2.66 | 2.70 | 2.61 | 2.73 | 2.67 | 2.71 |
| **KMR-344** | 4.9 | 4.6 | 4.75 | 4.6 | 4.9 | 4.75 | 4.83 | 3.22 | 3.86 | 3.54 | 3.26 | 3.22 | 3.24 | 3.38 |
| **DHWFM 11-3** | 7.32 | 7.41 | 7.37 | 7.41 | 7.32 | 7.37 | 7.34 | 3.23 | 3.17 | 3.20 | 3.16 | 3.23 | 3.20 | 3.22 |
| **DHWFM 2-3** | 3.84 | 3.58 | 3.71 | 3.58 | 3.48 | 3.53 | 3.60 | 4.02 | 3.88 | 3.94 | 4.02 | 4.03 | 4.01 | 3.97 |
| **GPU-67** | 5.09 | 5.09 | 5.09 | 5.09 | 5.04 | 5.07 | 5.07 | 2.93 | 2.91 | 2.92 | 2.92 | 2.93 | 2.93 | 2.93 |

**Table.3** Estimates of genetic components in white finger millet genotypes for grain nutrient contents in different locations

| Traits | Range | | | | PCV (%) | | | | GCV (%) | | | | $H^2$(bs) (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bengaluru | | Mandya | | Bengaluru | | Mandya | | Bengaluru | | Mandya | | Bengaluru | | Mandya | |
| | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 |
| **P** | 6.77-11.07 | 6.83-11.6 | 6.6-11.5 | 6.6-11.6 | 13.1 | 12.6 | 12.53 | 12.7 | 12.87 | 12.4 | 12.45 | 12.76 | 96.5 | 96.7 | 98.75 | 26.27 |
| **Ca** | 171.2-424 | 171.4-420 | 164-424 | 169-422 | 28.9 | 25.8 | 27.54 | 27.7 | 28.89 | 25.4 | 27.49 | 27.68 | 99.6 | 96.50 | 99.6 | 56.92 |
| **Fe** | 2.91-10.04 | 2.90-10.0 | 2.91-10.4 | 2.9-10 | 41.6 | 41.0 | 40.92 | 41.1 | 41.65 | 40.8 | 40.82 | 40.9 | 99.8 | 98.8 | 99.5 | 84.00 |
| **Zn** | 2.55-6.8 | 2.55-6.88 | 2.61-6.78 | 2.9-6.66 | 32.4 | 32.4 | 31.74 | 30.9 | 32.40 | 32.4 | 31.645 | 30.27 | 99.85 | 99.8 | 99.3 | 61.04 |

P- Protein Ca- Calcium Fe- Iron Zn- Zinc

**Table.4** Analysis of variance for white finger millet genotypes for grain nutrient characters over locations and years

| Source of variation | Df | Mean sum of squares | | | |
|---|---|---|---|---|---|
| | | P | Ca | Fe | Zn |
| Location | 1 | 0.078 | 20.136 | 0.113 | 0.0002 |
| Year | 1 | 0.0167 | 369.54** | 0.0005 | 0.1074 |
| Location × year | 1 | 0.0720 | 7.690 | 0.0102 | 0.042 |
| Genotype | 13 | 15.225** | 55934.52** | 73.912** | 20.028** |
| Location × genotype | 13 | 0.0153 | 759.21** | 0.1254** | 0.079** |
| Genotype × year | 13 | 0.0164 | 544.03** | 0.0102** | 0.0427 |
| Genotype × year × location | 13 | 0.0466 | 595.09** | 0.0732 | 0.0513 |
| Error | 112 | 0.0359 | 47.325 | 0.0396 | 0.0277 |

P- Protein Ca- Calcium Fe- Iron Zn- Zinc content
*Significance at 0.05 probability ** Significance at 0.01 probability

**Table.5** AMMI ANOVA of white finger millet genotypes for grain nutrient content traits

| Source of variation | | Mean Sum of Squares | | |
|---|---|---|---|---|
| Traits | df | Ca | Fe | Zn |
| Genotype | 13 | 18321.15** | 24.893** | 6.62** |
| Environments | 3 | 53.777 | 0.0024 | 0.0309 |
| G*E Interaction | 39 | 250.754 | 0.0121 | 0.028 |
| PCA 1 | 15 | 651.96** | 0.0260* | 0.068 |
| PCA 2 | 13 | 0.00 | 0.0064 | 0.0058 |
| Pooled residual | 24 | 250.75 | 0.0121 | 0.003 |
| % contribution of PCA 1 | | 100% | 82.44% | 93.08% |
| % contribution of PCA 2 | | 0.00% | 17.58% | 6.92% |
| Residual | | 0.00% | 0.02% | 0.00% |

Ca- Calcium Fe- Iron Zn- Zinc content
*Significance at 0.05 probability ** Significance at 0.01 probability

**Table.6** Eberhart and Russel stability parameters for yield and its attributing traits in white finger millet genotypes

| Genotype | Calcium (mg/100g) | | | Iron (mg/100g) | | | Zinc (mg/100g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ |
| TNEC-1234 | 244.81 | 4.83 | -25.69 | 9.19 | 4.750 | -0.006 | 5.52 | -1.40 | -0.009 |
| OUAT-2 | 254.91 | -4.17 | -25.67 | 10.22 | -3.523 | 0.059* | 6.60 | -3.12 | -0.007 |
| VR-1034 | 360.67 | -6.62 | -25.70 | 7.81 | 0.845 | -0.005 | 5.66 | 8.99 | -0.024* |
| GPU-71 | 286.42 | -1.11 | -25.60 | 9.91 | -1.740 | 0.006 | 5.30 | 1.77 | -0.010 |
| VR-936 | 220.27 | 0.35 | -25.65 | 4.58 | 1.865 | 0.009 | 4.95 | -0.83 | -0.006 |
| GE-728 | 265.78 | 0.19 | -25.65 | 2.90 | -0.252 | 0.009 | 2.92 | -0.03 | -0.010 |
| GE-6834-1 | 171.30 | 0.06 | -25.68 | 4.68 | 0.943 | -0.009 | 3.72 | 4.12 | -0.009 |
| VL-384 | 239.63 | -4.62 | -25.66 | 5.24 | 0.481 | -0.004 | 3.10 | 0.15 | -0.005 |
| JWM-1 | 422.73 | -1.07 | -25.70 | 6.76 | 0.632 | -0.008 | 3.69 | -0.18 | -0.066 |
| WFM-10 | 226.59 | -1.63 | -27.60 | 2.93 | -0.620 | -0.007 | 2.68 | 0.35 | -0.005 |
| KMR-344 | 218.21 | 27.52 | -25.66 | 4.15 | 2.756 | -0.033 | 3.39 | 5.51 | -0.034 |
| DHWFM 11-3 | 169.00 | 2.51 | -25.52 | 7.36 | -0.813 | -0.006 | 3.20 | 0.04 | -0.009 |
| DHWFM 2-3 | 244.00 | -0.61 | -25.65 | 3.53 | -0.929 | -0.003 | 3.98 | -1.25 | -0.010 |
| GPU-67 | 224.24 | -1.35 | -25.60 | 5.06 | -0.532 | -0.008 | 2.92 | -0.10 | -6.010 |

**Table.7** Estimates of environmental indices for grain nutrient traits in finger millet

| Trait | Environment 1 | Environment 2 | Environment 3 | Environment 4 |
|---|---|---|---|---|
| Calcium | 1.69 | 1.53 | 1.54 | 1.71 |
| Iron | -0.013 | -0.002 | -0.0003 | 0.018 |
| Zinc | -0.003 | -0.054 | 0.061 | -0.003 |

Environment 1-----kharif 2013 at Bengaluru
Environment 2-----kharif 2013 at Mandya
Environment 3-----kharif 2014 at Bengaluru
Environment 4------kharif 2014 at Mandya

Analysis of variance revealed highly significant differences among the genotypes for protein, calcium, iron and zinc content across the four environments. Analysis of variance indicated significant mean squares due to genotypes; genotype × environment interaction, genotype × year, location × year and genotype × location × year were significant for calcium. The mean sum of squares attributable to genotype, location × genotype and genotype × year were significant for grain iron content. Analysis of variance revealed significant variation among genotypes and location × genotype interaction for grain zinc content. Maximum variation towards total variation is contributed by genotypes alone for grain protein, calcium, iron and zinc content (Table 4).

Environmental indices of kharif 2013 at Bengaluru and Mandya were positive for grain calcium content. During 2014 at Bengaluru environmental indices were positive for calcium and zinc content while they were negative during kharif 2014 at Mandya for grain zinc content (Table 7).

AMMI analysis of variance indicated significant mean squares due to PCA1 for calcium, iron and zinc content (Table 5). First principal component axis explains 100%, 82.44% and 93.08% genotype × environment interaction for calcium, iron and zinc content, respectively.

The regression coefficient of genotypes OUAT-2, VR-1034, GPU-71, GE-728 and JWM-1 was highly non-significant coupled with high grain calcium content and non-significant deviation from regression indicating they were consistently adapted across the environments. On the other hand TNEC-1234, VR-936, GE-6834-1, VL-384, WFM-10, KMR-344, DHWFM 11-3, DHWFM 2-3 and GPU-67 exhibited lower grain calcium content compared to overall mean (253.504.41mg/100g) with their unit regression coefficient and non-significant deviation from regression (Table 6) inferring they were poorly adapted across the environments which was in conformity with AMMI biplot analysis (Fig. 4).

For mean grain iron content, the genotypes VR-1034, GPU-71, DHWFM 11-3 and JWM-1 had higher values than that of overall mean (6.06 mg/100 g) indicated they were consistently stable across the environments. On the other hand, genotypes VR-936, GE-728, GE-6834-1, WFM-10, KMR-344, DHWFM 2-3 and GPU-67 had lower calcium content compared to overall mean coupled with non-significant regression coefficient and deviation from regression showing they were poorly adapted across the environments for their grain iron content (Table 6). Interaction biplot analysis of AMM sowed that the genotypes KMR-344, VR-936, WFM-10, JWM-1 and VL-384 are best suitable genotypes during kharif 2013 at Mandya, genotype TNEC-1234 is best suited during kharif 2013 at Bengaluru and genotypes OUAT-2, GPU-71, GPU-67 and DHWFM 2-3 are best suited during kharif 2014 at Mandya (Fig. 5).

The seeds of genotypes TNEC-1234, VR-936, and GPU-71 recoded higher grain zinc content inferred they were consistently stable. The genotypes OUAT-2, GE-728, GE-6834-1, VL-384, JWM-1, KMR-344, DHWFM 2-3, GPU-67 and DHWFM 11-3 recorded lower grain zinc content compared to the overall mean (4.41 mg/100 g) indicating their poor stability across the environment for their grain zinc content. Besides this, all these genotypes manifested highly non-significant regression coefficient and deviation from the regression. The genotype VR-1034 had higher grain zinc content with significant $S^2d_i$ (Table 6). AMMI biplot interaction showed that the genotypes VR-1034 is best genotype during kharif 2014 at Bengaluru, genotypes WFM-10, GE-6834-1, GPU-71 and JWM-1 are best suited genotypes during kharif 2013 at Mandya and genotypes TNEC-1234, DHWFM 2-3 and OUAT-2 are best suited at kharif 2014 at Mandya (Fig. 6).

To summarize it is observed that genotype GPU-71 is stable for iron, calcium and zinc contents across the two locations and two years. This genotype could be used as a parent for hybridization to improve micronutrient content.

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