Adaptation of Food Oat (*Avena sativa* L.) Genotypes in Amhara Region, Ethiopia

Misganaw Ferede[1]*, Melle Tilahun[1], Zina Demsie[1], Ermias Abate[2], Molla Mekonnen[1], Gebremariam Asaye[1], Mequanint Andualem[1], Fentanesh Sendekie[1], Desalegn Getaneh[1], Yasin Taye[1], and Sefinew Wale[1]

[1]Adet Agricultural Research Center, ARARI, EIAR, P.O. Box 08, Bahir Dar, Ethiopia
[2]Amhara Agricultural Research Institute, EIAR, P.O. Box 527, Bahir Dar, Ethiopia

Abstract

Background: Oat is one of the soil acidity tolerant crops among cereal crops. In Ethiopia, However, it is mainly cultivated for animal feed using local cultivars with poor agronomic and soil management practices in soil acidity prone areas.

Objective: There are a lot of improved and commercial oat varieties released by European countries that are recommended for both food and feed. Therefore, the study was conducted to identify high-yielding and disease-resistant oat genotypes in acid soil highland areas of Amhara region.

Materials and Methods: The study was conducted at Adet, Banja, Fajie, Farta, Geregera, Sekela, Sekota and Sinan in the Amhara Regional State of Ethiopia. Thirteen introduced food oat genotypes and one local cultivar as a check were used as experimental treatments. The experiment was laid out as a randomized complete block design with three replications.

Results: The combined analysis of variance showed significant ($P \leq 0.05$) differences for grain yield and yield related traits of among genotypes, environments, and their interactions. The combined grain yield performance range was 3904 kg/ha to 3045 kg/ha in food oat genotypes. Food oat genotypes G4, G5, G10, G2, G13, G8 and G12 showed higher interaction to the environmental factors and also higher in grain yielding performance than the remaining tested oat genotypes across the tested environments. Therefore, these genotypes are relatively wider in adaptation across the tested environments. However, food oat genotypes only Goslin (G4) and Souris (G12) were more both widely adaptable and resistance to oat diseases over the local cultivars.

Conclusion: Among the 13 introduced food oat genotypes, Goslin (G4) and Souris (G12) were higher in grain yield performance, with a grain yield advantage of 26.93% and 18.16% and resistance to oat diseases over the local cultivars. Therefore, Food oat genotypes Goslin (G4) and Souris (G12) should be demonstrated and scaled out in soil acidity prone high land areas of Banja, Fajie, Farta, Geregera, Sekela and Sinan districts and in areas with similar agro-ecologies of Ethiopia.

Keywords: Grain yield; Oat diseases; Resistant; Soil acidity

1. Introduction

Oat (*Avena sativa* L.) is an important food crop as oat grain contains high levels of β-glucan, which has been found to decrease serum glucose and cholesterol levels. In addition, the high levels of oil and protein, as well as other beneficial attributes of oat grain, offer advantages for human consumption when compared with other grain cereals (Loader, 1991; Douhlert *et al*., 2001). In proportion to other cereal crops, oat is considered to be better suited for production under marginal environments, including acidity soils and soils with low fertility (Hoffmann, 1995). Currently Russia, Canada, Australia, Finland and USA are the major oat producing countries (FAOSTAT, 2018). However, in Ethiopia, oat is a minor crop grown in cooler highlands.

Oat is remaining an important crop in marginal ecologies, for grain as well as for feed. It is adapted to a wide range of soil types and can perform better than other small-grain cereals on acid soils. Low soil pH and associated soil infertility problems are considered to be amongst the major challenges to acid sensitive crops production. The farmers consider it as healthy food and suitable to human health. The farmers report that the cattle also prefer oat straw to tef straw. This suggests that oat is an ideal crop for mixed farming system of acid soil affected areas as quality food and feed. Currently, there is no any research and development support for oat production in the areas. On the contrary, according to the market assessment information, imported oat is sold for over 65 birr per 500g at supermarkets in urban centers like Bahir Dar, suggesting ample opportunity for oat production, processing and marketing.

Tolerant genotypes are used in rotation with crops such as potato which require acid soil (pH <5.4) so as to control potato scab disease and therefore are best options in areas where application of lime is difficult (Foy *et al*., 1987). Oat is tolerated to Al-toxicity through release of malate from their roots (Radmer *et al*., 2012). These organic acids detoxify Al ion by chelating and forming Al-carboxylate complex which cannot enter the

*Corresponding Author. E-mail: misganaw1129@gmail.com

ISSN 1993-8195 (Online), ISSN 1992-0407(Print)

root system (Kochian *et al*., 2005). Tolerance of oat to acid soil with high exchangeable Al is controlled by dominant genes that allow easy identification and selection of tolerant lines by using simple screening protocols (Nava *et al.,* 2006; Radmer *et al*., 2012).

Major limitations constraining oat production and productivity in the acid soil prone highlands are poor quality and productivity of existing cultivars. On other hand, there are high grain yielding and disease resistant oat genotypes resistant to stress environments out of Ethiopia. Therefore, it was important to introduce and evaluate the high yielding and diseases resistant oat genotypes. The study was conducted with the objective of to identify high yielding and acidic soil tolerant oat genotypes with resistance to economically important disease in soil acidity prone highlands of Amhara region.

2. Materials and Methods

2.1. Description of Experimental Sites, Materials and Procedures

The study was conducted at Adet and Farta (potential areas), Banja, Sinan, Sekela and Fajie (soil acidity prone highland areas), Sekota and Geregera (moisture deficit highland areas) in 2017 cropping season. The experimental environments are depicted in Tables 1 and 2, respectively.

Table 1. The description of agro ecological information of environments.

Environment	Geographical location		
	Altitude (m.a.s.l.)	Latitude	Longitude
Adet	2238	11°16′N	37°29′E
Farta	2706	11°51′N	38°01′E
Sekela	2490	10°51′N	37°08′E
Banja	2560	10°57′N	36°56′E
Sekota	2266	12°38′N	39°02′E
Sinan	2782	10°32′N	37°43′E
Fajie	2840	09°41′N	39°32′E
Geregera	2865	10°68′N	38°68′E

Note: Data organized from Ethiopia Metrological Agency (Bahirdar Branch) and GPS and m.a.s.l = meters above sea level.

Table 2. Soil physio-chemical properties of the study areas.

Location	Soil physico-chemical data						
	PH	Ex. Acidity	Ex. Al	%OC	%N	P ppm	CEC
Banja	5.29	0.25	-	3.01	0.25	23.75	28.91
Farta	5.41	-	-	1.92	0.14	26.96	35.65
Sekela	5.30	0.21	0.00	3.55	0.28	15.64	27.70
Sinan	5.3	1.2	0.09	1.60	-	10.90	-

Note: Data on soil physical and chemical properties were sourced from soil analysis laboratory of Adet Agricultural Research Center.

Thirteen introduced oat genotypes and one local cultivar as check were used as experimental treatments. The trail was laid out in randomized complete block design with three replications. Each genotype was planted on 6 rows with 2.5 m length. Spacing between rows, plots, and replications were 0.2 m, 0.4 m, and 1.5 m, respectively. The gross and net harvestable plot area were 2.5m x 1.2m and 2.5m by 0.8 m respectively. Seed, Nitrogen+Phosphorus+Sulphur (NPS) and Urea fertilizers were used at rates of 100,100 and 50 kg ha^{-1}, respectively. Planting was carried out from end of May to 2nd week of July in 2017 cropping season. All NPS and one third of urea was applied at planting while the remaining two third of urea was top dressed at tillering just after first weeding.

Table 3. Pedigree, origin and growth habit food oat genotypes for the study.

Genotype	Pedigree	Origin	Growth habit
Chaps	Ogle (Brave/unnamed_336)X Unnamed_5458(IL75-5667/Ogle)	Illinois	Spring
Florida501	Florad (Floriland Irradiated/Unknown) X Unnamed_6485(unnamed_6484/Unnamed_6483) -	Florida	Winter
Gem (**X6166-2)**	WI X6051 (MO 07468/unnamed_4882) X Ogle (Brave/unnamed_336)	Wisconsin	Spring
Goslin	OA952-3(OA797-7/02540-3-7-2) X 06196(Pc48/OA952-3)	Ottawa	Spring
Horizon	Ck92Ab719/Horizon314	Florida	Winter
Kangaroo	Unnamed_15143(SV88123-104/WA84Q406) X SV86153_101(unnamed_11891/Unknown)	Australia	Winter
Noble-2	Noble(Tippecanoe/unnamed_10546) X Noble(Tippecanoe/unnamed_10546)	Minnesota	Spring
OA600-32	NA	NA	NA
OA602-4	NA	NA	NA
Pusa hybrid G	Unknown	India	Unknown
Souris(ND961161)	ND90141(ND894904/ND852107) X ND900118(MN78142/ND852158)	North Dakota	Spring
TAM 0-397	re-selection from TAMO- 386(TAMO-386/TAMO -386) X reselection from TAMO-386(TAMO-386/TAMO-386)	Texas	Winter
UFRGS930605	Unknown	Brazil	Winter
Local		Ethiopian cultivar	

NA = Not available.

2.2. Data Collection and Statistical Analyses

Data were collected on days to physiological maturity, plant height, panicle length, number of seeds per spike, thousand seed weight, straw yield, grain yield and disease severity and reaction of the varieties. Data on days to physiological maturity was collected at 75% of the harvestable plot area become physiologically mature. The agronomic traits, namely, plant height, panicle length, and number of seeds per panicle data were collected from randomly selected 5 plants per plot whereas straw yield and grain yield data were collected on the harvestable plot area per plot across environments. Thousand seed weight was measured from the randomly taken thousand seed in each plot counted by electronic seed counter.

The oat rust diseases severity scoring was done based on Cobb modified scoring method (Peterson *et al.,* 1948). The oat rust and scab diseases varietal reaction/response scoring was done based on Cobb modified scale (Stakman *et al.,* 1962). Oat leaf blotch was scored based on modified version of Saari and Prescott's scale of two digits scoring system (00-99: the 1st digit is appearance of disease on plant height whereas the 2nd digit represents the severity % of the disease) (Saari and Prescott, 1975). The data were analyzed using GenStat statistical software (17thedn). The AMMI analysis of variance summarizes most of the magnitude of genotype by environment interactions into one or a few interaction principal component axes (IPCA) (Crossa, 1990). Least significant difference (LSD) method (P≤0.05) was used for mean separation among genotypes.

3. Results and Discussion

3.1. Analysis of Variance of Grain Yield and Yield Related Traits of Food Oat Genotypes

The combined analysis of variance of varieties, environments and their interactions showed the presence of significant (P≤0.05) difference among varieties for days to maturity, plant height, panicle length, and number of seeds per panicle, thousand seed weight, straw dry biomass and grain yield (Table 4). The higher variation due to the main effect of varieties on panicle length was 71.08 % followed by plant height (57.05 %) and thousand seed weight (51.52 %) and whereas the higher variation expressed by environment main effect on straw dry biomass was 87.83% followed by number of seeds per panicle (70.39%) and grain yield (69.04) in food oat genotypes. The findings of this study were in line with as Atefah and Sohbat (2012) reported in oat genotypes. In addition, the variation accounted by the interaction of genotypes by environments on thousand seed weight was (39.39%) followed by straw dry biomass and grain yield were 24.86 % and 24.54%, respectively. According to Atefah and Sohbat (2012) and Mushtag *et al.* (2013) report, higher variations on grain yield and number of seeds per panicle response was accounted by environment main effects where as higher variations on plant height and thousand seed weight was accounted by genotype main effects and higher variations scored on straw yield due to the interaction of genotypes by environments.

Table 4. The AMMI analysis of variances accounted by genotypes, environments and their interaction of food oat varieties across environments.

Trait	Gen SS	Env SS	G*E SS	IPCA1	IPCA2	Error SS	% SS Gen	% SS Env	% SS G*E
DM	16470	160641	7125	3894**	1297**	2760	8.94	87.19	3.87
PH	108777	72261	9642	4649**	2125**	7992	57.05	37.89	5.06
PL	4872	1026	956	454**	234 ns	1629	71.08	14.97	13.95
NSPP	20553	92299	18258	13289**	2718 ns	13996	15.68	70.39	13.93
TSW	5724	1028	4359	3365**	433*	1814	51.52	9.25	39.23
SDM	18365	15546	11186	5605**	5134**	8667	40.83	34.31	24.86
GY	1436	15433	5485	1595**	1443**	3611	6.42	69.04	24.54

*Note: DM = Days to physiological maturity; PH = plant height; PL = panicle length; NSPP = Number of seed per panicle; TSW = Thousand seed weight; SDM = Straw dry biomass; GY = Grain yield; ** = Significant at 0.01; Gen = Genotype; Env = Environments; Gen*Env = Genotype by environment interactions; IPCA = Interaction principal component axis; DF = Degree of freedom; SS = Sum squares; VR = Variance ratio and F Pr = F-Probability.*

3.2. Performance of Grain Yield and Yield Related Traits of Food Oat Genotypes

The performance of yield related traits of food oat genotypes are depicted in Table 5. The maturity time of food oat genotypes range was from 138.1 and 138.2 days for the genotypes Horizon and UFRGS930605, respectively and 164.2 days for the genotype kangaroo across environments. The plant height in oat genotypes varies 89.2 cm to 153.1 cm for the genotypes UFRGS930605 and OA602-4 respectively. The panicle length in oat genotypes varies 15.7 cm to 29.1 cm for UFRGS930605 and Chaps, respectively. The studies reported by Amanuel *et al.* (2019), Dawit and Mulusew (2017), Mushtag (2013), Yasemin (2012) and Nehvi *et al.*(2007) the analysis of variances showed significant differences in oat genotypes. Here, in the study, the performance of yield related traits were varied in oat genotypes as per the tested materials, environments and their interactions.

As showed in Table 6, analysis of variances of grain yield performance showed significant ($P \leq 0.05$) differences for genotypes, environments and their interactions. The combined grain yield performance range was 3904 to 3045 kg ha^{-1} in food oat genotypes. As Amanuel *et al.* (2019), Zeki *et al.* (2018), Dawit and Muluse (2017), Atefah and Sohbat (2012) and Yasemin (2012) and Nehvi *et al.* (2007) studies the grain yield performance was different in the oat genotypes across environments. As a result, the performance of grain yield and yield related traits of oat genotypes were significantly affected by the main genetic, environmental and interaction of genotype by environment effects.

Table 5. The phenological and agronomic traits response of food oat genotypes across environments.

Genotype	Trait					
	DM	PH (cm)	PL (cm)	NSPP	TSW (g)	SDM (kg ha^{-1})
Chaps(G1)	155.9	129.4	29.1	76.9	34.1	6620
Florida501(G2)	148.7	120.4	21.0	57.6	37.9	4900
Gem(G3)	156.8	122.0	18.7	58.4	35.5	6210
Goslin(G4)	150.3	127.5	23.3	79.9	38.7	5690
Horizon(G5)	138.1	103.1	20.6	58.0	32.2	3170
Kangaroo(G6)	164.2	126.9	23.0	51.8	40.2	4670
Local(G7)	156.9	146.7	27.8	78.4	33.5	5870
Noble-2(G8)	150.1	137.9	25.0	74.0	40.9	5190
OA600-32(G9)	153.4	149.6	27.7	76.5	39.4	6570
OA602-4(G10)	155.2	153.1	28.1	66.3	43.6	5300
PusaHybridG (G11)	147.0	117.9	20.5	60.1	29.6	4560
Souris(G12)	150.0	115.4	23.5	75.0	33.3	5250
TAM 0-397(G13)	145.7	103.8	23.7	55.1	36.3	4210
UFRGS930605(G14)	138.2	89.2	15.7	60.1	29.5	2810
Mean	150.8	124.5	23.4	66.3	36.0	5070
CV(%)	2.6	5.8	12.7	20.2	8.7	22.3
LSD(5%)	6.2	11.6	4.8	21.8	5.1	1840
Gen	**	**	**	**	**	**
Env	**	**	**	**	**	**
Gen*Env	**	*	**	**	**	**

*Note: DM = Days to physiological maturity; PH = Plant height; PL = Panicle length; NSPP = Number of seed per panicle; TSW = Thousand seed weight; SDM = Straw dry biomass; ** = Significant at 0.01; Gen = Genotype; Env = Environments and Gen*Env = Genotype by environment interactions.*

Table 6. The grain yield (kg ha^{-1}) performance of the food oat genotypes across environments.

Genotype	Environment								Mean grain yield	Yield advantage over local (%)
	Adet	Farta	Sekela	Banja	Sekota	Sinan	Fajie	Geregera		
Chaps	5101^{a}	4935^{ab}	4012^{abcd}	2583^{abcd}	3665^{abc}	2551^{d}	3132^{cd}	2510^{abc}	3565^{abcd}	17.08
Florida501	4682^{ab}	4082^{bcd}	3386^{def}	2644^{abcd}	3684^{abc}	4037^{a}	4806^{a}	2877^{a}	3768^{ab}	23.74
Gem	3625^{cd}	4066^{bcd}	3115^{f}	2660^{abcd}	3103^{cdef}	2853^{cd}	3551^{bcd}	2275^{bc}	3155^{de}	3.61
Goslin	4142^{bcd}	5075^{a}	4064^{abcd}	3026^{a}	4134^{ab}	4180^{a}	3717^{bcd}	2655^{ab}	3865^{a}	26.93
Horizon	4413^{ab}	3929^{cd}	4198^{abc}	2900^{ab}	4235^{a}	3815^{ab}	4913^{a}	2831^{a}	3904^{a}	28.21
kangaroo	2906^{e}	4232^{abcd}	4487^{ab}	2677^{abcd}	2895^{cdef}	3011^{bcd}	3465^{bcd}	2757^{ab}	3307^{bcde}	8.60
Local	4095^{bcd}	3664^{d}	3780^{bcdef}	2420^{bcd}	2795^{def}	3717^{abc}	1401^{e}	2537^{abc}	3045^{e}	–
Noble-2	4191^{bc}	4409^{abcd}	4555^{a}	2612^{abcd}	3318^{cdef}	3956^{a}	4167^{ab}	2774^{a}	3748^{ab}	23.09
OA600-32	4975^{a}	4216^{abcd}	3201^{ef}	2162^{d}	2527^{f}	3531^{abc}	2879^{d}	2545^{abc}	3255^{cde}	6.90
OA602-4	4263^{bc}	4664^{abc}	3756^{bcdef}	2991^{ab}	3372^{bcde}	4162^{a}	3070^{d}	2902^{a}	3647^{abc}	19.77
Push hybrid-G	4245^{bc}	3579^{d}	4032^{abcde}	2206^{cd}	2737^{ef}	4228^{a}	4115^{abc}	2061^{c}	3401^{bcde}	11.69
Souris	4053^{bcd}	3907^{cd}	4403^{ab}	2841^{ab}	3290^{cdef}	4011^{a}	3656^{bcd}	2615^{ab}	3598^{abcd}	18.16
TAM 0-397	4079^{bcd}	4196^{abcd}	3503^{cdef}	2757^{abc}	3567^{abcd}	3768^{ab}	3376^{bcd}	2975^{a}	3528^{abcde}	15.86
UFRGS930605	3473^{de}	4208^{abcd}	3892^{abcde}	2671^{abcd}	2693^{ef}	3361^{abcd}	4362^{ab}	2912^{a}	3447^{bcde}	13.20
Mean	4160	4230	3880	2650	3290	3660	3620	2660	3520	
CV(%)	10.1	12.9	11.8	12.9	14.3	14.4	16.4	11.1	13.6	
LSD(5%)	710	912	770	579	796	884	994	497	769	

3.3. AMMI and GGE Biplot Analysis of Grain Yield of Oat Genotypes

The oat genotypes Gem (G3), Local (G7), Pusa Hybrid G (G11) and OA602-4 (G10) of the grain yield performance were weakly influenced by environmental factors (lower interaction effects). The genotypes Kangaroo (G6), OA600-32 (G),Chaps (G1), Florida501 (G2), Goslin (G4), Horizon (G5), Noble-2 (G8), Souris (G12), TAM 0-397 (13) and UFRGS930605 (G14) of gain yield performance were strongly affected by environmental factors(higher interaction effects) as showed in Figure 1. However, the genotypes were less sensitive to environmental factors may not be higher in grain yield response. As Crossa (1990), Zobel *et al.* (1988) and Voltas (2002) reported that genotypes near the origin/center of the biplot are not sensitive to environmental interaction, whereas genotypes distant from the origin of the biplot are sensitive and have large interaction effects. In addition, according to Yan *et al.* (2000) ideal genotypes are those having large PC1 scores (wider in adaptable) and small absolute PC2 scores (high stability). In figure 1, the environments Adet and Fajie followed by Sekela were discriminated the genotypes grain yield performance than Farta, Banja, Sekota, Sinan and Geregera. As Akter *et al.* (2014) report environments with short spokes exert small interactive forces, whereas environments with long spokes exert strong interaction on the performance of oat genotypes.

Among oat genotypes, Goslin (G4) was ideal which was nearest to the concentric circle of the biplot. In addition to G4, the genotypes G10, G5, G13, G8, G2, G1, G12 and G14 which were more adaptable and stable across the tested environments. While the genotypes G11, G9, G7, G3 and G6 were far from the concentric circle of biplot compared to the ideal genotype Goslin (Figure 2). The genotypes closest to the ideal genotype drawn on the center of concentric and/or average environmental coordinate (AEC) are highest yielder (Zerihun, 2011 and Yan *et al.*, 2002).

In the consideration of AMMI and GGE biplot analysis of oat genotype based on the grain yield performance, Genotypes G4, G5, G10, G2, G13, G8 and G12 showed higher interaction to the environmental factors and also higher in grain yielding than the remaining tested oat genotypes across the tested environments. Therefore, these genotypes are relatively wider in adaption across the tested environments.

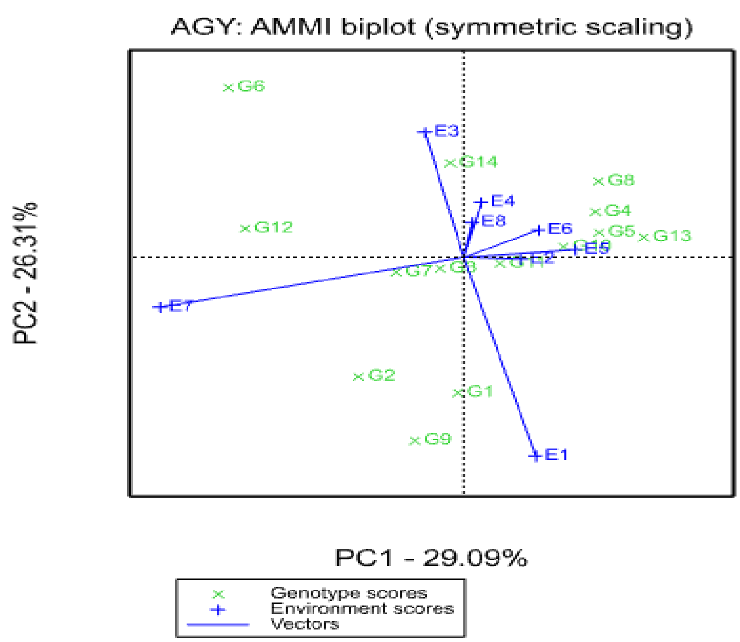

Figure 1. Graphics of AMMI biplot of grain yield of oat genotypes using symmetrical scaling of both genotypes and environments (E1=Adet,E2 = Farta, E3 = Sekela, E4 = Banja, E5 = Sekota, E6 = Sinan, E7 = Fajie, E8 = Geregera, G1 = Chaps, G2 = Florida501, G3 = Gem, G4 = Goslin, G5 = Horizon, G6 = Kangaroo, G7 = Local, G8 = Noble-2, G9 = OA600-32, G10 = OA602-4, G11 = Pusa Hybrid G, G12 = Souris, G13 = TAM 0-397, G14 = UFRGS930605, IPCA = Interaction principal component axis and AGY = Adjusted grain yield).

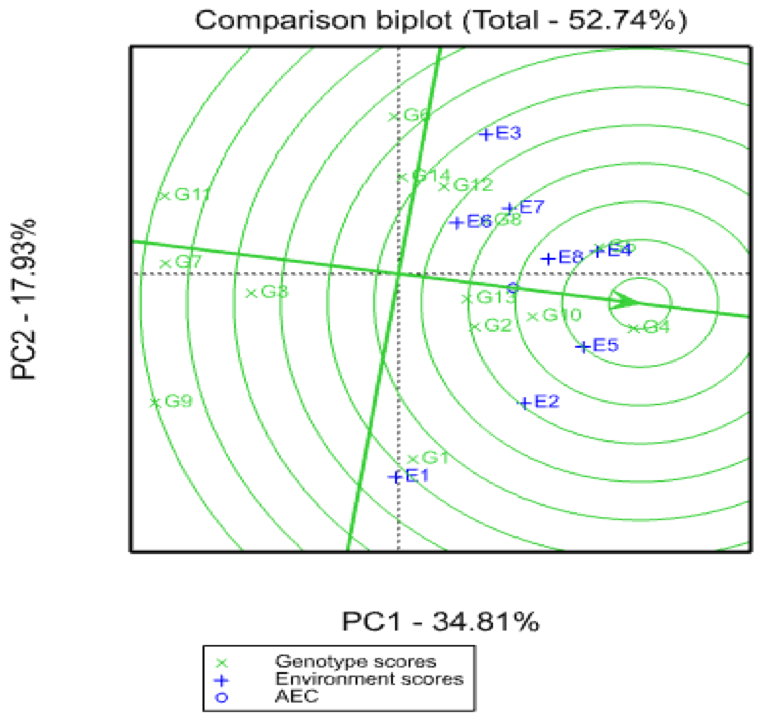

Figure 2. Graphics of GGE biplot of grain yield of oat genotypes using comparison biplot, genotype method and scaling (E1 = Adet, E2 = Farta, E3 = Sekela, E4 = Banja, E5 = Sekota, E6 = Sinan, E7 = Faji, E8 = Geregera, G1 = Chaps, G2 = Florida501, G3 = Gem, G4 = Goslin, G5 = Horizon, G6 = Kangaroo, G7 = Local, G8 = Noble-2, G9 = OA600-32, G10 = OA602-4, G11= Pusa Hybrid G, G12 = Souris, G13 = TAM 0-397, G14 = UFRGS930605, PC = Principal component and AEC = Average environmental coordinate).

3.3. Disease Severity and Reaction of Food Oat Genotypes

The food oat diseases such as scald, net blotch and rust (stem and crown) were recorded according to Cob modified scoring method. The oat genotypic responses were resistant to scald and net blotch except Horizon (84) which is categorized under moderately resistant. The response of the genotypes to stem and crown rusts were varied in severity scores (0-90%) and their reaction. Among 14 tested oat genotypes G3, G4, G9, G10, G12, G13 and G14 were resistant to stem rust whereas G6 was moderately resistant and genotypesG1, G2, G5, G7, G8, and G11 were susceptible to stem rust. On the other hand, genotypes G1, G2, G3, G4, G5, G6, G8, G12 and G14 were resistant to crown rust while genotypes G7, G9, G10, G11 and G13 were susceptible to crown rust (Table 7). The studies illustrated that oat rusts, blotch and scald could cause economical yield losses when the oat genotypes are susceptible to oat diseases (Paul, 2019 and Bowen *et al*., 2016).

Table 7. Diseases severity and reactions of food oat genotypes.

Genotype	Disease severity and reaction			
	Scald (1-5)	Net blotch (00-99)	CR	SR
Chaps(G1)	1	R	R	60S
Florida501(G2)	1	R	R	90S
Gem(G3)	1	R	R	TrR
Goslin(G4)	1	82	R	R
Horizon(G5)	1	84	R	R
Kangaroo(G6)	1	R	R	10MR
Local(G7)	1	R	85S	80S
Noble-2(G8)	1	R	R	60S
OA600-32(G9)	1	R	20MR	TrR
OA602-4(G10)	1	31	85S	R
PusaHybrid G (G11)	1	R	80S	80S
Souris(G12)	1	R	TrR	R
TAM 0-397(G13)	1	R	40MS	TrR
UFRGS930605(G14)	1	R	R	R

Note: LR = Stem rust; CR = Crown rust; TrR = Trace and Resistant; MS = Moderately susceptible; MR = Moderately resistant; R = Resistant and S = Susceptible.

4. Conclusion

The analysis of variance showed significant (P≤0.05) differences for grain yield and yield related traits in genotypes, environments and their interactions. The performance of grain yield and yield related traits of food oat genotypes were significantly affected by the main genetic, environmental and genotype by environment interaction effects. The source of variation for grain yield in food oat genotypes accounted by environments, genotype by environment interactions and genotypes were accounts 69.04%, 24.54% and 6.42%, respectively. Among 13 introduced food oat genotypes, Goslin and Souris were wider in adaptation, higher in grain yield and resistant to crown and stem rust which showed 26.93% and 18.16% grain yield advantage over local variety across tested environments. In the study the genotypes Horizon, Florida501, OA602-4 and Naval-2 showed no significant difference with Souris in grain yield performance, however susceptible to crown and stem rusts. Therefore, oat genotypes Goslin and Souris should be demonstrated and scaled out in soil acidity problem areas of Banja, Fajie, Farta, Geregera, Sekela and Sinan districts and in areas with similar agro-ecologies of Ethiopia.

5. Acknowledgements

The authors acknowledge Adet Agricultural Research Center, Amhara Agricultural Research Institute and Dr. Higgns project based in Ethiopian Sustainable Food Project for the financial aid as well as technical support. The acknowledgment is also extended to all who actively participated in the research work from the beginning to the end.

6. References

Akter, A., Hassen, J.M., Kulsum, U.M., Islam, M.R., Hossain, K. and Rahman, M.M. 2014. AMMI biplot analysis for stability of grain yield in hybrid rice (*Oryza sativa* L.). *Journal of Rice Research*, 2(2): 1–4.

Amanuel Wada, Kassa Shawle and Deribe Gemiyo. 2019. Biomass yield and nutritional quality of different oat genotypes (*Avena sativa*) grown under irrigation condition in Sodo Zuriya District, Wolaita Zone, *Ethiopia. Agricultural Research and Technology*, 20(4): 197–204.

Atefah Zaheri and Sohbat Bahraminejad. 2012. Assessment of drought tolerance in oat (Avenasativa) genotypes. *Annals of Biological Research*, 3 (5): 2194–2201.

Bowen, K.L., Hagen, A.K., Pegues, M. and Jones, J. 2016. Yield losses due to crown rust in winter oat in Alabama. *Plant Health Research*, 17(2): 95–100.

Butler-Stoney, T.R. and Valentine, J. 1991. Exploitation of the genetic potential of oats for use in feed and human nutrition. Home-Grown Cereals Authority, London, UK. Pp. 45–56.

Crossa, J. 1990. Statistical analysis of multi-location trials. *Advances in Agronomy*, 44: 55–85.

Dawit Abate and Mulusew Fikere. 2017. Performance of fodder oat (*Avena sativa* L.) genotypes for yield and yield attributes in the Highland of Bale. *Journal of Biology, Agriculture and Healthcare*, 7(19): 29–33.

Doehlert, D.C., McMullen M.S. and Hammond J.J. 2001. Genotypic and environmental effects on grain yield and quality of oat grown in North Dakota. *Crop Science*, 41: 1066–1072.

FAOSTAT. 2018. FAOSTAT-Crops/GHDx. www.fao.org/faostat/en/#data/QC. Accessed on October, 2019).

Foy, C.D. and Murray, J.J. 1998. Developing aluminium-tolerant strains of tall fescue for acid soils. *Journal of Plant Nutrition,* 21(13): 1–25.

Hoffmann, L.A. 1995. World production and use of oats. Pp. 34–61. *In*: Welch, R.W. (ed.). *The Oat*

Crop-Production and Utilization. Chapman and Hall, London.

Kochian, L., Piñeros, M. and Hoekenga, O. 2005. The physiology, genetics and molecular biology of plant aluminum resistance and toxicity. *Plant and Soil*, 274: 175–95.

Lange, C.J. 2012. Reaction of North American oats (*Avena sativa* L.) to crown rust. MSc Thesis, Texas A and M University, United states.

Mushtag, A., Gul, Z., Razvi, S.M., Mir, S.D. and Rather, M.A. 2013. Stability properties of certain oats (*Avena sativa*.L) genotypes for major grain yielding characteristics. *International Journal of Plant Breeding and Genetics*, 7(3): 182–187.

Nava, I.C., Carla, A.D., Ismael, T.L.D., Marcelo, T.P. and Luiz, C.F. 2006. Inheritance of aluminum tolerance and its effects on grain yield and grain quality inoats (*Avena sativa* L.). *Euphytica*, 148: 353–58. DOI:10.1007/s10681-005-9048-5.

Nehvi, F.A., Wani, S.A., Hussain, A., Maghdoom, M.I., Allai, B.A., Yousuf, W., et al. 2007. Stability analysis for yield and yield related traits in fodder oat (*Avena sativa* L). *Asian Journal of Plant Science,* 6(4): 628–632.

Paul, M.N. 2019. Cereal disease laboratory, Agricultural research service. https://www.ars.usda.gov/midwestarea/stpaul/cereal-disease-lab/docs/cerealrusts/oat-crown-rust/. Accessed on 6 October 2019.

Peterson, R.F., Campbell, A.B. and Hannah, A.E. 1948. A diagrammatic scale for estimating rust intensity on leaves and stems of cereals. *Canadian Journal of Research,* 26: 496–500.

Radmer, L., Tesfaye, M., Somers, D.A., Temple, S.J., Vance, C.P. and Samac, D.A. 2012. Aluminum resistance mechanisms in oat (*Avena sativa* L.). *Plant Soil*, 351: 121–34. DOI 10.1007/s11104-011-0937-1.

Saari, E.E. and Prescott, L.M.A. 1975. Scale for appraising the foliar intensity of wheat diseases. *Plant Disease Report*, 59: 377–380.

Stakman, E.C., Stewart, D.M. and Loegering, W.Q. 1962. Identification of physiologic races of *Puccinia graminis* var. *tritici*. Agricultural Service, United States Department of Agriculture. Pp. 1–54.

Voltas, J., Van, E.F., Igartua, E., García del Moral, L. F.,Molina-Cano, J.L. and Romagosa, I. 2002. Genotype by environment interaction and adaptation in barley breeding: Basic concepts and methods of analysis. Pp. 205–241. *In*: Slafer, G.A., Molina-Cano, J.L., Savin, R., Araus, J.L. and Romagosa, I. (eds.). *Barley Science: Recent Advances from Molecular Biology to Agronomy of Yield and Quality*. The Harworth Press Inc., New York.

Yan, W., Hunt, L.A., Sheng, Q. and Szlavnics, Z. 2000. Cultivar evaluation and mega-environment investigation based on the GGE biplot. *Crop Science*, 40: 597–605.

Yan, W. and Rajcan, I. 2002. Biplot analysis of test sites and trait relations of soybean in Ontario. *Crop Science*, 42: 11–20.

Yasemin, H., Rukiye, K. and Tevrican, D. 2012. Evaluation of oat (*Avena sativa* L.) genotypes for grain yield and physiological traits. *Agriculture*, 99(1): 55–60.

Zerihun, J. 2011. GGE-biplot Analysis of Multi-environment Yield Trials of Barley (*Hordeium vulgare* L.) Genotypes in Southeastern Ethiopia Highlands. *International Journal of Plant Breeding and Genetics*, 5(1): 59–75.

Zobel, R.W., Wright, M.J and Gauch, H.G. 1988. Statistical analysis of a yield trial. *Agronomy Journal*, 80: 388–393.