Registration of '*Diga-2*' Finger Millet (*Eleusine coracana* sub.spp. *coracana*) Variety

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Abstract
Background: Finger millet is an important staple food crop widely grown in Ethiopia. The national average yield is far below the potential yield of the crop. Limited availability of stable, high yielding and disease tolerant finger millet varieties is one of the major production constraints in the country.
Objective: The objective of this study was to identify stable high yielding and diseases tolerant genotypes for production.
Materials and Methods: twelve black seeded pipeline finger millet genotypes were evaluated under a regional variety trial at Bako and Gute research stations from 2014 to 2016 main cropping seasons including the standard (*Degu*) and local checks using randomized complete block design. *Diga-2* variety is black seeded finger millet (*Eleusine coracana* sub.spp. *coracana*) with the pedigree of Acc. BKFM0010 has been collected from Beneshangul Gumuz Regional State by Ethiopian Institute of Biodiversity.
Results: The results from Additive Main effect and Multiplicative Interaction (AMMI) and Eberhart and Russell regression stability models as well as Genotype and Genotype by Environment interaction (GGE) biplot analysis revealed that *Diga-2* variety was relatively stable and high yielder (2.38 t ha^{-1}) among the tested genotypes. The new variety, *Diga-2* had a yield advantage of 33.7% over *Degu*, the standard check variety used for multi-environment evaluation.
Conclusion: Among the tested genotypes, *Diga-2* finger millet variety was selected and released in 2018 for its high grain yield potential, stable and resistant against finger millet blast (*Magnaporthe oryzea*) disease which is the most important finger millet production constraints in Ethiopia in general and western Oromia in particular.

Keywords: Additive main effect and multiplicative interaction; Blast (*Magnaporthe oryzea*); Genotype by environment interaction; Stability

1. Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn) is an allotetraploid (2n = 4× = 36) annual cereal crop that includes two distinct sub-species: *coracana* (cultivated finger millet) and *Africana* (wild finger millet) (Hilu, 1994). Finger millet is a climate-resilient (Kumar *et al.,* 2017) and highly adapted to adverse agro-ecological conditions with minimal inputs, produced on marginal land where other crops cannot perform, and tolerant to acidic soil (Upadhyaya *et al.,* 2007; Gull *et al.*, 20014) . Finger millet is largely produced and consumed by marginalized inhabitants of semi-arid region of Asia and Africa; and it helps subsistence farmers with additional income from the grain sales (Dida *et al.*, 2007).

Finger millet is an important staple food crop widely grown in Ethiopia. The crop was produced by 1,765,407 farmers on 456,057.31 hectares of land with total production of 1,030,823.15 tons in 2017/18 Meher cropping season. Finger millet production accounted 3.6% of 80.71% cultivated land for cereal crops and 3.37% of 87.48% cereal crops production (CSA, 2018). Its grain is gluten-free; rich in calcium, fiber, iron, and has excellent malting qualities (Chandrashekar, 2010; Pradhan *et al.*, 2010; Gupta *et al.*, 2014). Research has shown that finger millet diets are rich in protective against several degenerative diseases such as diabetes, cardiovascular diseases, and few types of cancers, metabolic syndrome and Parkinson's disease (Fardet *et al.*, 2008).

The national average yield is 2.26 t ha^{-1} (CSA, 2018) lower than the potential yield of the crop. Limited availability of stable high yielding and disease tolerant finger millet varieties is one of the major production constraints in the country. Accordingly, Bako Agricultural Research Center evaluated different accessions of finger millets collected from different regions of the country categorized in to seed color class to identify stable, high yielding, and disease-resistant varieties in order to address farmers' needs. Therefore, *"Diga-2"* Finger millet variety was released for the test environments (Bako and Gute) and similar agro-ecologies of the country.

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2. Varietal Origin and Evaluation

Diga-2 (Acc. BKFM0010) finger millet (*Eleusine coracana* sub.spp. *coracana*) variety was obtained from Ethiopian Institute of Bio-diversity (EBI). Originally, it was collected from Beneshangul Gumuz Regional State, western Ethiopia. This variety and the other black-seeded genotypes were evaluated against the standard check, *Degu*, for three consecutive years (2014 - 2016) at Bako and Gute research stations.

2. Agronomic and Morphological Characteristics

The released variety, *Diga-2* (Acc. BKFM0010) is characterized by loose finger type, black seeded, average 1000 seeds weight of 3 grams, an average plant height of 103.61 cm and 104 mean days to flower (Table 5). The released black seeded finger millet variety *Diga-2* is relatively stable with optimum mean grain yield (2.38 t ha^{-1}), (33.7 %) yield advantage over the standard check, *Degu* (Tables 1 and 5).

3. Yield Performance

The released black seeded finger millet variety *Diga-2* (Acc. BKFM0010) is relatively stable with optimum mean grain yield (2.38 t h^{-1}) and having (33.7 %) yield advantage over the standard check (1.78 t ha^{-1}) Degu. Genotypes (BKFM0020 and BKFM0006) among tested genotypes were better in average grain yield but are not stable and had agronomic defects like logging (Table 1).

Table 1. Genotypes mean grain yield (Ton Ha-1) Over Location across years.

	Mean grain yield (t ha^{-1})							
Genotype	Bako			Gute			Mean	BSS
	2014	2015	2016	2014	2015	2016		
215984	1.136	3.205	1.821	1.841	1.406	2.146	1.93	2
216035	1.301	2.531	2.177	2.557	1.657	2.535	2.13	1
216045	1.042	3.064	1.412	2.304	1.374	2.67	1.98	1
BKFM0001	1.469	3.342	2.184	3.059	1.204	2.427	2.28	1
BKFM0006	1.814	3.263	2.562	2.776	2.015	2.886	2.56	1
BKFM0010	1.196	3.419	2.247	3.228	1.676	2.508	2.38	1
BKFM0014	1.578	2.979	1.748	2.776	1.338	1.813	2.04	2
BKFM0020	2.56	3.549	2.721	2.889	2.446	2.41	2.78	1
BKFM0023	1.617	3.367	1.984	3.327	1.788	1.9	2.33	2
BKFM0024	0.938	2.92	1.669	3.189	1.458	2.44	2.10	2
Degu	1.59	2.636	1.926	1.526	1.343	1.628	1.78	2
Local	0.972	2.68	2.264	1.723	1.313	2.544	1.92	2
Mean	1.435	3.127	2.06	2.6	1.535	2.325	2.18	
LSD	0.579	0.794	0.712	0.977	0.7692	0.945	0.796	
CV(%)	23.8	15	20.3	22.2	29.2	23.9		
F-value	**	*	*	**	ns	ns		

Note: BSS = Blast severity score made at 1-5 scale; CV = Coefficient of variation and LSD = Least significant difference.

4. Stability and Adaptability Performance

Eberhart and Russell (1966) model ANOVA revealed highly significant for mean square due to variety (Table 2). *Diga-2* (Acc. BKFM0010) showed regression coefficient (bi) relatively closer to unity, so that the variety is relatively more stable and widely adaptable than other genotypes (Table 3). The GGE biplot analysis showed that the variety fell in the second concentric circle away from vertical mean line and closer to the stability line crossing the origin (Figure 2), indicating its high yield potential and relative stability compared to the other genotypes (Yan, 2001). Similarly, the AMMI analysis revealed that *Diga-2* attained IPCA values relatively close to zero (Table 4) and hence are better stable and widely adaptable genotype across locations with higher yield potential (Figure 1).

Table 2. Analysis of variance for grain yield using the Eberhart and Russell regression model.

Source	df	SS	Mean square or MS
Total	215	38.620	
Variety	11	5.570	0.506**
Env.+ in Var. x Env.	60	33.050	0.551
Env. in linear	1	25.202	
Var. x Env. (linear)	11	2.029	0.184Ns
Pooled deviation	48	5.819	0.121

*Note: Grand mean = 2.18; R2 = 0.8239; Coefficient of variation = 24.51% and ** = *, ** = Significant at P < 0.05 and P < 0.01 levels, respectively.*

Table 3. Regression coefficient (bi) and squared deviation from linearity of regression (s2di) by the test genotypes revealed using Eberhart and Russell model.

Genotype	Regression coefficient and bi	Squared deviations from regression or S2di	Grain yield (t ha^{-1})
Local	0.8531	0.1408	1.92
BKFM0020	0.7416	0.0385	2.78
BKFM0023	1.1115	0.0702	2.34
215984	1.0165	0.0095	1.93
BKFM0006	0.8176	-0.0661	2.56
BKFM0024	1.2493	0.0580	2.10
BKFM0010	1.0578	-0.0284	2.38
216045	1.1817	0.1351	1.91
BKFM0014	0.9784	-0.0117	2.05
BKFM0001	1.2590	-0.0387	2.28
216035	0.7171	-0.0184	2.13
Degu	0.4956	0.0358	1.78

Note: Standard error of beta = 0.2403.

Table 4. Analysis of variance for additive main effects and multiplicative interaction (AMMI) for yield stability of black seeded finger millet genotypes from 2014-2016 at Bako and Gute research station.

Source	df	SS	MS	% GXE	Cumulative interaction Explained (%)
Environment	5	75.606	15.121**		
Genotype	11	16.710	1.519**		
Genotype x Envt. interaction	55	23.544	0.428*		
IPCA I	15	11.394	0.760 **	48.39	48.39
IPCA II	13	6.740	0.518 *	28.63	77.02
IPCA III	11	3.276	0.298ns	13.91	90.93
Residual	132	35.702	0.270		

*Note: Grand mean = 2.18; R2 = 0.7719; Coefficient of variation (CV, %) = 23.98%; *, ** = significant at P < 0.05 and P < 0.01 levels, respectively.*

5. Reaction to Major Diseases

Diga-2 (Acc. BKFM0010) finger millet variety showed tolerant to blast *(Magnaporthe oryzea)* which is the major production constraint of finger millet at national level, but much severe in western Oromia.

6. Conclusion

Diga-2 (Acc. BKFM0010) Finger millet (*Eleusine coracana* sub.spp. *coracana*) variety gave relatively high grain yield, showed wider adaptability and stable performance than the standard check and the other pipeline varieties evaluated. In general, Eberhart and Russell, GGE biplot analysis and AMMI model analysis results revealed that *Diga-2* (Acc.BKFM0010) is a stable and high yielding (2.38 ton ha^{-1}) finger millet variety with 33.7% yield advantage over the standard check variety, *Degu* (1.78 ton ha^{-1}) and also tolerant to blast disease. Therefore, it was officially released for wider production in west Oromia (Bako, and Gute) and areas with similar agro-ecologies.

Table 5. Agronomic/morphological characteristics of *Diga-2* (Acc.BKFM0010) finger millet variety.

Characteristic parameter	Description of agronomic/morphological characteristics
Variety Name	Diga-2 (Acc.BKFM0010)
Adaption area:	Western Oromia (Bako, Gute and similar agro-ecologies
Altitude (meter above sea level)	1200−2300
Rainfall (mm)	1000−1300
Seed rate (kg/ha)	15 kg for row planting and 25kg for broadcasting
Spacing	40 cm between rows
Planting date	Early June
Fertilizer rate (kg ha^{-1})	
Dap	100 kg ha $^{-1}$ at planting
Urea	65 kg ha^{-1} split application (half at planting and half at 35 days after emergence)
Days to flowering	104 days
Days to maturity	164 days
Finger type	Loose
Fingers per ear	7
Finger length (cm)	10.6
Thousand seed weight (g)	3
Plant height (cm)	103.6
Seed color	Black
Growth habit	Erect
Crop pest reactions	Tolerant to major finger millet diseases (Leaf and head blast)
Yield (t ha^{-1})	
Research field	2.24−3.42
Farmers field	2.32−2.98
Year of release	2018
Breeder seed maintainer	Bako Agricultural Research Center (BARC/OARI)

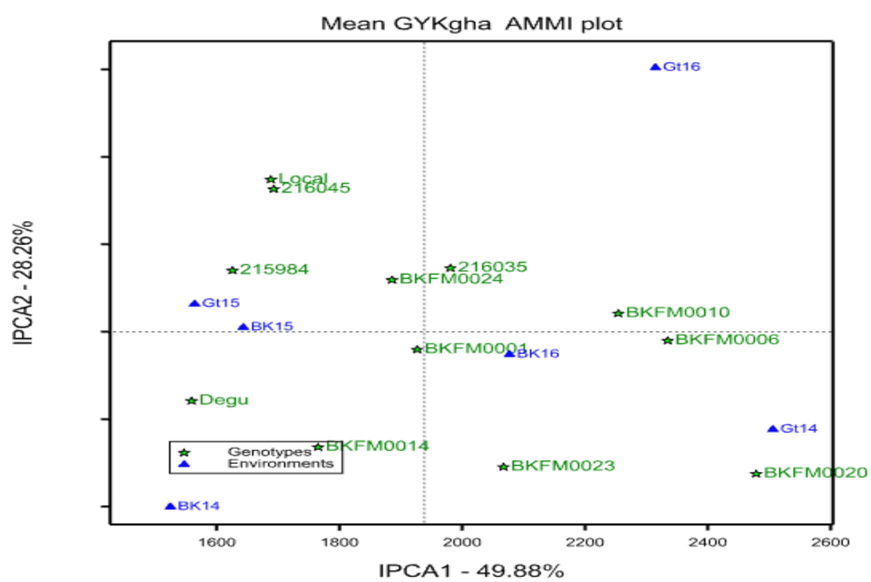

Figure 1. AMMI Biplot showing genotypes grain yield stability and preferential.

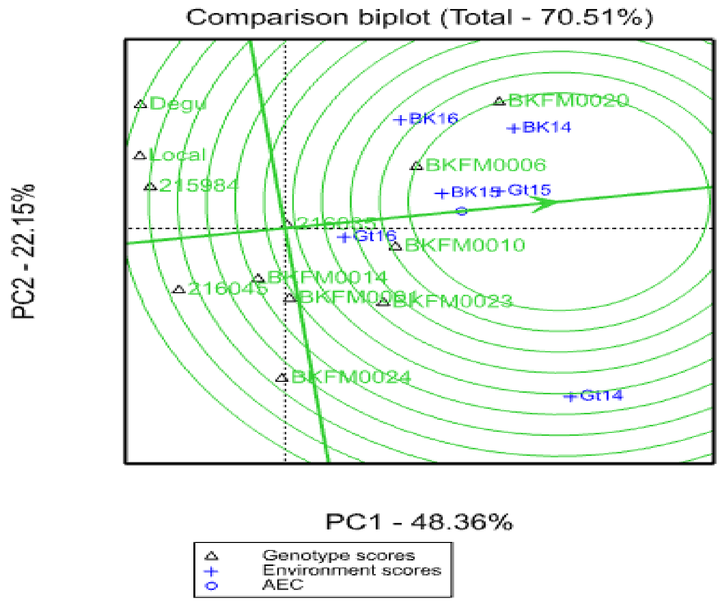

Figure 2. GGE biplot based on grain yield for the 12 genotype showing the relationship among environments.

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