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GENOTYPE BY ENVIRONMENT INTERACTION FOR YIELD AND YIELD CONTRIBUTING TRAITS OF FINGER MILLET (*ELEUSINE CORACANA*) IN BANGLADESH

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Abstract

Stability of for yield and yield contributing traits of finger millet is an important consideration for identification of superior genotypes, which is highly influenced by agro-climatic conditions. The present study was conducted to determine stability for grain yield and yield contributing traits of four finger millet genotypes at three different locations viz; Gazipur, Jamalpur, and Rangpur during 2019-20. In AMMI (Additive Main and Multiplicative Interaction) model, G × E interaction analysis of grain yield and yield contributing traits showed differential interaction of the genotypes in the different environmental conditions. Rangpur and Gazipur were rich for finger millet production while the environment of Jamalpur was poor. Among the genotypes, IE-501 produced the maximum grain yield (5.81 t/ha), followed by IE-2043 (4.69 t/ha) in the favorable environment. Genotypes IE-2043 and IE-3392 exhibited higher yielding as well as stable over all environments. Considering the AMMI model and mean, bi and S^2di, the genotypes IE-2043 and IE-3392 would be suitable across environment whereas genotype IE-501 would be suitable under favorable environmental. For all of the traits evaluated, none of the genotypes were found stable across locations. The genotypes IE-2043 and IE-3392 with high mean grain yield could be utilized for developing high yielding stable finger millet genotypes.

Keywords: Finger millet, G × E interaction, yield and stability analysis.

Introduction

Millets are a great source of nutrition and medicinal components (Amadou and Le, 2013 and Shobana *et al.,* 2013). However, they are essential but under-utilized crops in tropical and semiarid regions of the world. Among the world's millets, Ragi or finger millet (Eleusine coracana Gaertn.) ranks fourth after pearl millet, foxtail millet, and proso millet (Chandra *et al.,* 2016). It is usually grown on marginal lands under moisture stress and low fertility. Therefore, this crop creates an opportunity of using arable dry land of Bangladesh under rainfed agriculture. It is well known for disease and pest resistance as well as good survival to a wide range of environment with, and their satisfying decent yield. Finger millet can persist significant levels of abiotic stress like salinity, waterlogging, drought and fits as short duration crop. It doesn’t require much

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inputs during its cultivation (Chandra *et al.,* 2016). The crop is generally grown under the direct-seeded condition in low rainfall zones in Bangladesh. Lack of high-yielding varieties adapted to diverse agro-ecological conditions is the primary reason for low productivity. The evaluation of genotypes' interaction with locations and other agro-management conditions would help get information on the adaptability and stability of genotypes' performance. However, there is not much available information or knowledge regarding the nature and magnitude of Genotype-Environment Interaction (GEI) on finger millet. Genotype’s relative performance can be improved with alterations in the environments and these diverse responses are due to the genotype environment interactions (GEI) because, environments might be either favorable to certain genotypes that not suitable for others (de oliveira *et al.,* 2003). Numerous methods for analyzing multi-environment trial data have been developed to expose the pattern of G × E interaction, Joint regression (Finlay and Wilkinson, 1963, Eberhart and Russel, 1966) and currently AMMI (Gauch, 1992) and GGE biplot (Genotype main effect plus genotype by environment interaction). AMMI model links the analysis of variance of genotypes and the environment main effect with principle component analysis of the genotype-environment interaction into a combined approach (Gauch and Zobel, 1996).

Multi-Environment Yield Trials (MEYT) are led for different crops all over the world (Yan and Rajcan, 2002; Dehghani *et al.,* 2006) not only to recognize high yielding cultivars but also to classify sites that best characterize the desired environment (Yan *et al.,* 2001). Typically, in MEYT, a number of genotypes are tested over multiple environments and sometimes several years to perceive the adaptation of the crop. Nonetheless, it is often difficult to detect the outline of genotypic responses across environments without the use of a proper analytical tools such as GGE biplot (Yan *et al.,* 2001; Yan and Tinker, 2006) for graphical display of data. The measured yield of each genotype in each test environment is a combined result of genotype main effect (G), an environment main effect (E) and genotype × environment (GE) interaction (Yan and Kang, 2003). However, E is responsible for about 80% of the total yield difference; though, it is only G and GE interaction that are related to cultivar evaluation and mega environment classification (Yan and Rajcan, 2002; Kaya *et al.,* 2006). Hence, selection of superior genotype for specific environment will assist to exploit GE interaction on the other hand, selection of widely adapted and stable genotype over diverse environments will help to avoid limitation of GE interaction (Zerihun, 2011). Therefore, the objectives of this study were to evaluate the yield performance of each genotype to find the stable high yielding in relation to each environment (Gazipur, Jamalpur and Rangpur) and best fit environment for this crop production.

Materials and Methods

The present study was conducted at three locations: Gazipur, Jamalpur, and Rangpur during *rabi*, 2019-20. Four finger millet lines (IE-501, IE-2043, IE-2619, IE-3392) were evaluated in this study. The trials were laid out in RCB design with three replications. Seeds of each entry were sown in a 4m X 3m plot with 25 cm row spacing. Seeds were sown at three locations on 1st December, 2019. Thinning was done three weeks after the date of sowing. Fertilizers were applied @ 45:30:20 kg/ha of N-P-K, respectively. All intercultural operations were done in time to raise the crop uniformly. Ten plants from each plot were selected randomly to record data of days to heading, days to maturity, plant height (cm), number of tiller/plants, panicle length (cm), number of fingers /plants, and grain yield (t/ha). The analysis of variance (ANOVA) was used, and the GE interaction was estimated by the AMMI model (Zobel *et. al.*, 1988).

Results and Discussion

A combined ANOVA could be done since the mean squares of individual environments were homogeneous as shown by the Bartlett test. Environments were significantly varied for all the traits except panicle length, which revealed a high differential genotypic response across the different environments. Test environments were significantly different in yield potential indicating that the mean yield of genotype differed from environment to environment. The main effects of genotype x environment interaction were highly significant ($P<0.01$) for grain yield and some other traits evaluated (Table 1). The genotype x environment interaction of the variation for grain yield, days to heading, days to maturity, plant height, were highly significant (Table 4). But the effect due to genotype x environment interaction was none significant ($P<0.05$) for tiller per plant, panicle length, and number of fingers per panicle. Genotype x environment interaction is important for grain yield and other yield related trait depends of genotypes which depend on environment (Solomon *et al.*, 2008). The presence of significant G x E interaction showed the differential in performance of finger millet across environments. Similar result was reported that a change in yield caused G x E interaction on finger millet by Patil, (2007); Misra *et al.*, (2009); Kebede *et al.*, (2019); Mamo *et al.*, (2018). Generally, the larger is the relative size of interaction component, the more complex the problem of identifying broadly adapted genotype. Highly significant ($P<0.01$) yield differences among genotypes and environments, and highly significant interaction of genotypes with environment indicated the need to develop cultivars that are adapted to specific environmental conditions, and need to identify cultivars that are exceptional in their stability across environments. Environment relative magnitude was much higher than both the genotypic and genotype-environment interaction effects. Explained variation (%) was also higher by the environment, suggesting that each genotype's performance was influenced more by environmental factors of these traits.

Table 1. Full Joint analysis of variance including the partitioning of the G × E interaction of four finger millet lines over three locations

Source of variation	df	Mean sum of square						
		DH	DM	PH	TP	PL	NFPP	TY
Genotypes (G)	3	12.03	12.012	115.69	0.20	0.98	0.25	0.73
Environment (E)	2	242.19**	819.84**	310.01*	3.06*	6.00	5.34*	1.22*
Interaction (G×E)	6	6.18*	9.85**	60.95**	0.68	2.05	0.62	0.26*
AMMI Component 1	4	6.25	9.07	71.192	1.00*	2.83	0.91**	0.24*
AMMI Component 2	2	6.03	11.41	40.47	0.027**	0.49	0.051**	0.065*
G×E (linear)	3	8.16	9.85	32.72	1.25	2.24	0.34	0.32
Pool deviation	3	4.19	10.08	89.18	0.10	1.86	0.90	-1.52E-07
Pooled error	28	9.75	12.29	61.58	0.79	2.23	1.51	0.80

$*P<0.05$, $**P<0.01$; DH=Days to heading, DM= Days to maturity, PH=Plant height (cm), TP=Tiller/plant, PL= Panicle length (cm), NFPP =Number of fingers per panicle, TY= Yield (t/ha).

Table 2. Stability analysis for days to heading of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Days to Heading (days)						
		Location			Overall mean	Pi	bi	S^2di
		Rangpur	Gazipur	Jamalpur				
1	IE-501	97.3	94.3	105.3	98.98	1.41	0.72	1.32
2	IE-2043	92.0	94.3	107.3	97.87	0.30	1.02	9.38
3	IE-2619	94.7	91.0	110.7	98.79	1.19	1.34	0.61
4	IE-3392	92.3	89.0	102.7	94.67	-2.91	0.91	1.28
	Mean	94.1	92.1	106.5				
	LSD (0.05)	2.92	8.80	3.92				
	Env. Index (Ij)	-3.5	-5.41	8.91				

Days to heading (days) along with the value of phenotypic index (Pi,) regression coefficient (bi), deviation from regression (S^2di) are presented in table 4. The genotypes mean ranged for days to Heading 94.67 (IE-3392) to 98.98 (IE-501). Three genotypes showed positive Pi index, while one showed negative Pi index for days to heading. The genotypes, which showed positive Pi index, these genotypes took longer period for heading and negative Pi index showing days to heading took shorter period for heading. For days to heading, Gazipur took a shorter duration (92 days) and Jamalpur took a longer period (106 days). In terms of days to heading (days), none of the genotype were stable across locations because they did not produce early flower, a regression coefficient close to one, or a minimum deviation. However, all genotypes produced early flowering in Rangpur and Gazipur. Shanthu kumar (2000) and Patil (2007) was found short duration stable finger millet genotypes that produced early flowering and regression coefficient greater than one with minimum deviation.

Table 3. Stability analysis for days to maturity of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Days to Maturity (days)						
		Location			Overall mean	Pi	bi	S^2di
		Rngpur	Gazipur	Jamalpur				
1	IE-501	114.3	124.3	138.3	125.6	-1.38	0.82	13.71
2	IE-2043	110.7	131.0	142.7	128.1	2.27	1.13	0.54
3	IE-2619	112.3	131.0	144.7	129.3	1.05	1.13	0.61
4	IE-3392	110.0	130.0	135.3	125.1	-1.94	0.91	14.03
	Mean	111.8	129.1	140.2				
	LSD (0.05)	2.92	7.58	5.54				
	Env. Index (Ij)	-15.22	2.02	13.19				

The days to maturity along with the phenotypic indices (Pi), regression coefficient (bi), and deviation from regression (S2di) are shown in Table 3. Days to maturity were earlier in Burirhat compared to other locations. The mean genotypic value over the location ranges from 125.1 (IE-3392) days to 129.33 (IE-2619) days. Positive Pi showing genotypes represent maturing late and negative Pi showing genotypes represent earlier maturing. The bi and S^2di values range for days to maturity were 0.82 (IE-501) to 1.13 (IE-2043, IE-2619) and 0.54 (IE-2043) to 14.03 (IE-3392), respectively.

Table 4. Stability analysis for Plant height of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Plant height (cm)						
		Location			Overall mean	Pi	bi	S^2di
		Burirhat	Gazipur	Jamalpur				
1	IE-501	102	95.67	121.6	106.42	8.98	1.53	0.61
2	IE-2043	98.33	96.33	104.5	96.38	-1.07	0.69	55.8
3	IE-2619	85.67	90.33	107.8	94.6	-2.85	1.22	40.6
4	IE-3392	90.7	80.67	95.8	92.39	-5.06	0.55	0.25
	Mean	94.17	90.75	107.4				
	LSD (0.05)	8.10	8.75	8.57				
	Env. Index (Ij)	-3.27	-6.69	9.97				

Plant heights along with the value of phenotypic index (Pi,) regression coefficient (bi) and deviation from regression (S^2di) are presented in table 4. The genotypic mean ranged for plant height 92.39 (IE-3392) to 106.42cm (IE-501). One genotype showed positive Pi index while rest three showed negative Pi index in plant height. The genotypes, which showed positive Pi index, represents taller plant and negative Pi index represent dwarf plant. In case plant height of the genotype, IE-3392 were stable across locations because they produced short type of plant, a regression coefficient close to one, or a minimum deviation.

Table 5. Stability analysis for tiller/plant of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Tiller per plant (number)						
		Location			Overall mean	Pi	bi	S^2di
		Rangpurt	Gazipur	Jamalpur				
1	IE-501	4.3	4.7	4.3	4.4	-.27	0.006	0.07
2	IE-2043	3.3	4.7	7.0	5.0	-.36	2.08	0.23
3	IE-2619	3.7	5.0	6.0	4.9	0.16	1.33	0.01
4	IE-3392	4.0	4.7	5.0	4.6	-.16	0.57	0.01
	Mean	3.8	4.8	5.58				
	LSD (0.05)	1.59	0.99	1.52				
	Env. Index (Ij)	-0.88	2.78E-02	0.86				

Tiller per plant, along with the value of phenotypic indices (Pi), regression coefficient (bi), and deviation from regression (S^2di), are shown in Table 5. The genotypic mean value over the location ranges from 4.4 (IE-501) to 5.0 (IE-2043). Positive Pi showing genotypes represent higher tilleng plant while negative Pi showing genotypes represent lower tillering plants.

For number tillers per plant, genotypes IE-2619 produced high mean, positive Pi value regression coefficient was less than unity, and non-significant S^2di showed above average stability.

Table 6. Stability analysis for panicle length of four finger millet lines over three environments during 2019-20

Sl. No.	Genotypes	Panicle length (cm)						
		Location			Overall mean	Pi	bi	S^2di
		Rangpur	Gazipur	Jamalpur				
1	IE-501	7.83	9.33	7.77	8.31	0.64	0.71	0.05
2	IE-2043	7.66	8.33	7.33	7.77	0.10	0.40	0.03
3	IE-2619	5	11	7.02	7.67	0.0027	2.28	3
4	IE-3392	7.73	7.66	5.37	6.92	-0.74	0.595	2.55
	Mean	7.05	9.08	6.87				
	LSD (0.05)	2.76	2.55	0.98				
	Env. Index (Ij)	-0.61	1.41	-0.79				

Panicle length along with the value of phenotypic indices (Pi), regression coefficient (bi), and deviation from regression (S^2di) are presented in Table 6. The genotypic mean value over the location ranges from 6.92 (IE-3392) to 8.31(IE-501). Positive Pi showing genotypes represent higher panicle length while negative Pi showing genotypes represent lower panicle length. The bi and S^2di values range for panicle length were 0.59 (IE-3392) to 2.28 (IE-2619) and 0.03 (IE-2043) to 2.55 (IE-3392), respectively. For Panicle length, genotype IE-501produced high mean, positive Pi value regression coefficient was less than unity, and non-significant S^2di showed above average stability.

Table 7. Stability analysis for number of fingers per panicle of four finger millet lines over three environments during 2019-20

S. No.	Genotypes	Number of fingers per panicle						
		Location			Overall mean	Pi	bi	S^2di
		Burirhat	Gazipur	Jamalpur				
1	IE-501	5.66	8	7	6.89	0.25	0.63	1.68
2	IE-2043	6.33	7.66	6	6.67	0.78	0.75	0.02
3	IE-2619	7	8.33	5	6.78	-0.80	1.36	0.65
4	IE-3392	6.33	7.66	4.66	6.22	-0.58	1.24	0.38
	Mean	6.33	7.91	5.66				
	LSD (0.05)	3.19	1.79	1.28				
	Env. Index (Ij)	-0.30	1.27	-0.97				

Number of fingers per panicle, along with the value of phenotypic indices (Pi), regression coefficient (bi), and deviation from regression (S^2di) are shown in Table7. The genotypic mean value over the location ranges from 6.22 (IE-3392) to 6.89(IE-501). Positive Pi showing genotypes represent higher number of fingers per panicle while negative Pi showing genotypes represent lower number of fingers per panicle. The bi and S^2di values range for number of fingers/panicle were 0.63(IE-501) to 1.36 (IE-2619) and 0.02 (IE-2043) to 1.68 (IE-501), respectively. For fingers per panicle, genotypes IE-2043 produced high mean, positive Pi value regression coefficient was less than unity, and non-significant S^2di showed above average stability.

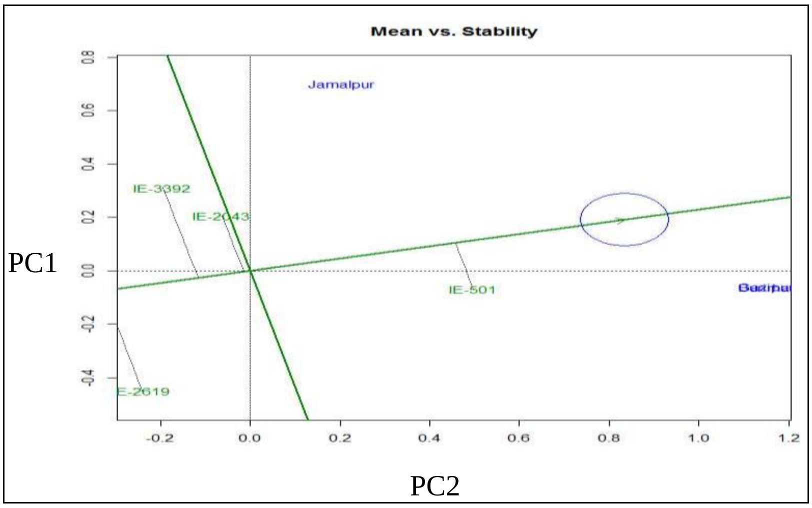
Table 8. Stability analysis for yield of four finger millet lines over three environments during 2019-20

S. No.	Genotypes	Grain Yield (t/ha)						
		Location			Overall mean	Pi	bi	S^2di
		Rangpurt	Gazipur	Jamalpur				
1	IE-501	5.79	5.81	3.96	5.20	0.68	1.92*	0.1
2	IE-2043	4.59	4.69	4.10	4.49	0.22	0.61	0.01
3	IE-2619	4.42	4.41	3.26	4.03	-0.48	1.20	0.03
4	IE-3392	4.43	4.42	4.18	4.34	0.17	0.25	0.04
	Mean	4.80	4.83	3.87				
	LSD (0.05)	1.55	1.57	0.19				
	Env. Index (Ij)	0.32	0.31	-0.23				

Yield along with the value of phenotypic index (Pi,) regression coefficient (bi) and deviation from regression (S^2di) are presented in table 8. The environmental mean and genotypic mean ranged from 9.29 to 10.95 t/ha and 5.56 to 12.29 t/ha, respectively. Among the genotypes, IE-501 produced the highest mean yield (5.20 t/ha) followed by IE-2043 (4.49 t/ha) whereas IE-2619 produced the lowest yield (4.03 t/ha) followed by IE-3392 (4.34 t/ha).

Three genotypes showed positive phenotypic index while the other genotype had negative phenotypic index for yield. Thus, positive phenotypic index represents the higher yield and negative represents the lower yield among the genotypes. Again, positive and negative environmental index (Ij) reflects the rich or favourable and poor or unfavorable environments for this character, respectively. The environment of Rangpur and Gazipur were rich whereas the environment of Jamalpur was poor for finger millet production. Rangpur was highly suitable for finger millet cultivation followed by Gazipur.

The values of regression coefficient (bi) for these genotypes were ranged from 0.25 to 1.92. These differences in bi values indicated that all the genotypes responded differently to different environments. For developing suitable varieties of finger millet, mean yield and stability parameter should be considered because the most stable genotypes not always give the best yield (Mohammadi *et al.*, 2010). Considering the mean, bi and S^2di, it was evident that all the genotypes showed different response of adaptability under different environmental conditions. Genotypes IE-501 performance for yield were better in Rangpur and Gazipur whereas in Jamalpur performance was poor. For all of the traits evaluated, none of the genotypes were found stable across location. Among the genotypes IE-2043 and IE-3392 exhibited the higher grain yield, bi~1 and S^2di~0 indicated that these genotypes were stable across the environment.



The x-axis represents the PC1value and the y-axis represents PC2 value.

Fig. 1. AMMI biplot from PC1 and PC2 of environment and genotype.

According to the AMMI biplot, Rangpur and Jamalpur were the most discriminating environments, whereas Rangpur t and Gazipur had the closest among the environments. Distribution of finger millet genotype points in the AMMI biplot showed that the genotype IE-2043 and IE-3392 scattered close to the origin, indicating minimal interaction of these genotypes with environment. A genotype or an environment with an IPCA score close to zero showed the small interaction effect and considered as stable (Crossa.1990). The genotype IE-2619 scattered away from the origin indicating that this genotype was more sensitive to environmental interactive forces. Genotypes that are closer to center tend to be stable, while those displayed further away do poorly plotted far apart are unstable in performance (Mamo *et al.,* 2018). Genotype IE-2043 showed the most stable genotype with moderate yield.

Conclusion

From the results of the study, it is revealed that the performance of finger millet yield was strongly influenced by the environment. Of the three environments, Rangpur (Burirhat) was found suitable for finger millet cultivation followed by Gazipur. Among the genotypes, IE-501 produced the highest mean yield in specific location. Considering the yield potentiality and stability parameter, genotypes IE-2043 and IE-3392 exhibited high yielding as well as stable over all environments.

Thus, genotypes IE-2043 and IE-3392 are recommended for possible release for wider adaptability around Rangpur (Burirhat), Gazipur and Jamalpur areas with similar agro-ecology in the country.

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