Disease Reaction and Seed Yield Stability of Advanced Lentil Genotypes in Bale Highlands

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Abstract

Twelve lentil genotypes were evaluated for their reaction to diseases (rust and Ascochyta blight) and seed yield stability together with two commercial varieties (Chalew and Ada'a) and the local cultivar (Bale), at Sinana, Lower Dinsho and Agarfa in Bale Zone of Oromiya Region during the 'bona' crop season (July–December) from 1999 to 2001. All the genotypes and varieties showed resistant reaction to rust and resistant-to-moderately-susceptible reaction to Ascochyta blight. Whereas, the local cultivar was susceptible to rust and moderately susceptible to Ascochyta blight. There was highly significant variation among environments (E) and genotypes (G) in seed yield. G x E interaction was also highly significant. Eight of the genotypes and Ada'a were stable in seed yield over environments. There was significant ($p < 0.01$) negative association of seed yield with rust (r-0.739) and Ascochyta blight (r-0.642) severity. There was also strong and highly significant linear association between yield stability parameters and disease reaction. This indicated that variation of disease severity over different environments on a particular genotype/variety might be one of the major factors for seed yield instability.

Key words: lentil, disease reaction, yield stability, Bale Highlands (Ethiopia)

Introduction

Two types of lentil are cultivated in the world. These are the *macrosperma* which is large-seeded and the *microsperma* which is small-seeded. The large-seeded lentil is generally late-maturing than the small-seeded one. Of the two types, the small-seeded and early-set lentil is largely cultivated in Ethiopia (Geletu and Yadeta 1994).

Ethiopia is one of the major lentil (*Lens culinaris* Medik.) producing countries in the world (Erskine 1985) and the first in Africa (FAO 2001). The crop occupies about 60,138 ha of land with a corresponding gross annual production of 38,430 t. About 2% of the total acreage is found in Bale Zone, Oromiya Region (CSA 2001). In Bale Zone, lentil occupies nearly 6% of the total area covered by pulses. The zonal average seed yield of the crop is about 0.39 t/ha, almost half of the national average, i.e. 0.64 t/ha (CSA 2001).

In Ethiopia, lentil is an important multipurpose pulse crop. It is a major cash crop that fetches the highest price in domestic market than all other food legumes and cereals. It is also an important export crop. In addition, lentil plays a major role in the daily diet of the people. It contains and provides a high content of protein reported to be in the range of 23–24% (Addise and Asfaw 1993). Lentil corrects important amino acid deficiencies in cereals when used in mixture with tef, wheat and barley. The by-product of lentil also provides nutritious feed for livestock.

In addition, lentil is an important component in the Ethiopian farming system. It helps to improve soil fertility through biological nitrogen fixation. Hence, it reduces the dependency of the major cereal crops like wheat, barley and/or tef on nitrogenous fertilizers in the cropping systems.

Although lentil plays important role in the country's agriculture, its average seed yield has remained very low in Bale Zone. The major reasons are the susceptibility of lentil landraces to an array of diseases, the inherently low yield potential of the landraces and poor management practices.

Diseases, particularly wilt/root rot, rust and Ascochyta blight, are the major constraints that cause substantial yield loss and instability in yield (ICARDA 2000). Rust (*Uromyces fabae*) and Ascochyta blight (*Ascochyta lentis*) cause severe damage to the local landraces. Rust can cause complete yield loss in the local cultivar during favorable seasons in the Bale Highlands. Geletu and Yadeta (1994) identified rust as the most important disease of lentil in Ethiopia that causes yield loss when it occurs before flowering and podding stages.

Therefore, breeding for disease resistant cultivars with high and stable seed yield is importnat. Singh and Chaudhary (1977) indicated that stability in yield performance is one of the most desirable properties of a genotype to be released as a variety for wide cultivation. Therefore, the present study was made to evaluate some advanced lentil genotypes for reaction to rust and Ascochyta blight and their seed yield stability over nine environments. Moreover, the study assessed the effect of disease severity on seed yield stability.

Materials and Methods

The experiment was made at Sinana, Lower Dinsho and Agarfa areas in Bale Zone, Oromiya Regional State, during the *bona* crop season (July–December) during 1999–2001. Sinana is found at an altitude of 2400 m. The range of mean annual rainfall for the last 13 years (1990–2002) was 563–1018 mm. The area has a minimum temperature of 7.9 ^{0}C and a maximum temperature of 24.3 ^{0}C. The soil is dark-brown with slightly acidic reaction (Geremew et al. 1998). Lower Dinsho is located at an altitude of 2400 m and Agarafa at 2440 m. The study areas represent the Highlands of Bale Zone.

Twelve lentil genotypes were evaluated together with two commercial varieties (Chalew and Ada'a) and Bale local cultivar. The experiment was laid out in a completely randomized block design with four replications. Plots consisting of 4 rows with a spacing of 0.2 m wide and and 4 m long were used. The net harvested area was 1.6 m^2 consisting of the two central rows from which seed yield converted to t/ha was used for the analysis.

Planting was done in late August at Sinana and Lower Dinsho and late July at Agarfa. A seed rate of 65 kg/ha was used without fertilizer application at all locations. Hand-weeding was done once just before flowering. Rust and Ascochyta blight occurred ring under natural condition. The data on the reaction of the lentil genotypes, commercial varieties and the local cultivar to each of rust and Asscochyta blight were collected. Disease severity was measured based on a 1–9 scale, where 1 stands for immune, 2 highly resistant, 3 resistant, 4 moderately resistant, 5 moderate, 6 moderately susceptible, 7 susceptible, and 8 and 9 highly susceptible.

Analysis of variance was computed using the MSTATC computer software. The genotypes by environment analysis of variance and stability parameters, i.e. linear regression coefficient (b_i) and standard deviation from regression (S_{di}^2) of genotypes measured over environmental index were computed using Eberhart and Russell's Model (1966).

The linear association between the linear regression and correlation between seed yield and environmental index were computed. The linear correlation between the diseases (rust and Ascochyta blight) and seed yield over individual environment and among mean seed yield and stability parameters were also computed.

Table 1. Average rust severity of 15 genotypes evaluated in 9 environments during bona season in Bale Highlands, 1999–2001

Genotype/Variety	Severity (1–9 scale)*									Mean
	1999/00			2000/01			2001/02			
	Sina†	L. Din	Agar	Sina	L. Din	Agar	Sina	L. Din	Agar	
FLIP-86-38L	1	1	3	2	1	1	3	3	1	2
FLIP-86-51L	1	1	4	1	1	1	3	1	2	2
FLIP-87-19L	1	1	4	2	1	2	2	1	1	2
FLIP-87-66L	1	2	3	2	1	1	1	2	1	2
FLIP-87-70L	1	2	2	1	1	2	2	2	2	2
FLIP-88-46L	1	1	2	2	1	1	2	1	2	2
ILL 590	2	1	3	1	1	1	3	2	1	2
PRECOZE-7/92-DZ/Z	1	1	2	1	1	1	2	2	2	1
FLIP-95-41L	2	2	2	2	1	1	1	1	2	1
NEL-358 x PGRC/E211126/92DZ/2	1	1	2	1	1	1	2	1	2	1
FLIP-92-52L	1	1	3	2	1	2	2	1	2	2
FLIP-86-16L	1	1	2	2	1	1	2	1	2	2
Ada'a	1	2	3	1	1	1	1	1	2	2
Chalew	2	2	2	1	1	2	1	1	1	1
Local cultivar	2	7	7	3	1	5	7	5	2	4
Mean	1	2	3	2	1	2	2	2	2	2
SE	0.1	0.2	1.8	0.1	0.0	0.2	0.2	0.1	0.1	0.1

where, 1 = immune; 2 = highly resistant; 3 = resistant; 4 = moderately resistant; 5 = resistant; 6 = moderately susceptible; 7 = susceptible; and 8 and 9 = highly susceptible
†Sina, Sinana; L. Din, Lower Dinsho; and Agar, Agarfa

Results

Disease reactions

Variable disease (rust and Ascochyta blight) severity scores were recorded for all genotypes in different environments. Except the local cultivar which exhibited resistant to susceptible (1–7) reactions, all the 11 genotypes showed resistant (1–3) reactions to rust over different environments. On the other hand, all of the genotypes including the local check showed resistant-to-moderately-susceptible (1–5) reactions to Ascochyta blight over different environments. Rust severity was higher on the local cultivar than others (tables 1 and 2).

Seed yield stability

The highest mean seed yield was recorded for PRECOZE-7/92-DZ/Z (2.48 t/ha) and the lowest for the local cultivar (1.16 t/ha) (Table 3). Analysis of data from individual locations revealed highly significant ($p < 0.01$) variation among genotypes for their seed yield (Table 4). From the combined analysis of variance, the G x E interaction, the variation between environments and between genotypes was highly significant.

From the stability analysis of variance, FLIP-86-38L, FLIP-86-51L, FLIP-87-19L, FLIP-87-66L, FLIP-87-70L, FLIP-88-46L (Assano), FLIP-95-41L, NEL-358xPGRC/E211126/92DZ/2, ILL-590, FLIP-92-52L, FLIP-86-16L, and Ada'a had non-significant ($p \leq 0.05$) deviation from their linear regression line. FLIP-86-38L, FLIP-87-19L, FLIP-87-66L, FLIP-87-70L, FLIP-88-46L (Assano), PRECOZE-7/92-DZ/Z, FLIP-95-41L, NEL-358xPGRC/E211126/92DZ/2, ILL-590, FLIP-86-16L, and Ada'a had a regression coefficient closer to unity (Table 5).

Table 2. Average Ascochyta blight severity of 15 lentil genotypes evaluated in 9 environments in Bale Highlands, 1999 – 2001

Genotype/Variety	Severity (1–9 scale)*									Mean
	1999/00			2000/01			2001/02			
	Sina[†]	L. Din	Agar	Sina	L. Din	Agar	Sina	L. Din	Agar	
FLIP-86-38L	5	3	3	3	5	3	2	3	2	3
FLIP-86-51L	4	2	3	3	5	1	3	2	2	3
FLIP-87-19L	4	2	3	3	5	2	2	3	2	3
FLIP-87-66L	5	2	3	2	5	2	1	3	2	3
FLIP-87-70L	3	3	3	2	5	2	2	3	2	3
FLIP-88-46L	4	2	2	3	5	2	3	3	2	3
ILL 590	5	2	3	2	5	3	2	3	2	3
PRECOZE-7/92-DZ/Z	4	1	3	2	5	2	2	3	2	3
FLIP-95-41L	5	2	3	1	5	1	2	3	2	3
NEL-358 x PGRC/E211126/92DZ/2	4	2	2	3	5	1	2	3	2	3
FLIP-92-52L	3	2	2	2	5	2	2	2	2	2
FLIP-86-16L	3	3	3	3	5	1	3	2	2	3
Ada'a	4	2	2	3	5	1	1	3	2	3
Chalew	4	2	2	2	5	2	1	3	2	2
Bale local	6	5	5	2	4	4	1	4	3	4
Mean	4	2	3	2	5	2	2	3	2	3
SE	0.2	0.1	1.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1

where, 1 = immune; 2 = highly resistant; 3 = resistant; 4 = moderately resistant; 5 = resistant; 6 = moderately susceptible; 7 = susceptible; and 8 and 9 = highly susceptible
[†]Sina, Sinana; L. Din, Lower Dinsho; and Agar, Agarfa

Table 3. Mean seed yield of 15 lentil genotypes evaluated in 9 environments in Bale Highlands, 1999–2001

Genotype/Variety	Yield (t/ha)									Mean
	1999/00			2000/01			2001/02			
	Sina	L. Din	Agar	Sina	L. Din	Agar	Sina	L. Din	Agar	
FLIP-86-38L	2.0	2.3	2.6	3.0	2.4	1.5	3.6	1.7	0.7	2.2
FLIP-86-51L	2.1	1.8	1.4	2.2	2.0	1.1	2.0	1.7	0.7	1.7
FLIP-87-19L	2.4	2.1	2.0	3.3	2.3	1.5	2.6	1.2	1.1	2.1
FLIP-87-66L	1.8	1.8	1.6	2.5	1.8	1.4	3.6	1.9	0.4	1.9
FLIP-87-70L	2.5	1.8	1.8	2.3	1.9	1.3	2.7	1.2	0.4	1.8
FLIP-88-46L	2.9	2.4	2.3	3.2	2.4	2.0	3.3	2.2	1.1	2.4
ILL 590	1.8	2.2	2.8	2.9	2.3	1.8	3.3	1.6	0.8	2.2
PRECOZE-7/92-DZ/Z	3.4	2.4	3.2	2.8	2.0	2.1	3.8	1.9	0.7	2.5
FLIP-95-41L	1.9	1.8	2.9	2.5	1.5	1.4	3.4	2.0	0.2	1.9
NEL-358 x PGRC/E 211126/92DZ/2	2.2	1.8	2.3	2.9	2.4	1.8	3.7	1.6	0.6	2.1
FLIP-92-52L	2.9	2.5	1.9	3.3	2.6	1.8	4.1	1.6	1.0	2.4
FLIP-86-16L	2.8	2.4	2.7	3.0	2.3	2.2	3.4	1.8	1.0	2.4
Ada'a	1.9	2.1	2.7	2.6	1.7	1.5	3.0	1.8	0.2	1.9
Chalew	2.2	2.0	3.0	2.7	1.8	1.2	4.4	2.3	0.2	2.2
Bale local	0.9	1.7	1.2	1.1	2.1	1.1	0.3	1.2	0.8	1.2
Mean	2.2	2.1	2.3	2.7	2.1	1.6	3.1	1.7	0.7	2.1
Mean Aschochyta blight severity	4	2	3	2	5	2	2	3	2	
Mean rust severity	1	2	3	2	1	2	2	2	2	
CV %	27.8	8.2	15.2	12.3	18.4	26.1	26.8	18.8	18.2	19.1
LSD (5%)	0.9	0.3	0.7	0.4	0.6	0.6	0.9	0.4	0.2	0.6

* Sina., Sinana; L. Din, Lower Dinshi; Agar, Agarfa

Table 4. Combined ANOVA of 15 lentil genotypes evaluated over 9 environments during bona season in Bale Highlands, 1999–2001

Source of variation	Degree of freedom	Sum of squares	Mean square
Environment (E)	8	235.66	29.46*
Genotype (G)	14	62.10	4.44*
G x E	112	81.34	0.73*
Error	378	65.67	0.17
Total	539	454.49	
CV %		20.25	

*Significant at 0.01 probability level

Table 5. Estimates of stability parameters for seed yield of 15 lentil genotypes grown in 9 environments in Bale Highlands, 1999–2001

Genotype	Regression coefficient (b_i)	Deviation from regression (S_{di}^2)	Coefficient of determination (R^2)	Coefficient of correlation with environmental index	Mean
FLIP-86-38L	1.168	-0.006	0.950	0.975	2.2
FLIP-86-51L	0.522	0.051	0.639	0.799	1.7
1FLIP-87-19L	0.835	0.114	0.711	0.843	2.1
FLIP-87-66L	1.107	0.072	0.854	0.924	1.9
FLIP-87-70L	0.980	0.028	0.883	0.940	1.8
FLIP-88-46L	0.923	-0.004	0.920	0.959	2.4
ILL 590	1.031	0.037	0.879	0.937	2.2
PRECOZE-7/92-DZ/Z	1.221	0.130*	0.826	0.909	2.5
FLIP-95-41L	1.205	0.109	0.840	0.917	1.9
NEL-358xPGRC/E-211126/92DZ/2	1.182	0.014	0.930	0.964	2.1
FLIP-92-52L	1.252	0.099	0.859	0.927	2.4
FLIP-86-16L	0.992	-0.017	0.951	0.975	2.4
Ada'a	1.135	0.032	0.904	0.951	1.9
Chalew	1.540	0.168*	0.861	0.928	2.2
Local cultivar	-0.123	0.257*	0.027	-0.165	1.2

Table 6. Linear correlation coefficients of seed yield and stability parameters with disease severity of 15 lentil genotypes evaluated in 9 environments in Bale Highlands

		Linear correlation coefficient of seed yield with:	
Year	Environment	Rust	Ascochyta blight
1999/00	Sinana	-0.379**	-0.607**
	Lower Dinsho	-0.768**	-0.715**
	Agarfa	-0.794**	-0.574**
2000/01	Sinana	0.089	0.071
	Lower Dinsho	0.024	0.091
	Agarfa	-0.231	-0.285*
2001/02	Sinana	-0.290*	0.074
	Lower Dinsho	-0.275*	-0.276*
	Agarfa	0.088	0.027
Mean (based on nine environmental means)		0.513	0.202
Total		-0.124	-0.025
Regression coefficient (b_i)		-0.857**	-0.840*
Residual mean square (S_{di}^2)		0.647**	0.349

* Significant at 0.05 probability level; ** Significant at 0.01 probability level

Regression and correlation analysis showed highly significant ($p \leq 0.01$) and positive linear response of all genotypes, with the exception of the local cultivar, to environmental index. Furthermore, higher coefficient of determination ($R^2 \geq 63.9\%$) was observed for all genotypes except the local cultivar (Table 5).

Correlation of disease reaction with seed yield and stability parameters

The linear correlation coefficients of disease with seed yield and stability parameters (b_i and S_{di}^{-2}) were computed (Table 6). The association of rust and Ascochyta blight severity with seed yield varied from environment to environment. There was strong and significant ($p < 0.01$) negative association at Sinana, Lower Dinsho and Agarfa during the first cropping season. The magnitudes of the association of both diseases with seed yield in different environments increased or decreased simultaneously. The association between mean disease (rust and Ascochyta blight) severity and seed yield over environments was positive though non-significant.

Generally, rust and Ascochyta blight were negatively associated with seed yield over all environments though with lower magnitude. Both diseases had strong negative and significant ($p < 0.01$) association with regression coefficient. On the other hand, deviation from regression had strong positive and significant ($p < 0.01$) association with rust. Its association with Ascochyta blight was also positive but non-significant.

Discussion

Disease reactions

The results revealed that all genotypes except the local cultivar had resistant reactions to rust, indicating that they could be used as a source of genes for resistance in breeding programs. However, the genotypes had resistant to moderately susceptible reactions to Ascochyta blight, indicating that yield loss could be inflicted during heavy infection.

Therefore, sources of resistance to this disease should be sought and utilized in breeding programs. Different severity scores were recorded for both diseases on the same genotype in different environments. This indicates that disease severity on a particular genotype depends on environmental factors that favor or disfavor disease buildup, and the inherent (genetic) potential of the genotype to resist the disease.

Seed yield stability

The results from the anålysis of variance showed significant ($p < 0.01$) variation among environments, which indicates that each environment is a separate testing site. The results also revealed significant ($p < 0.01$) variation between genotypes and G x E interaction, indicating that the genotypes performed differently in different environments, which necessitated stability analysis to identify stable genotypes.

The results of the stability analysis of variance indicated that FLIP-86-38L, FLIP-87-19L, FLIP-87-66L, FLIP-88-46L (Assano), FLIP-95-41L, NEL-358xPGRC/E211126/92DZ/2, FLIP-87-70L, ILL-590, FLIP-86-16L, and Ada'a were stable with a lower regression coefficient closer to unity and non-significant deviation from zero. They were less responsive to environmental change and hence more adaptive. FLIP-86-51L had non-significant deviation from the linear regression line but lower regression coefficient that indicated it was not responsive to favorable environmental condition. This suggests that FLIP-86-51L could only be recommended for poor environments.

PRECOZE-7/92-DZ/Z had a regression coefficient closer to unity, but the deviation from the linear regression line was significant. Therefore, its performance was not stable or predictable. FLIP-92-52L had non-significant deviation from the linear regression line but higher regression coefficient, indicating that it was more responsive to environmental change, i.e., it may be recommended only for highly favorable environments or under high fertility conditions.

Chalew had higher regression coefficient and significant ($p < 0.05$) deviation from regression, which indicated that its performance was not predictable. The local variety had significant ($p < 0.05$) deviation from regression and negative and very low regression coefficient, which suggested that its performance was unpredictable. However, the situation could be well explained in terms of its susceptibility to disease, especially rust. The results from regression and correlation analysis indicated that environment had a major effect on seed yield of lentil genotypes. On the other hand, the local cultivar showed non-significant and negative linear response and association with the environment, which resulted from the susceptibility of the cultivar to diseases.

Correlation of disease severity with seed yield and stability parameters

The results of correlation analysis of seed yield with rust and Ascochyta blight indicated that an environment that favors disease development also favors the crop for higher seed yield. In other words, both disease severity and seed yield have similar environments which favor or disfavor them simultaneously in the same direction.

In favorable environmental conditions, rust severity scores could increase from 1 to about 3 inflicting no or less damage to resistant genotypes, which in turn could utilize the favorable environmental conditions to result in higher seed yield. However, susceptible genotypes could die, resulting in dramatic yield loss and some times in total crop failure in favorable environmental conditions.

Generally, rust and Ascochyta blight were negatively associated with seed yield over all environments though with lower magnitude. Both diseases had strong negative and significant ($p < 0.01$) association with the regression coefficient. Furthermore, rust severity had strong, positive and significant ($p < 0.01$) association with deviation from regression.

Ascochyta blight had also positive, but non-significant association with the same stability parameter. This shows that the variation of disease severity over different environments on a particular genotype was among the major factors that contributed to seed yield instability of the genotype.

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