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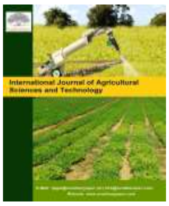

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Genotype by Environment Interaction and Stability Analysis for Yield of Chili Pepper (*Capsicum annuum* L.) in East Hararghe, Ethiopia

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Abstract

The experiment was conducted at three locations viz., Fedis, Babile and Gursum with the objective to identify chili pepper genotypes with high fresh pod yield and the most stable genotypes to different environments. To this end, 14 chili pepper genotypes, including the standard check were evaluated in a field experiment laid out in Randomized Complete Block Design with three replications, based on the GGE Biplot and mean, the genotypes FB-25, KW-14 and FB-26 had significantly higher fresh pod yield but higher regression coefficients indicated their suitability for favorable environmental conditions. The GGE Biplot also depicted the same result indicating genotypes FB-25 and KW-14 to be stable genotypes with lower IPCA 1 axis score, thus it had the lowest contribution towards the G×E interaction for fresh pod yield. The genotypes FB-25 and KW-14 were found to be generally adaptable for all the three different growing environments as compared to other genotypes. Therefore, the genotypes FB-25 and KW-14 were selected for their highest red pod yield and highest stability to the different environments under which the study was conducted. Therefore, these two genotypes were promoted to variety verification stage for possible release in the subsequent growing season.

Keywords: *Chili pepper, Genotype, Environment, Stability, Yield*

1. Introduction

Chili pepper (*Capsicum annuum* L., 2n=2x=24), belonging to the family Solanaceae is an indigenous crop to South America. The word 'Chili' is a Mexican origin and is still under use in India (Kraft *et al.*, 2014). Chili crop performs well in warm humid tropical and subtropical regions extending from equator 45º latitude on both southern and Northern hemispheres. It can do well up to an altitude of 2000 meters above sea level. In the genus *Capsicum*, it is the only plant known for its pungency, which is due to the presence of capsaicinoids (the group of 15 different alkaloids).

In relation to the impact of the environment on the content of the various quality traits in chili peppers, only limited information is available. Most of the studies have been confined to the genotype-environmental effect on the content of capsaicinoids and flavonoids (Justin *et al.*, 2012; Zewdie and Bosland, 2000). The coloring matter, ascorbic acid,

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oleoresin and other quality parameters were highly influenced by the environment (e.g., temperature, light intensity and humidity). The interactions between genotype and environment were also observed and indicated that different genotypes responded varyingly to the changes in the environment (Gurung *et al.*, 2012). Thus, the stability of pod yield and quality traits in chili and its processed products is one of the major concerns to the processing industry. Plant breeders, taking this into account the environmental effect, develop stable cultivars, which may have certain level of pungency, coloring matter, ascorbic acid, pod yield and other quality traits within a certain range. It is of huge importance because environmental conditions vary from year to year and genotype-environment (GE) interactions have a masking effect on the genotype's performance. Therefore, it is important to identify stable genotypes across the multi-environments through stability parameters.

From 144 chili pepper landrace collections which were screened based on pod yield performance and color at different breeding stages, 12 genotypes were evaluated across three different locations to select the most stable genotypes. There are several techniques to evaluate the stability of genotypes over the environments and each method has its own merits and demerits. The different stability parameters explained genotypic performance differently and the popular method for stability analysis is regression analysis by Eberhart and Russell (1966) model. While, GGE (Genotype-Genotype-by-Environment) bi-plot method is a more efficient tool to analyze GE interaction; because it can provide the bi-plots and information on genotype, environment and their interaction, the Eberhart and Russell analysis gives information only on genotype evaluation (Ashraful *et al.*, 2017). Thus, the stability analysis of pod yield traits in chili was undertaken over the three varied environments for selected genotypes to understand the responses and to identify the stable genotypes. Therefore, the objective of this study was to identify chili pepper genotypes with high fresh pod yield and the most stable genotypes across the different environments.

2. Materials and Methods

2.1. Description of the Study Site

The experiment was conducted at three locations - Fedis, Babile and Gursum. Fedis Research sub site, Boko research station is located at latitude of 9° 07' North and longitude of 42° 04' East, and at an altitude of 1702 m.a.s.l. The experimental area is characterized as lowland climate. The mean annual rainfall is about 860.4 mm, averaged over the last five years. The rainfall has a bimodal distribution pattern with heavy rains often received from April to June and long and erratic rains from August to October. The mean maximum and minimum annual temperatures are 27.7 and 11.3 °C, respectively averaged over the last five years. Babile is located at 30 km from Harar City in the Eastern direction in the Eastern part of Ethiopia in Oromia Regional State in the lowlands of Hararghe Zone. The altitude of the area ranges between 950 - 2000 masl. The area receives an average annual rainfall of about 400-600 mm. Gursum is located at 75 km far away from Harar City in the same direction to Babile. The altitude of the district ranges from 1200 to 2938 masl with an annual rain fall ranging from 650 to 750 mm and the mean annual minimum and maximum temperature of 18 and 25°C, respectively. The area has short rainy season from March to April and long rainy season extending from June to August.

2.2. Planting materials and Experimental Design

Chili pepper genotypes collected from local farmers and screened based on pod yield performance through different breeding stages were planted and evaluated at three locations. The genotypes are listed below in (Table 1). Improved varieties, Dame and Kume were used as standard check.

Table 1: Genotypes and Standard Checks Used for Planting Materials

No.	Genotypes	No.	Genotypes
1	FB-25	8	KW-20
2	FB-26	9	FB-31
3	KW-13	10	FB-31
4	FB-27	11	KW-29
5	KW-14	12	FUK-2
6	KW-1	13	Dame
7	FB-2	14	Kume

The experiment was arranged in Randomized Complete Block Design (RCBD) in three replications each genotype was assigned randomly to each experimental unit within a block. Plot area was 3.0 × 3.2m which consists of six rows and 48 plant populations. The intra and inter row spacing was 40 and 60cm, respectively. Plants in the middle four rows were considered for recording data.

2.3. Trial Management

The experimental plots were ploughed to a depth of 25 - 30 cm by a tractor and the seed bed was harrowed to a fine tilt manually before planting. The land was leveled well and NPS was added uniformly into the prepared ridges in bands before sowing at nursery as per recommendation. Seeds were sown on well-prepared seed beds. The seedlings were raised on a 10.0 m × 1.2 m of raised beds in 5 cm spaced rows in similar ways for the three locations. Watering and weeding of seedling at nursery were carried out manually. Normal and uniform seedlings were transplanted into the experimental plots when seedlings were at the growth stage of 3 or 4 leaves (eight weeks after sowing). Nitrogen was side dressed in the form of Urea (46% N) in two splits of equal amounts after 3 and 6 weeks of transplanting depending on the specified rate. Plots were supplemented with irrigation during transplanting and at different growth stage due to shortage of rainfall. Watering was carried out using watering can and provided uniformly to each plot.

2.4. Data Collection

Days to 50% maturity: Number of days after transplanting (DAT) to 50% maturity (50% of the plants in a plot have ripe fruits at the first node).

Fresh biomass: After the last harvest, randomly chosen 10 plants per plot were cut off at the ground; all fruits were removed and fresh weight of the plants was recorded.

Fresh ripe fruit yield: the weight of marketable yield of fresh, red fruits harvested from each plot over a 10-week period was recorded for the first and last harvest dates.

Fruit weight: Average weight (grams) of 20 fresh, ripe fruits from the second harvest.

Fruit length: Average length (cm) of 20 fresh, ripe fruits from the second harvest.

Fruit width: Average width (cm) of 20 fresh, ripe fruits from the second harvest.

2.5. Statistical Analysis

Red fresh yield data was subjected to analysis of variance (ANOVA) using SAS Statistical Software package. Yield stability analysis was carried out using AMMI model and genotype and genotype by environment (GGE) Biplot using GenStat 18th.

2.6. Stability Analysis

AMMI Stability Value (ASV): According to Purchase (1997)

$$ASV = \sqrt{\left(\frac{SS_{IPCA1}}{SS_{IPCA2}}\right)\left(IPCA1_{score}\right) + \left(IPCA2_{score}\right)^{2}}$$

3. Results and Discussion

3.1. Fresh Fruit Yield and Yield Components

The analysis of variance (ANOVA) revealed that there were highly significant (P<0.01) differences among the genotypes for all traits, except days to maturity. The pooled mean squares due to genotypes and genotypes and environment interaction indicated evidences for genetic variability among the genotypes for all the traits, except days to maturity (Table 2).

The mean of genotypes for red fresh pod yield indicated that there were significant differences across the six locations revealing that there is a variability in genotypes in yield potential (Table 3). There were also significant differences among the genotypes for red fresh pod yield at all locations, except at Fedis in 2019 and at Gursum in 2021. The maximum mean of red fresh pod yield (averaged over the two years) were 9.41, 8.91 and 8.82 t ha^{-1} for FB-25, FB-26 and KW-14 genotypes at Babile, respectively. Among genotypes studied across the six environments, the means of FB-25, KW-14 and FB-26 genotypes recorded higher yield advantages of 25.05, 14.04 and 18.2%, respectively as compared to the best standard check.

Table 2: ANOVA for Mean Square of Chili Pepper Yield and Yield Components

Agronomic and Yield Parameters	Days of Maturity	Average Fruit Length	Average Fruit Diameter	Average Fruit Weight	Red Fresh Pod Yield
Replication (2)	39.31	73.73	2.277	0.3441	7.593
Genotypes (13)	54.55	235.46**	9.027**	0.7471**	7.687**
Location (2)	2166.96**	466.38**	2.818*	9.5925**	299.435**
Year (1)	11427.81**	1144.51**	46.283**	8.3494**	176.697**
G × Rep (26)	42.3	0.35	1.501	0.1772	3.668
G × E (26)	42.82	105.77**	3.449**	0.5646**	7.166**
G × Year (13)	34.09	77.62**	1.539*	0.4592*	2.592
G × E × Year (26)	46.1	60.79**	1.1588	0.4549**	3.629

Note: G=genotypes; E=environment; Rep=replication; and *= significant difference, **= highly significant difference, and number in the parentheses is degree freedom.

Table 3: Chili Pepper Red Fresh Pod Yield (tons ha^{-1}) Performance Across Locations and Years

Genotypes	2019			2021				
	Fedis	Babile	Gursum	Fedis	Babile	Gursum	Mean	Yield Advantages (%)
FB-25	6.05	9.66	5.51	6.07	9.16	3.10	6.59	25.05
FB-26	4.51	9.16	4.99	6.97	8.66	1.76	6.01	14.04
KW-13	5.85	6.88	3.91	4.50	6.38	2.47	5.00	
FB-27	6.29	6.19	3.32	5.07	5.69	1.89	4.74	
KW-14	6.24	9.07	5.58	5.00	8.57	2.85	6.22	18.02
KW-1	6.33	7.06	2.45	4.50	6.56	1.89	4.80	
FB-2	7.91	8.47	4.12	4.50	7.97	1.48	5.74	
KW-20	7.16	5.38	4.57	2.97	4.88	2.29	4.54	
FB-31	8.35	8.05	1.89	3.60	7.55	1.53	5.16	
FB-31	7.18	6.93	3.19	3.60	6.43	2.28	4.94	
KW-29	7.24	6.41	7.18	3.60	5.91	2.93	5.54	
FUK-2	5.88	8.26	5.24	3.60	7.76	2.08	5.47	
Dame	6.22	4.55	5.01	3.60	4.05	2.00	4.24	
Kume	4.50	7.28	7.05	3.60	6.78	2.43	5.27	
CV (%)	41.8	19.1	29.7	29.1	20.5	46.4		
LSD (0.05)	4.500	2.364	2.276	2.111	2.364	1.666		
p-value	Ns	**	**	**	**	Ns		

Note: CV= coefficient variation, LSD= least significant difference, NS= non significant, and ** = highly significant.

3.2. AMMI Analysis

The AMMI model stands out as the first choice with its high degree of accuracy when the interaction effect with the main effect is important. From AMMI analysis, there were highly significant differences for Environments, Genotypes, and Genotype by environment interactions (GEI). G x E interaction was significant, further calculation of genotype stability is possible. Similarly, Farshadfar and Sutka (2006) evaluated 20 bread wheat genotypes for four years under two different conditions and reported that significant variations among genotypes, environments and environment G X E interaction were recorded and thus necessitate stability analysis. Substantial percentage was explained by IPCA-1 (39.95%) followed by IPCA-2 (32.79%) and IPCA-3 (24.71%) (Table 4). Genotype, Environment and GEI explained a variation of 5.9%, 48.46% and 18.57% of the sum square, respectively (Table 4). A large sum of squares for genotypes indicated that the genotypes were genetically diverse, with large differences among genotypic means causing variation in the red fresh fruit yields. This result indicated that there was a variation among testing environments and tested genotypes that genotypes are responded differently across locations. It also revealed that the potential fruit yield variation among genotypes across locations is due to the existence of genotype by environment interaction (GEI).

Table 4: ANOVA for AMMI Model for Fresh Pod Yield

Source	d.f.	s.s.	m.s.	Explained %SS
Genotypes	13	99.9	7.69***	5.90
Environments	5	820.2	164.04***	48.46
Block	12	53.5	4.45ns	3.16
Interactions	65	314.4	4.84***	18.57
IPCA 1	17	125.6	7.39***	39.95
IPCA 2	15	103.1	6.87**	32.79
IPCA 3	13	77.7	5.97**	24.71
Error	156	404.7	2.59	

3.3. Stability Analysis

The genotype with an ASV score which approach to zero is stable, whereas genotypes with high ASV score are unstable. Accordingly, genotypes (KW-13 and FUK-2) showed low ASV and the most stable. Stability by itself should not be the only parameter for selection, because the most stable genotype would not necessarily give the best yield performance (Mohammadi *et al*., 2007). Therefore, the study indicated that, KW-13 and FUK-2 were recorded the lower ASV (Table 5), but recorded lower yield than the standard check. Thus, if the genotypes (KW-13 and FUK-2) to be selected based on ASV value only, there to be a risk of yield reduction. Hence, there is a need for approaches that incorporate both mean yield and stability in a single index. Genotype selection index confirmed that the genotype with the lowest GSI value is more stable and high yielding. Accordingly, genotypes (KW-14 and FB-25) were more stable genotypes with the score of minimum genotype selection index (Table 5). This results were in agreement with (Hintsa and Abay, 2013) who has used ASV as one method of evaluating grain yield stability of bread wheat varieties and similar reports been made by Gebeyehu and Shimelis (2018) in five chili pepper genotypes.

Table 5: AMMI Stability Value and Genotypic Slection Index

Genotype	Mean	Rank	IPCAg1	IPCAg2	ASV	Rank	GSI
Dame	4.47	14	-1.00847	0.18157	1.12779727	9	23
FB-2	5.741	4	0.41901	-0.55003	0.7186221	7	11
FB-25	6.59	1	0.70757	0.53336	0.94572119	8	9
FB-26	6.006	3	1.06799	1.02542	1.56237253	14	17
FB-27	4.574	12	0.09789	-0.17019	0.20158946	3	15

Table 5 (Cont.)

Genotype	Mean	Rank	IPCAg1	IPCAg2	ASV	Rank	GSI
FB-30	5.16	7	0.63981	-1.2989	1.4784566	12	19
FB-31	4.975	10	0.00577	-0.62614	0.62617239	5	15
FUK-2	5.068	8	-0.09011	0.02968	0.10379181	2	10
Kume	5.5	5	-0.36426	1.25007	1.31313248	11	16
KW-1	4.798	11	0.43507	-0.43968	0.65108614	6	17
KW-13	4.998	9	0.01835	0.03955	0.04443433	1	10
KW-14	6.218	2	0.3799	0.37091	0.55981671	4	6
KW-20	4.539	13	-0.95718	-0.42359	1.13822989	10	23
KW-29	5.315	6	-1.35136	0.07799	1.49358322	13	19

3.4. Genotype and Genotype by Environment interaction (GGE) biplot analysis

Relationship among test environments, the mean yield data of both years were used to assess the relationships between the different test environments and this was visualized by the line connecting each environment to the biplot origin or environment vectors. Genotypes proximal to the arrow at the center of the concentric circles (ideal genotype) are assumed to be suitable (Yan and Tinker, 2006). Hence, genotype FB-25 and KW-14 were the most desirable genotypes. GGE biplot analysis showed that PCA1 and PCA2 explained 60.84 % and 30.30 % of the GGE variance, respectively (Figure 1). Accordingly, the biplot figure showed that genotype FB-25 was in the first concentric circle, closer to IPCA stability horizontal line followed by KW-14 away from the mean vertical line which indicated that these genotypes were stable and high yielders of all the tested genotypes. Out of the genotypes, Genotypes FB-25, FB-26 and KW-14 were close to IPCA stability horizontal line that revealed the more stable genotype across locations (Figure 1).

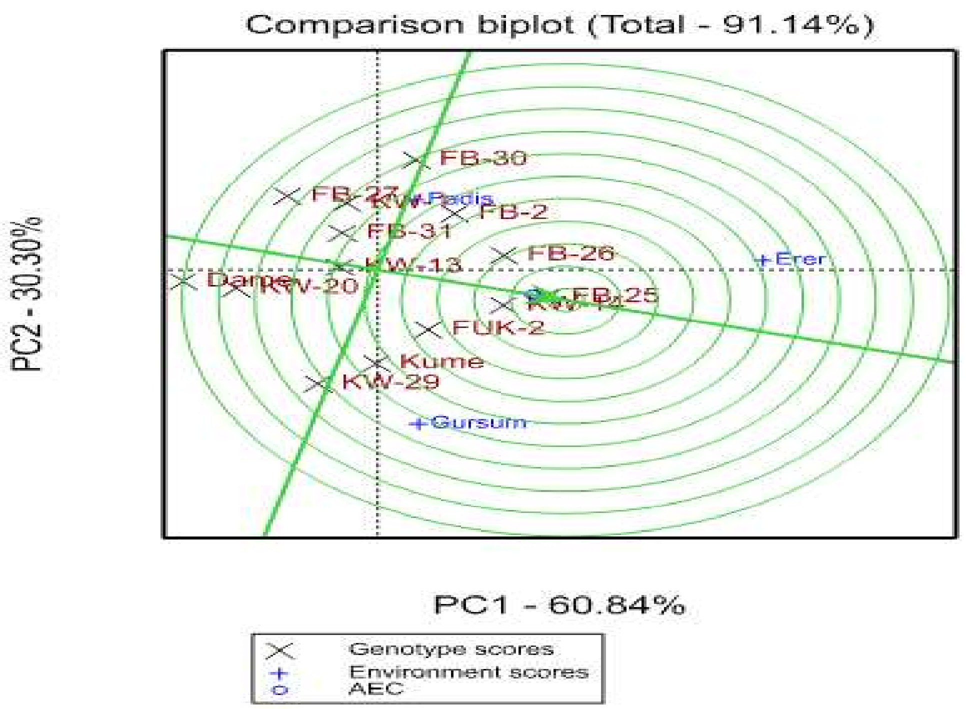

Figure 1: GGE Biplot

4. Conclusion and Recommendations

The experiment was conducted at six environments to evaluate genotypes' fresh pod yield performance and yield stability across environments. The multi-environmental evaluation of chili pepper genotypes for pod yield and yield components revealed resulted in the identification of the best genotypes and environments for the selection of generally adaptable, stable and superior genotypes for the three distinct growing seasons. It was evident from the study that traits like days to maturity, average pod width and diameter, average pod weight and red pod yield were under great influence of the different environments.

Based on the GGE Biplot and mean yield, genotypes FB-25, KW-14 and FB-26 had significantly higher fresh pod yield and higher regression coefficients also indicated their suitability for favorable environmental conditions. The GGE Biplot also depicted the same result indicating FB-25, KW-14 as stable genotypes with lower IPCA 1 axis score, thus it had lowest contribution towards the G×E interaction for fresh pod yield. The genotypes FB-25 and KW-14 were found to be generally adaptable for all three different growing environments as compared to other genotypes. In general, the genotypes FB-25 and KW-14 were selected for their highest red pod yield and most stability among their entries to the different environments under which the study was conducted. Therefore, these two genotypes were promoted to variety verification trial for possible release in the subsequent season.

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References

Ashraful, A., Farhad, A.H., Naresh, C.D.B., Paritosh, K.M., Mostofa, A.R., Amir, H. and Mingju, L. (2017). AMMI and GGE Biplots for Wheat Genotypes Yield Stability in Bangladesh. *Pak. J. Bot.*, 49(3), 1049-1056.

Eberhart, A. and Russell, W. (1966). Stability Parameters For Comparing Varieties. *Crop Science*, 6(1), 36-40.

Farshadfar, E. and Sutka, J. (2006). Biplot Analysis of Genotype-environment Interaction In Durum Wheat Using the AMMI Model. *Acta Agron. Hung*., 54(4), 459-467.

Gebeyehu and Shimelis (2018). Stability Analysis of Chili (*Capsicum frutescens* L.) Genotypes in the Rift Valley Areas of Ethiopia. *J Agri Sci Food Res.,* 9(1), 208.

Gurung, T., Suchila, T., Suriharn, B. and Sungcom, T. (2012). Stability Analysis of Yield and Capsaicinoids Content in Chili (*Capsicum* spp.) Grown Across Six Environments. *Euphytica*, 187, 11-18. doi: https://doi.org/10.1007/s10681-012-0672-6

Justin, D.B., Crosby, K.M., Yoo, K.S. and Patil, B.S. (2012). Environmental and Genotypic Variation of Capsaicinoid and Flavonoid Concentrations in Habanero (*Capsicum chinese*) Peppers. *HortSci.,* 47(5), 574-79.

Kraft, H.K., Brown, H.C., Nabhan, P.G., Luedeling, E., Ruiz, J.J., Coppens, G., Hijmans, J. and Gepts, P. (2014). Multiple Lines of Evidence for the Origin of Domesticated Chilli Pepper, *Capsicum annuum*, in Mexico. *Proc. Nat. Acad. Sci.*, USA, 111(17), 6165-6170.

Mohammadi, R., Armion, M., Shabani, A. and Daryaei, A. (2007). Identification of Stability and Adaptability in Advanced Durum Wheat Genotypes Using AMMI Analysis. *Asian Journal of Plant Sciences,* 6(8), 1261-1268.

Purchase, J.L. (1997). Parametric Analysis to Describe Genotype X Environment Interaction and Yield Stability in Winter Wheat. Free State University, Bloemfontein, South Africa. Ph.D. Thesis.

Yan, W. and Tinker, N.A. (2006). Biplot Analysis of Multi-environment Trial Data: Principles and Applications. *Canadian Journal of Plant Science*, 86(3), 623-645.

Zewdie, Y. and Bosland, P.W. (2000). Evaluation of Genotype, Environment and Genotype-by Environment Interaction for Capsaicinoids in *Capsicum annuum* L. *Euphytica*, 111, 185-190. doi: https://doi.org/10.1023/A:1003837314929.

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