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MULTI-ENVIRONMENT STABILITY ANALYSIS FOR YIELD RELATED TRAITS OF FINGER MILLET (*ELEUSINE CORACANA* (L.)

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Abstract
An experiment involving 50 genotypes of Finger millet (*Eleusine coracana* (L.) Gaertn)" was conducted in randomized block design with three replications, during *Kharif* 2021. Fifty finger millet genotypes were tested for four different environments viz., E1 and E2 at Student Research Farm, C.S.A.U.A.&T. Kanpur sown on 21 June, 2021 and 20 July, 2021 respectively and E3 and E4 sown at Research Farm, Daleep Nagar, Kanpur on 22 June, 2021 and 26 July, 2021respectively. The analysis of variance for pooled data revealed that the mean sum of square for genotypes and environments was highly significant against pooled error for all the characters except ear head width, ear head length and harvest index. The mean sum of square for genotypes against pooled error was highly significant for ear head length and harvest index; significant for ear head width. The mean sum of square for genotype × environment (G×E) was found highly significant for finger width while, significant for plant height, ear head weight and protein content. The overall performance of genotypes for grain yield per plant indicated that the genotypes IC0475654, IC0346263, IC0476359, IC0298482, IC0474862 and IC0475798 showed average stability while, for the protein content, the genotypes IC0347254, IC0474862, IC0475632 and IC0475457 showed average stability across all environments.

INTRODUCTION

Finger millet (*Eleusine coracana* (L.) Gaertn) is self- pollinated annual herbaceous allotetraploid (2n=4x=36, AABB) which have been evolved from *E. indica* (AA) and *E. floccifolia* or *E. tristachya* (BB) and member of the genus *Eleusine* which belongs to the family poaceae and is more commonly known as ragi or mandua in India, rapoko in South Africa and dagusa in Ethiopia. Finger millet has been perceived as a potential "super cereal" by the United State National Academies being one of the most nutritious among all major cereals. Millet is an annual plant widely grown as an important cereal crop largely grown in the arid areas and semi-arid areas of Africa and Asia. It is

also known by different common names as mandua, nagli, kapai, thaidalu etc. Finger millet is said to be originated from Africa and India as a secondary centre of origin. (**Chandra *et al*., 2016**).
The millets production in the World accounts for 30.73 million tonnes, out of which 11.42 million tonnes is produced in India accounting for 37% of total World production. In India, finger millet is grown in an area of 1.19 million hectares with a production of 1.20 million tonnes and average productivity of 1.66 tonnes per hectare (**Sakamma *et al*., 2018**). Ragi is mainly grown in Karnataka followed by Tamil Nadu, Maharastra, Uttarakhand and Andhra Pradesh, Orrisa, Uttar Pradesh, Bihar and Gujarat are the major finger millet growing states together.
It is one of the minor cereals known with several health benefits which are attributed to its high level of polyphenol, dietary fibers, minerals and essential amino acids. Millets are nutria-cereals and rich in carbohydrates (76.32%), dietary fibers energy, essential fatty acid, proteins (9.2%), vitamin-B, fat (1.29%) and minerals (2.70%). It is rich in minerals like calcium (452mg/1000g), magnesium, phosphorus, iron (3.90mg/100gm) and potassium, Zinc and Ash (3.90%) which are the core ingredients of normal human diet **(Pandey and Kumar, 2005)**. The straw is also nutritive and serves as an excellent fodder for cattle which can be feed green or as hay.
Apart from its nutritional attributes, finger has excellent environmental sustainability credentials. It can easily withstand harsh climatic condition, low soil fertility, requires very low inputs with a short growing season. Among the abiotic stresses constraining finger millet production is soil salinity, which is a devastating environmental stress factor that has a substantial negative impact on crop quality and production **(Hema *et al*., 2014).**

Material and Methods

The field experiment was conducted at Student Research Farm, College of Agriculture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur and Research Farm, Daleep Nagar, Kanpur by taking three replications with seven row and a spacing of 30 cm by 10 cm for each plot in Randomized Block Design during *Kharif* season, 2021. Experiments conducted with seven row per plot. Experimental material comprises of forty-five different genotypes with five checks -VL324(CH), VL380(CH), VL352(CH), VL376(CH), and VL379(CH) from different diverse sources. The observation were obtained by selected randomly five plants from each genotype in three replications from all four different environments. Data were recorded and analyzed for all the characters *viz.*, days to 50% flowering, days to maturity, plant height (cm), number of productive tillers per plant, number of fingers per ear, length of finger (cm), finger width (cm), ear head width (cm), ear head length (cm), ear head weight (g), straw yield per plant (g), harvest index (%), 1000 grain weight (g), protein content (%) and grain yield per plant (g).

Table-1: Description of environments.

Environment	Location	Date of sowing	Sowing season	P^H of soil	EC of soil (dsm^{-1})
E_1	Student Research Farm C.S.A.U.A.&T. Kanpur	June 21, 2021	Early sown	7.5	0.31
E_2	Student Research Farm C.S.A.U.A.&T. Kanpur	July 20, 2021	Normal sown	7.5	0.31
E_3	ResearchFarm Daleep Nagar Kanpur	June 22, 2021	Early sown	9.6	1.59
E_4	Research Farm Daleep Nagar Kanpur	July 26, 2021	Normal sown	9.6	1.59

The stability analysis was performed for the characters under study separately using the model of

Eberhart and Russell (1966).
Regression of the mean yield and its attributing traits of the individual genotypes on the environmental index and deviations of the regression coefficient from the unity as suggested by Eberhart and Russell were used to calculate stability of the trait for each genotype.
The yield performance for each genotype was calculated by regressing the mean yield of individual genotypes on environmental index and calculating the deviations from regressing the mean yield of

individual genotypes on environmental index and calculating the deviations from regression. Regression coefficient (bi) was considered as an indication of the response of the genotype to varying environment while the environment and genotype × environment interactions were partitioned into three components *viz.*, environment (linear), genotype x environment (linear) and deviation from regression (pooled deviation over the genotypes). Environmental index i.e. means of all genotypes at j^{th} environment minus grand mean d_{ij}=Deviation from regression of i^{th} genotypes at j^{th} environment.

Result and Discussion

The analysis of variance presented in Table 2 for pooled data revealed that the mean sum of square for genotypes and environments was highly significant against pooled error for all the characters except ear head width, ear head length and harvest index. The mean sum of square for genotypes against pooled error was highly significant for ear head length and harvest index; significant for ear head width. The mean sum of square for environment was significant for harvest index while, was found non-significant for ear head length and ear head width.

The mean sum of square for genotype × environment (G×E) was found highly significant for finger width while, significant for plant height, ear head weight and protein content. Similarly, mean sum of square of environments (linear) *i.e.* E and genotypes x environments (linear) *i.e.* G×E was found highly significant for plant height, finger width, ear head weight and protein content.

Mean sum square for pooled deviation was found to be highly significant for number of productive tillers per plant, number of fingers per ear, finger length, ear head width, ear head length, ear head weight, straw yield per plant, harvest index, 1000 grain weight, protein content and grain yield per plant while, it was significant for plant height. Similar findings were also reported by **Anarase *et al.* (2000), Shinde *et al.* (2002), Patil (2006) and Sharathbabu *et al.* (2008).**

Environmental indices (I_j):

The comparison of environmental indices presented in Table 3 for both the locations indicated that performance of genotypes over two locations for different characters varied substantially. For the first location, the data revealed that E_1 is best for all characters. E_2 is best for all the characters except for days to 50 % flowering, days to maturity, plant height and harvest index. E_3 is best for days to 50 % flowering, days to maturity, plant height, ear head length and harvest index. E_4 is not favorable for any characters.

Table: 3 Estimation of environment index for each character in four environments expressed as deviation from grand mean.

S.No.	Characters	E_1	E_2	E_3	E_4	Grand mean
1.	Days to 50 % flowering	7.305	-4.875	2.825	-5.255	70.768
2.	Days to maturity	12.937	-10.997	9.517	-11.457	108.563
3.	Plant height	10.952	-6.498	3.714	-8.168	70.403
4.	Number of productive tillers per plant	0.913	0.073	-0.313	-0.673	2.360
5.	Number of fingers per ear	1.287	0.340	-0.780	-0.847	5.547
6.	Finger length	1.031	0.186	-0.316	-0.901	6.650
7.	Finger width	0.092	0.065	-0.032	-0.125	0.870
8.	Ear head width	0.026	0.006	-0.012	-0.020	1.252
9.	Ear head length	0.072	0.052	0.045	-0.168	7.749
10.	Ear head weight	0.694	0.186	-0.059	-0.821	8.712
11.	Straw yield per plant	4.733	3.382	-0.757	-7.359	30.541

12.	Harvest index	0.631	-0.752	0.329	-0.208	33.854
13.	1000 Grain weight	0.689	0.296	-0.145	-0.840	2.266
14.	Protein content	0.659	0.061	-0.331	-0.390	6.499
15.	Grain yield per plant	2.894	0.895	-0.183	-3.560	15.681

Stability parameter

The number of different predictable and unpredictable genotypes is explained in the Table 4. For days to 50 % flowering and days to maturity 46 genotypes were predictable with 44 genotypes having bi and S^2di value non-significant and 2 genotypes having significant value of bi only while, 4 genotypes were unpredictable because of significant S^2di value. While, for plant height 41 genotypes having bi and S^2di value non-significant and 5 genotypes having significant value of bi only. 43 genotypes were predictable and 7 genotypes were unpredictable for number of productive tillers while, for number of fingers per ear these numbers were 33 and 17 respectively. Similarly, for finger length 42 genotypes were predictable and 8 were unpredictable. For finger width all the genotypes were predictable. For ear head width only 17 genotypes were predictable and 33 genotypes were unpredictable. Similarly, for ear head length 14 were predictable and 36 genotypes were unpredictable. 41 genotypes were predictable and 9 were unpredictable for ear head weight. Also, for straw yield per plant and harvest index 23 genotypes were predictable and 27 were unpredictable. For protein content are 33 genotypes were predictable and 17 were unpredictable while, for grain yield per plant these numbers were 41 and 9 respectively.

Table 4: Distribution of different genotypes on the basis of different stability parameters for various characters in finger millets.

S.No.	Characters	Predictable		Unpredictable	
		Both bi and S^2di non-significant	Only bi significant	Both bi and S^2di significant	Only S^2di significant
1.	Days to 50 % flowering	44	2	0	4
2.	Days to maturity	44	2	0	4
3.	Plant height	41	5	0	4
4.	Number of productive tillers per plant	42	1	0	7
5.	Number of fingers per ear	29	4	0	17
6.	Finger length	39	3	0	8
7.	Finger width	36	14	0	0
8.	Ear head width	16	1	0	33
9.	Ear head length	12	2	0	36
10.	Ear head weight	36	5	0	9
11.	Straw yield per plant	19	4	0	27
12.	Harvest index	18	5	0	27
13.	1000 Grain weight	17	2	0	31
14.	Protein content	22	11	0	17
15.	Grain yield per plant	40	1	0	9

Details of stable genotypes

The genotypes *viz.,* IC0478760, IC0476076, IC0475632 and VL324 showed average stability for days to 50% flowering, **Bandopadhyay (2001)** also reported similar findings for this character while, IC0476577, IC0298482, IC0475129 and IC0475798 showed average stability for days to maturity, Similar results were also reported by **Yadav *et al*. (2001) and Shinde *et al*. (2002).**

The genotypes *viz.,* IC0475654, IC0478760, IC0475697, IC0476359 and IC0476610 showed average stability for plant height. These results are in close conformation with results obtained by **Sathish (2003)** while, IC0476315, IC0475632, IC0283451, IC0283409 and VL380 showed average stability for number of productive tillers per plant, Similar results were also reported by **Yadav and Singh (2003).**

The genotypes IC0346263, IC0478760 and IC0471513 showed average stability for number of fingers per ear. These results are in close conformation with results obtained by **Patil (2006)** while, IC0475654, IC0478760, IC0475053, IC0283451 and IC0347252 showed average stability for finger length. Similar results were also reported by **Fentie *et al*. (2013).**

The genotypes IC0476092, IC0283454, IC0347254 and VL379 showed average stability for finger width. These results are in close conformation with results obtained by **Das *et al*. (2016).** while, IC0474840 and IC0049949 showed average stability for ear head width. Similar results were also reported by **Sood *et al*. (2016).**

The genotypes IC0474862, IC0476006, IC0475632 and IC0474840 showed average stability for ear head length. These results are in close conformation with results obtained by **Jawle *et al*. (2017)** while, IC0475457, IC0049949, IC0298482 and IC0476092 showed average stability for ear head weight. Similar results were also reported by **Nagraja *et al*. (2017).**

The genotypes IC0476303 and VL352 showed average stability for straw yield per plant, Similar results were also reported by **Chevan *et al*. (2018)**. while, IC0321513 and IC0346263 showed average stability for harvest index. These results are in close conformation with results obtained by **Dhami *et al*. (2019).**

The genotypes IC0475525, IC0475632 and IC0347252 showed average stability for 1000 grain weight, Similar results were also reported by **Kebede *et al*. (2019).** while, IC0347254, IC0474862, IC0475632 and IC0475457 indicated average stability for protein content. These results are in close conformation with results obtained by **Solanki *et al*. (2020).**

The genotypes IC0475654, IC0346263, IC0476359, IC0298482, IC0474862, IC0475798, IC0283409, IC0476818, IC0347254, IC0476303, IC0476242, VL376 and VL379 showed average stability for grain yield per plant. These results are in close conformation with results obtained by **Anuradha *et al*. (2021) and Kandel *et al*. (2022).**

Conclusion:

The overall stability performance of genotypes as shown in Table 5 and table 6; for grain yield per plant indicated that the genotypes IC0475654, IC0346263, IC0476359, IC0298482, IC0474862 and IC0475798 showed average stability and genotypes IC0475632, IC0476006, IC0476315 and IC0321513 showed above average stability across all environments. Also, for the protein content, the genotypes IC0347254, IC0474862, IC0475632 and IC0475457 showed average stability and genotypes VL352, VL324, IC0049949, IC0475053 and IC0475334 showed above average stability across all environments. It can be concluded that the genotypes *viz.,* IC0476242 and VL 376 were high yielder across all the environments. Quality parameters revealed that the genotypes IC0347254, IC0475457 and IC0475632 were found to be good source of protein. These genotypes can be used for cultivation since these are stable genotypes.

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Table: 2 Pooled analysis of variance for grain yield, its components and quality characters in Ragi.

Sources	D.F.	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of productive tillers per plant	Number of Fingers per ear	Finger length (cm)	Finger width (cm)	Ear head width (cm)	Ear head length (cm)	Ear head weight (g)	Straw yield per plant (g)	Harvest Index (%)	1000 grain weight (g)	Protein content (%)	Grain yield per plant (g)
Genotypes	49	80.164**	146.146**	685.631**	0.342**	1.044**	3.002**	0.054**	0.016*	3.088**	19.917**	174.437**	127.610**	0.930**	1.285**	76.460**
Environments	3	1878.738**	8501.768**	4044.727**	23.185**	51.606**	33.488**	0.487**	0.021	0.637	19.897**	1476.092**	18.586*	21.746**	11.656**	360.433**
G × E	147	5.328	8.991	12.669*	0.141	0.399	0.141	0.003**	0.006	0.983	0.354*	12.582	6.167	0.128	0.088*	0.709
E+(G×E)	150	42.796**	178.846**	93.310**	0.601**	1.423**	0.808**	0.012**	0.006	0.977	0.745**	41.852**	6.415	0.555**	0.320**	7.903**
E (linear)	1	5636.214**	25505.304**	12134.182**	69.556**	154.818**	100.464**	1.461**	0.062*	1.911	59.691**	4428.276**	55.758*	64.427**	34.967**	1081.298**
G×E (linear)	49	6.318	12.324*	21.906**	0.106	0.409	0.137	0.006**	0.001	0.688	0.544**	12.981	6.537	0.152	0.145**	0.256
Pooled deviation	100	4.736	7.178	7.890*	0.155**	0.386**	0.140**	0.001	0.008**	1.108**	0.254**	12.135**	5.862**	0.114	0.059**	0.917**
Pooled Error	392	4.292	8.744	5.947	0.097	0.158	0.077	0.001	0.001	0.091	0.102	1.394	1.207	0.015	0.014	0.405

* Significant at 5%, ** Significant at 1%
*Significant at p = 0.05 **Significant at p = 0.01
G=Genotype;E=Environment

Table No. 5. The genotypes showing different stability for different characters.

S. No.	Character	Average stability	Below Average stability	Above Average stability
1.	**Days to 50 % flowering**	IC0478760, VL324, IC0476076, IC0475632, IC0474806, IC0478790, IC0478720	IC0476421, IC0475978, IC0346263, IC0475654, IC0476610, IC0475678, IC0049949, IC0478776, IC0283451	IC0475697, VL380, IC0476359, IC0476006, IC0283454, IC0476315, IC0294882, IC0476418, IC0283409, IC0346264, IC0474887, VL380, VL376, VL379
2.	**Days to maturity**	IC0476421, IC0476577, IC0298482, IC0475129, IC0475798, IC0474806, IC0346263, IC0475697, IC0475457, IC0049949, IC0298448, VL324, VL380	IC0478760, IC0476610, IC0476242, VL379	IC0476359, IC0476006, IC0475678, IC0346264
3.	**Plant height (cm)**	IC0475654, IC0478760, IC0475697, IC0476359, IC0476610, VL324	IC0476315, IC0476006, IC0283451, IC0475678, VL380, IC0298482, IC0475798, IC0476418, IC0346164, IC0476242	IC0476421, IC0476076, IC0478790, IC0475978, IC0474806, IC0475525, IC0475632, IC0049949, IC0478720
4.	**Number of productive tillers per plant**	IC0476315, VL380, IC0475632, IC0283451, IC0283409, VL376	IC0476818, IC0476242, IC0476006	IC0346263, VL379, IC0478760, IC0476359, IC0476076, IC0475798, IC0476577, IC0475053, IC0478776
5.	**Number of fingers per ear**	IC0346263, IC0478760, IC0471513, IC0476610, IC0476115, IC0298448	IC0475525, IC0475654, IC0283409, IC0476092, IC0476359, IC0474840	IC0476242, VL324, IC0478482, IC0476315

6.	**Finger length (cm)**	IC0475654, IC0478760, IC0475053, IC0283451, IC0474887, IC0476303, IC0347252	IC0476359, IC0471513, IC0475334, IC0474840, IC0476818	IC0283409, IC0475129, IC0347251, VL376, IC0475525, IC0346263, IC0476418, VL379, IC0346264
7.	**Finger width (cm)**	IC0476092, VL379, IC0283454, IC0347254, VL352	IC0476421, IC0475978, IC0476115, IC0476006, IC0347251, IC0283451, IC0346264, IC0474887, IC0476242, VL324	IC0478720, IC0476359, IC0475334, IC0476577
8.	**Ear head width (cm)**	IC0474840, IC0049949	VL376, VL380, IC0476115	IC0298448, IC0476818, IC0476006
9.	**Ear head length (cm)**	Nil	IC0321513	Nil
10.	**Ear head weight (g)**	IC0475457, IC0049949, IC0298482, IC0476092, IC0475697	IC0475525, IC0475654, IC0478760, IC0476359, IC0283451, IC0283409, IC0298448, IC0347254, VL324	IC0475798, IC0476303, IC0476610, IC0321513
11.	**Straw yield per plant (g)**	IC0476303, VL352	IC0283451	VL376, VL379
12.	**Harvest index (%)**	IC0321513, IC0346263	IC0476577, IC0476315	IC0478760, IC0476359
13.	**1000 grain weight (g)**	IC0475525, IC0475632, IC0347252	VL324, IC0476242, IC0347251, IC0476359	IC0478776
14.	**Protein content (%)**	IC0347254, IC0474862, IC0475632, IC0475457, IC0347252	IC0475678, IC0476418, IC0283409, IC044089, IC0476242, VL379, IC0298448	VL352, VL324, IC0049949, IC0475053, IC0346263
15.	**Grain yield per plant (g)**	IC0475654, IC0346263, IC0476359, IC0298482, IC0474862, IC0475798, IC0283409, IC0476818, IC0298448, IC0476303, IC0476242, VL376	IC0347252, VL324, IC0476577	IC0475632, IC0476006, IC0321513, IC0477254, IC0475525, IC0478760

Table 6: Top 5 genotypes for various characters in all the environments.

S. No.	Characters	Genotypes
1.	Days to 50 % flowering	IC0475978, IC0474806, IC0476006, IC0475678, IC0049949
2.	Days to maturity	IC0474806, IC0476359, IC0475678, IC0475798, VL379
3.	Plant height (cm)	IC0475798, IC0475678, IC0049949, VL380, VL379
4.	Number of productive tillers per plant	VL379, VL352, IC0478776, IC0475798, IC0476315
5.	Number of fingers per ear	IC0476092, IC0475654, IC0478760, IC0321513, IC0476818
6.	Finger length (cm)	VL324, IC0476303, IC0283451, IC0347251, IC0475654
7.	Finger width (cm)	IC0476421, IC0475334, IC0474887, IC0476242, VL376
8.	Ear head width (cm)	IC0475525, IC0476359, IC0474880, IC0049949, IC0283451
9.	Ear head length (cm)	IC0475334, IC0283451, IC0346264, IC0474887, VL352
10.	Ear head weight (g)	VL380, VL324, IC0476818, IC0347254, IC0476359
11.	Straw yield per plant (g)	IC0475678, IC0049949, IC0478720, IC0476242, VL380
12.	Harvest index (%)	IC0476359, IC0475654, IC0346263, IC0475525, IC0476115
13.	1000 grain weight (g)	IC0476359, VL324, VL380, VL376, VL379
14.	Protein content (%)	IC0475678, IC0474862, IC0475632, IC0475334, IC0475978
15.	Grain yield per plant (g)	IC0476359, IC0347254, IC0476242, VL380, VL376