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Original Research

Seed Physical Quality of Common Bean (*Phasolus vulgaris* L) as Influenced by Genotype and Aluminium Concentration under Lime-treated and Lime-untreated Soils

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Abstract

This study was carried out to assess the effects of different concentrations of exchangeable aluminum on seed physical quality of two common bean genotypes grown on lime-treated and lime-untreated acidic soils. Factorial combinations of five rates of aluminum (0.0, 12.5, 25.0, 50.0, and 100.0 mg Al kg soil^{-1}) and two common bean genotypes (New BILFA 58 and Roba 1) were laid out in a completely randomized design with three replications per treatment.The results showed significant differences among aluminum levels and genotypes in relation to dry seed density, seed length, seed width, seed hydration ratio, swelling ratio, water absorption, seed coat proportion, germination percentage, 100 seed weight, cooking time, percent residue (solid loss) in both lime untreated and lime treated soil. However, aluminum by genotype interaction showed a non- significant($P>0.05$) difference for almost all physical properties on both soil types except seed width, water absorption, cooking time and percent seed coat. The genotype new BILFA 58 (acid soil tolerant) gave higher values in almost all physical quality of the seed on both lime treated and untreated soil than Roba 1(acid soil sensitive). Lime application had improved the physical quality parameters of both genotypes as compared to lime untreated soil, with the values of 8.6,10.5, 10.9 and 6.7% increments in seed length, seed width, 100 seed weight and germination percentage, respectively. However, lime application reduces number of unsoaked seeds (26.5%) and seed coat proportion (17%) as compared to lime untreated soil. Lime application had no significant effect on cooking time and water absorption of the seeds as compared to lime untreated soil. The study showed aluminum toxicity affects physical bean seed quality. Therefore, screening genotypes tolerant to soil acidity with appropriate agronomic management practices (lime application) can improve bean seed physical quality and has a potential to improve the nutritional status of the people who grow beans on acid soils.

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INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) has evolved rapidly in Africa and is steadily transforming from a traditional subsistence to a market-oriented crop, with major impacts on household incomes, food and nutritional security, and national economies. However, these benefits are yet to be felt in many parts of the continent because of multiple constraints that limit bean productivity (Burchara *et al*., 2011). Common beans are grown throughout Ethiopia and are an increasingly important commodity in the cropping systems of smallholder producers for food security and income (Ferris and Kaganzi, 2008). In Ethiopia two types of common bean are grown: the canning type primarily grown for export market dominantly grown in the Oromiya region (Northeast rift valley), and the cooking type primarily grown for food in the Southern National Nationality Peoples' Region (Alemu and Bekele, 2005).

Common bean is mainly produced on small-scale farms (80% of the world's dry bean production) where about 40% and 30 to 50 % of the bean-growing area in Latin America and Central, Eastern and Southern Africa, respectively are affected by aluminum (Al) toxicity, the most important soil factor limiting crop yields on acid soils (Wortmann *et al*. 1998), leading to 30 to 60% yield reduction (CIAT, 1992). However, significant genotypic differences in Al resistance in common bean were reported based on Al-inhibited root elongation in nutrient solution (Manrique *et al.,* 2006).

As observed in the field and pot screening on strongly acid soil in western Ethiopia new BILFA 58 and Roba 1 were identified as tolerant and sensitive genotype to soil acidity stress. However, the response of these genotypes to soil acidity stress in terms physical seed quality was not unknown. Thus, to obtain higher grain yield and quality common bean seeds, it would be necessary to search for varieties adapted to acid soil conditions and with high grain yield to meet the demand of common bean in the western part of the country where soil acidity is a major crop production. In addition limited information available on about physical properties and cooking quality of common bean seeds grown in Ethiopia especially that on those grown under acid soil conditions. Therefore, knowing these parameters of common bean genotypes that are grown in acid soils is crucial for researchers, nutritionist and the farmers growing this crop in the area in order to promote its consumption. This paper presents the results of a study conducted to determine the effect of exchangeable aluminium on seed physical quality of common bean under lime-treated and lime-untreated acidic soils.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Nekemte soil laboratory in western Ethiopia. The experimental site is located at 9^0 08' N latitude and $36^0$46' E longitude with an altitude of 2080 metres above sea level. According to the weather data recorded at the Nekemte Meteorological Station, the average annual rainfall of the study site is 1300 mm with 725 mm for the experimental period (July – October) and the monthly mean minimum and maximum temperatures are between 10-15°C and 24 to 28 ^{0}C. The soil used for the pot experiment had a pH (H_2O) of 4.81, exchangeable acidity of 4.92 cmol/kg soil, exchangeable Al of 3.1 cmol/kg soil and acid saturation of 53.3 % before applying the treatments.

Description of Planting Materials

From the results of field (pH 4.5) and pot (pH 4.8) screening experiments conducted in 2009 and 2010, respectively, new BILFA 58 (NB 58) and Roba1 were identified as the most tolerant and sensitive genotypes to soil acidity, respectively. New BILFA 58 is an inbred line with type III growth habit having large-sized seeds (53 g per 100 seed) whereas Roba 1 is a small-seeded (22 g per 100 seed) commercial cultivar in Ethiopia with type II growth habit.

Treatments and Experimental Design

The treatments consisted of factorial combinations of the two common bean genotypes (new BILFA 58 and Roba 1) and five rates of aluminium (0.0, 12.5, 25.0, 50.0, and 100.0 mg Al/kg soil) applied to the soil. The different rates of aluminium were applied in the form of $Al_2(SO_4)_3$. The ten treatments were laid out in a completely randomized design with three replications. The experiment consisted of two sets with similar procedures. The first set consisted of treatments grown on lime-treated soil whereas in the second set the treatments were grown on untreated soil.

Experimental Procedure

Seeds of the two common bean genotypes were sown in pots (18 x18 cm) filled with 10 kg soil. At the time of planting, the soil was fertilized with phosphorus at the rate of 92 kg P_2O_5 per hectare. Six seeds per pot were initially sown and later thinned to four plants when the first trifoliate leaves unfolded. The different rates of aluminium and lime were applied four weeks prior to planting the seeds and worked into the soil. Lime was applied at the rate of 20 g pot^{-1}(9 tonnes/hectare) after determining by the incubation method. Pots were watered periodically with tap water to the approximate field capacity to facilitate normal plant growth. All the recommended agronomic management practices including weeding were applied as required.

Collection and Preparation of Samples

Seed Physical Analysis

The harvested bean seeds from all the treatment combinations were hand cleaned to remove foreign materials, sealed in plastic bags and stored at 4 ^{O}C until use for laboratory analysis. Physical properties were estimated for each of the tolerant and sensitive genotypes by using the following methods.

Moisture Content: of the seed was analyzed by oven drying method as described in the AACC method 44-17 (AACC, 2000).

Hundred Seed Weight: This was determined by measuring the mass of 100 seeds on electronic balance by taking dockage free homogenous sample for each treatment.

Seed Size: The length (L) and breadth (B) of the seed of the two genotypes of the various treatments were measured by digital caliper (0.01 mm). From the measured L and B, the value L/B ratio was also analyzed.

Dry Seed Density: Seed of each treatment (20 g) was placed in a 100 ml measuring cylinder filled with 50 ml water. The rise in water level after thorough shaking to remove air bubble was recorded as the dry seed volume. Dry seed density was estimated by dividing 20 g with the dry seed volume (Ajeigbe *et al*., 2008).

Wet Seed Volume (WSV): The 20 g seeds of each treatment was allowed to stay overnight in the measuring cylinder with 50 ml of water. The water level in the cylinder was noted in the morning as total volume of the wet seeds and unabsorbed water. The excess water was then saved in another measuring cylinder. The difference between the total volume and excess water was recorded as the wet seed volume.

Wet Seed Volume: Total Volume-Excess Water

Swelling ratio (SR): The wet seed volume was divided by the dry seed volume to obtain swelling ratio.

$$Swelling\ Ratio\ (SR) = \frac{wet\ seed\ volume}{dry\ seed\ volume}$$

Water Absorbed (WA): Excess water was removed after overnight soaking and was subtracted from 50 mL, the difference was recorded as water absorbed and the result was reported as percentage water absorbed.

Water Absorbed (WA), %=
(50mL–Excess Water Removed) X 100

Hydration Ratio (HR): Hydration ratio was computed as weight of soaked beans (W2) divided by initial weight (W1) (Ghaderi *et al*., 1984).

Seed Coat Proportion (SCP): Bean seeds (150 g) were sampled from each treatment and soaked for 24 h in 750 ml of distilled water at room temperature. After soaking, the seed coats of 10 randomly chosen seeds were separated from the rest of the seed (endosperm plus embryo) and was dried to constant weight allowing calculation of the ratio of the seed coat weight to the total weight (seed coat proportion, as percentage) (Ajeigbe *et al*., 2008).

Cooking Time: Cooking time determination was done in the food science laboratory of Melkassa Agricultural Research center. Prior to cooking, dried 100 bean seeds from each treatment were soaked for 16 hours in distilled water at room temperature and then drained (Martin-cabrejes *et al*., 1997). The numbers of seeds soaked and unsoaked were counted after 16 hours soaking, and then the ratio (%) of unsoaked to soaked was calculated prior to cooking. A modified Mattson-type cooker (Proctor and Watts, 1987) was used to determine the cooking time of the individual beans. This cooker utilized 25 stainless steel, cylindrical, piercing tip rods (82 g each) in contact with the surface of the bean. The cooker was then placed into a 2-L beaker containing 1.4 L of boiling water. Bean grains were judged as “cooked” when the 2 mm diameter tip of the brass rods passed through the beans. The cooking time was reported as the time required for 60 % of the grains to be cooked, as indicated by plungers dropping and penetrating individual beans.

Dry Weight of Solids after Cooking (DWS (g): 5 g dry seeds were pre-soaked in distilled water (20 mL) for about 16 hrs. The beans were then cooked in 50 mL beakers until to get tenderness. The cooked beans were allowed to stand at room temperature about (23^{o}C) and the water was drained to separate the cooked beans from residue. The drained water was dried at 60^{O}C in an oven for 24 hours and the weight was determined on analytical balance (Ajeigbe *et al*., 2008).

Germination Test: Germination was determined by using four hundred (400) common bean seeds. The seeds were divided into four replicates of 100 seeds each and then sown in between blotter papers. The planted seeds were incubated at a temperature of 20 ^{0}C for 8 days as specified by ISTA (1993). Germinated beans are defined as beans with minimum sprout length of 0.5 cm (Berrios *et al*., 1999). First count was done at five days where as the last count was after nine days of sowing (Agrawal, 1980). On the final day of the germination test germinated seedlings were divided into normal seedlings, abnormal seedlings, and ungerminated seeds to determine the percentage of normal seedlings. Both germinated and ungerminated (hard seed or dead seeds) was recorded and the result of the germination test was calculated as the average of four hundred seed of four replicates based on the final seedling count expressed of the percentage by number of normal seedlings.

Data Analysis

Data were subjected to analysis of variance (ANOVA) according to the Generalized Linear Model of SAS version 9.1 (SAS institute, Cary, 2004). Mean differences were separated using the least significant difference (LSD) test at 5% level of significance. For all analyses, a *P*-value of less than 0.05 was interpreted as statistically significant.

RESULTS

Seed Size

Common bean seed physical quality parameters were significantly influenced by the main as well as the interaction effects of aluminum rates as well as the common bean genotypes in both lime treated and untreated soils (Table 1). Similarly, aluminum rate interacted with genotype to influence seed width in both liming regims. Dry seed density, seed length and width were significantly reduced as the applied aluminum rate increased (Table 2). On average the genotypes gave higher values of these parameters under lime treated than untreated soils. Lime application improves length of the seeds by 8.6 % and seed width by 10.5 % as compared to when the genotypes grown under lime untreated soil. New BILFA 58 had higher dry seed density; seed length and width than Roba 1 at each aluminum level both under lime-treated and lime-untreated soils (Table 2).

Effect of Treatments on Water Absorption of Seeds

The main and interaction effects due to aluminum rates and genotypes were significant ($P<0.01$) for water absorption under lime-treated and lime-untreated soil conditions (Table 1). However, wet seed volume, swelling ratio, and hydration ratio of bean seeds were affected by aluminum rates and genotypes in both lime treated and untreated soils. Aluminum application affects the water absorption and hydration ratio of both genotypes, where the maximum water absorbed was recorded at the maximum aluminum (100 mg Al/kg soil) applied (Figure 1). However, the maximum hydration ratio was recorded at 50 and 100 mg Al applied for lime untreated and lime treated soil, respectively (Table 3). New BILFA 58 had higher water absorption than Roba 1 in both soil types. In both lime untreated and treated soils the maximum water absorption was recorded at the maximum aluminum applied (100 mg Al/kg soil). On average the genotypes gave almost similar water absorption under lime treated and untreated soils. The wet seed volume and swelling ratio of the seeds of both genotypes relatively increased to some extent as the applied aluminum increases (Table 3, Figure, 1). For wet seed volume the maximum was recorded at the maximum aluminum applied (100 mg/kg soil) in lime untreated soil and at 50 and 100 mg Al/kg soil in lime treated soil. New BILFA 58 had higher wet seed volume, swelling ratio and hydration ratio in both lime untreated and treated soils.

On average the genotypes attained 21.9 and 74.6% of their seed dry mass when soaked in water, with 38.9 and 82.8% for new BILFA 58, and 4.83 and 55.70% for Roba 1 under lime untreated and treated soils, respectively. From the result obtained on average aluminum toxicity affects the water absorption of the seeds by 70.6% in lime untreated soil as compared to lime-treated soil. Comparing the two genotypes aluminum toxicity reduces 52.9 and 91.6% water absorption when the genotypes grown under lime untreated soil as compared to treated soil for new BILFA 58 and Roba 1, respectively.

Table 1: Mean squares of seed physical quality paramters of common bean genotypes as affected by aluminum treatment and genotypes on lime untreated and lime-treated soil

Parameters	Lime	Al	G	Al*G	Error
Dry seed density (g/mL)	UL	0.0087^{***}	0.0149^{**}	0.00021^{ns}	0.00113
	L	0.0044^{*}	0.0062^{ns}	0.0048^{*}	0.00142
Length (L) (mm)	UL	2.71^{*}	191.3^{***}	0.80^{ns}	0.886
	L	1.55^{ns}	256.6^{***}	0.52^{ns}	0.884
Width(W) (mm)	UL	0.288^{*}	19.2^{***}	0.716^{***}	0.093
	L	0.16^{ns}	23.3^{***}	1.38^{*}	0.409
Ratio (L/W)	UL	0.0164^{ns}	1.016^{***}	0.059^{ns}	0.0513
	L	0.055^{ns}	1.43^{***}	0.213^{*}	0.055
Wet seed volume(WSV) (mL)	UL	20.17^{*}	62.7^{**}	6.22^{ns}	5.192
	L	59.25^{***}	214.7^{***}	10.36^{ns}	6.17
Swelling Ratio (SW)	UL	0.0717^{**}	0.376^{***}	0.0267^{ns}	0.0154
	L	0.138^{**}	0.933^{***}	0.023^{ns}	0.022
Water absorption (WA) (%)	UL	38.2^{***}	114.9^{***}	49.4^{***}	5.06
	L	100.3^{***}	225.8^{***}	56.9^{**}	10.95
Hydration Ratio(HR)	UL	0.0674^{ns}	0.073^{ns}	0.017^{ns}	0.0253
	L	0.093^{*}	0.401^{***}	0.137^{**}	0.023
Number unsoaked	UL	124.69^{*}	7684.5^{***}	6.06^{ns}	29.71
	L	16.74^{ns}	3554.5^{***}	58.53^{ns}	8.83
Number soaked	UL	124.7^{*}	7684.5^{***}	58.53^{ns}	29.71
	L	16.74^{ns}	3554.5^{***}	6.06^{ns}	8.83
Ratio	UL	655.6^{*}	27325.6^{***}	437.1^{*}	145.62
	L	35.07^{ns}	8064.9^{***}	13.96^{ns}	27.46
Dry seed weight (g)	UL	0.506^{***}	2.403^{***}	0.0133^{ns}	0.0286
	L	0.75^{***}	1.55^{***}	0.006^{ns}	0.0274
Fresh weight cooked (g)	UL	1452.66^{ns}	18746.0^{***}	319.47^{ns}	839.39
	L	9856.2^{***}	30839.8^{***}	1137.6^{ns}	1059.6
Cooking time (min)	UL	42.28^{***}	64.39^{***}	13.31^{***}	1.276
	L	48.1^{***}	40.2^{***}	10.4^{**}	2.049
% seed coat	UL	8.15^{***}	72.9^{***}	3.80^{**}	0.668
	L	0.533^{*}	8.14^{***}	2.26^{***}	0.169
Residue (%)	UL	20.74^{*}	123.9^{***}	10.06^{ns}	5.34
	L	16.8^{**}	206.4^{***}	03.03^{ns}	3.125
100 seed weight (g)	UL	23.76^{**}	3778.2^{***}	2.98^{ns}	4.184
	L	32.9^{**}	4146.6^{***}	1.69^{ns}	5.72
Germination (%)	UL	63.2^{***}	423.3^{***}	23.61^{*}	7.879
	L	22.68^{ns}	521.8^{***}	71.2^{ns}	29.45

Where; UL-unlimed, L- Limed, ns- non-significant, Al- aluminum, G-genotypes

Table 2: Dry seed density, seed length, and seed width of two common bean genotypes Grown on different aluminum treatment with lime treated and untreated soil

Treatments	Density (g/mL)		Length (mm)		Width (mm)	
Al level (mg/kg soil	**UL**	**L**	**UL**	**L**	**UL**	**L**
0	$1.17±0.02^{a}$	$1.19±0.02^{a}$	$10.9±1.4^{a}$	$11.6±1.3^{ab}$	$5.5±0.6^{a}$	$5.9±0.5^{ns}$
12.5	$1.16±0.02^{ab}$	$1.14±0.01^{ab}$	$10.9±1.2^{a}$	$11.9±1.2^{a}$	$5.4±0.5^{ab}$	$5.8±0.6^{ns}$
25	$1.14±0.01^{b}$	$1.16±0.01^{ab}$	$10.1±1.3^{ab}$	$10.8±1.4^{ab}$	$5.2±0.3^{abc}$	$6.0±0.4^{ns}$
50	$1.12±0.01^{bc}$	$1.12±0.02^{bc}$	$9.9±1.1^{ab}$	$10.7±1.3^{b}$	$5.1±0.2^{bc}$	$5.6±0.1^{ns}$
100	$1.1±0.02^{c}$	$1.11±0.03^{c}$	$9.4±0.9^{b}$	$11.2±1.5^{ab}$	$4.9±0.3^{c}$	$5.8±0.6^{ns}$
Genotypes						
NB58	$1.16±0.01^{a}$	$1.16±0.01^{ns}$	$12.8±0.4^{a}$	$14.2±0.3^{a}$	$6.1±0.2^{a}$	$6.7±0.2^{a}$
Roba 1	$1.11±0.01^{b}$	$1.13±0.02^{ns}$	$7.75±0.2^{b}$	$8.3 ± 0.2^{b}$	$4.4±0.1^{b}$	$4.9±0.1^{b}$
Mean	**1.13**	**1.14**	**10.3**	**11.25**	**5.23**	**5.84**
***CV* (%)**	**2.95**	**3.30**	**9.16**	**8.36**	**5.84**	**10.94**

Where, UL - unlimed. L- limed, , NB58= new BILFA 58 bean variety, Means followed by the same letter in a column are not significantly different at 5 % significant level.

Table 3: Wet seed volume, swelling ratio, and water absorption (%) and hydration ratio of two common bean genotypes grown with different aluminum treatments with lime treated and untreated soil

Factors	Wet seed volume (mL)		Swelling Ratio (SR)		Hydration Ratio HR	
Al level	**UL**	**L**	**UL**	**L**	**UL**	**L**
0	26.5±1.4^{ab}	26.1±1.5^{bc}	1.6±0.1^{a}	1.5±0.1^{b}	1.7±0.08^{ab}	1.72±0.2^{bc}
12.5	28.6±0.8^{a}	26.2±1.5^{b}	1.7±0.04^{a}	1.4±0.01^{bc}	1.6±0.09^{b}	1.63±0.1^{c}
25	27.7±1.3^{a}	23.1±2.1^{c}	1.6±0.08^{a}	1.3±0.2^{c}	1.7±0.08^{ab}	1.82±0.06^{ab}
50	24.4±1.1^{b}	30.9±0.9^{a}	1.4±0.07^{b}	1.7±0.1^{a}	1.9±0.06^{a}	1.89±0.04^{ab}
100	28.9±1.0^{a}	28.8±1.7^{a}	1.6±0.07^{a}	1.6±0.1^{ab}	1.6±0.07^{b}	1.93±0.05^{a}
Genotypes						
NB58	28.7±0.6^{a}	29.9±0.7^{a}	1.7±0.04^{a}	1.73±0.04^{a}	1.8±0.8^{ns}	1.91±0.05^{a}
Roba 1	25.8±0.8^{b}	24.6±1.2^{b}	1.4±0.04^{b}	1.4 ±0.06^{b}	1.7±0.8^{ns}	1.68±0.07^{b}
Mean	**27.24**	**27.22**	**1.54**	**1.55**	**1.73**	**1.795**
***CV* (%)**	**8.36**	**9.12**	**7.99**	**9.49**	**9.21**	**8.43**

Where, UL = lime untreated, L = lime treated. Mean followed by the same letter in a column shows non-significant difference at *P* >0.05.

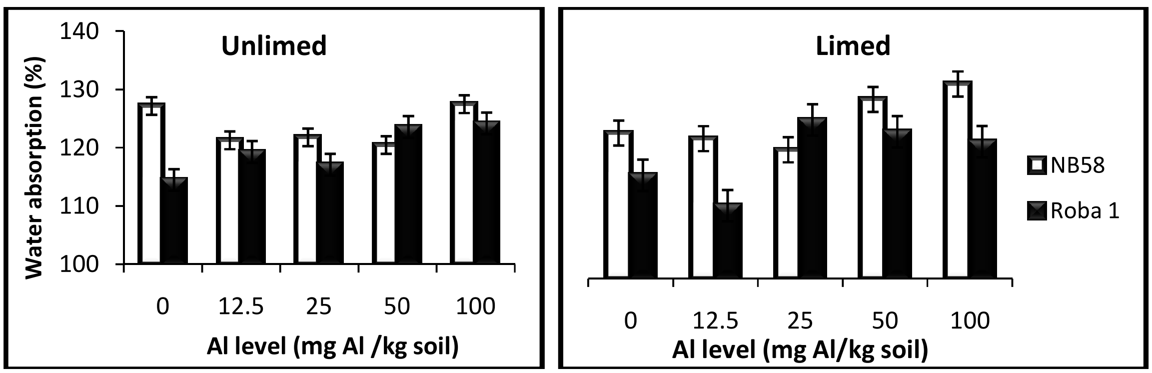

Figure 1: Percent water absorption by two common bean genotypes as influenced by aluminum levels on lime untreated and treated soils.

Effect of Treatments on 100-seed Weight and Germination

Differences among aluminum levels, between the bean genotypes, and their interaction terms were significant for seed germination percentage in lime untreated soil (Table 1). However, 100 seed weight was significantly affected by the main factors in both liming regims. New BILFA 58 had higher 100 seed weight and germination percentage than Roba 1 in both lime treated and untreated soils (Figure 2, 3). The highest 100-seed weight and germination percentage were recorded for the control (no aluminum) treatment whereas the lowest was at the highest Al rate under both lime treated and untreated soils. The rate of reduction in 100-seed weight and percentage germination increased with rates of aluminum applied and the reduction was higher for lime-untreated soil than for the treated soil. On average, the genotypes suffered 10.9% reduction in 100-seed weight and 6.7% in percentage germination when grown on lime-untreated soil as compared to when they were grown in lime-treated soil with similar rates of aluminum applied. Comparing the two genotypes, new BILFA 58 suffered a lower reduction in 100 seed weight (9.2%) than Roba 1(14.8%) when grown under different rates of aluminum on the lime-untreated soil. However, the reduction in percentage germination of the genotypes was almost similar.

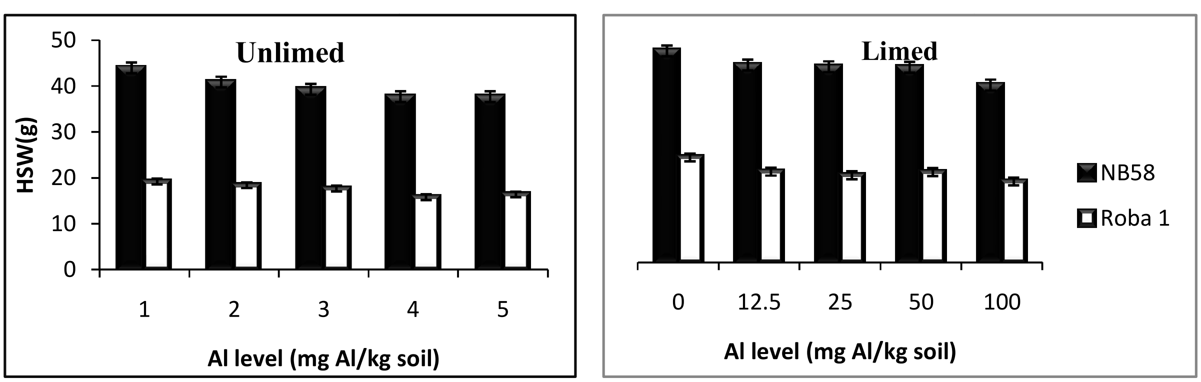

Figure 2: Hundred seed weight of two common bean genotypes as influenced by different rates of aluminum applied on lime untreated and treated soils.

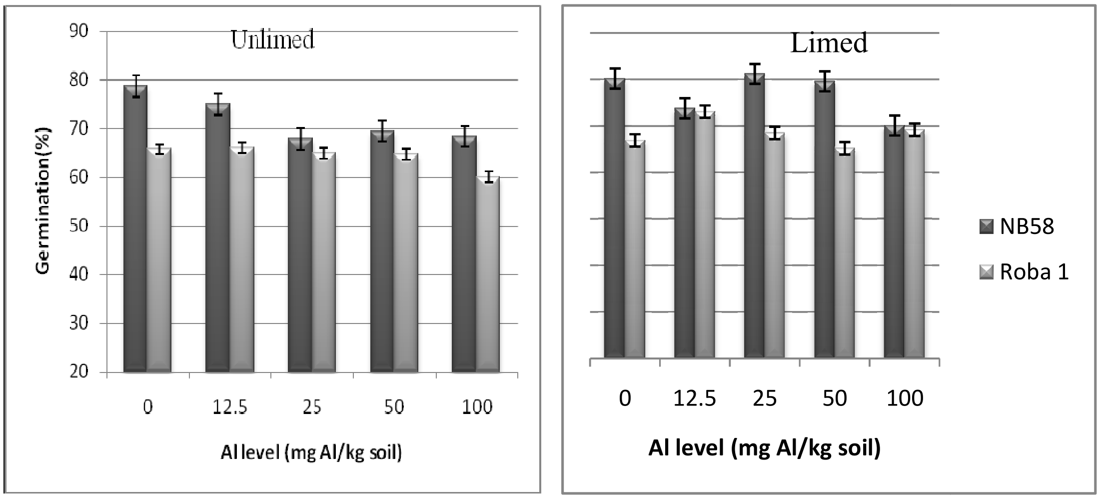

Figure 3: Percent seed germination of common bean genotypes as influenced by aluminum rates on unlimed soil

Effect of Treatments on Proportion of Common Bean Seed Anatomical Parts

Differences among the aluminum levels, between the bean genotypes, and their interaction terms were significant for seed coat proportion under the lime treated and untreated soils. In general, the relative weight of the grain anatomical parts (seed coat and cotyledons) was variable between the two genotypes. New BILFA 58 had lower seed coat proportion (higher cotyledons) than Roba 1 under both soil treatment conditions (Table 4). Seed coat proportion tended to increase as the aluminum level increased from 0 to 100 mg Al/kg soil on lime-untreated soil. On the other hand, application of lime reduces the seed coat proportion (higher cotyledons) in both genotypes at each aluminum rate applied. However, plants supplied with 100 mg Al per kg soil had higher seed coat proportion in lime untreated soil; hence aluminum toxicity increases the seed coat proportion of the genotypes. The reductions of seed coat proportion in lime treated soil was observed for Roba 1 but the tolerant genotype(new BILFA 58) gave almost similar seed coat proportion in both soil types. On average 17 % reduction in seed coat proportion observed in lime treated soil as compared to untreated soil.

Table 4: Fresh weight of cooked beans (g), seed coat, dry seed weight of seed cooked, and % residue (solid loss) of two common bean genotypes grown with lime treated and untreated soil

Al level (mg/kg soil)	Fresh weight cooked (g)		% seed coat		Residue (%)	
	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed
0	319.4±19.2^{ns}	338.7±17.5^{a}	8.3±0.2^{b}	8.8±0.03^{b}	19.7±0.06^{b}	17.3±0.06^{c}
12.5	294.5±17.5^{ns}	333.9±30.2^{a}	10.8±0.4^{a}	8.6±0.02^{b}	19.2±0.09^{b}	18.9±0.05^{bc}
25	298.7±18.8^{ns}	352.7±18.3^{a}	10.9±0.2^{a}	9.4±0.7^{a}	21.2±0.08^{ab}	18.5±0.08^{bc}
50	324.6±12.4^{ns}	264.5±14.9^{b}	8.9±0.7^{b}	8.9±0.2^{ab}	21.9±0.07^{ab}	19.4±0.07^{b}
100	289.9±20.7^{ns}	371.2±7.7^{a}	10.5±4.2^{a}	8.9±0.2^{ab}	23.8±0.03^{a}	21.8±0.03^{a}
Genotypes						
NB58	330.5±11.2^{a}	364.3±11.01^{a}	8.3±0.1^{b}	8.4±0.1^{b}	19.1±0.04^{b}	16.6±0.02^{b}
Roba 1	280.5±7^{b}	300.2±13.5^{b}	11.4±1.8^{a}	9.5±0.2^{a}	23.2±0.04^{a}	21.8±0.03^{a}
Mean	**305.5**	**332.2**	**9.89**	**8.8**	**21.2**	**19.2**
CV (%)	**9.49**	**9.79**	**8.27**	**4.88**	**10.92**	**9.22**

Where: NB58- new BILFA 58,

Effect of Treatments on Seed Cooking Quality

Cooking time was significantly influenced by the main as well as the interaction effects of aluminum rates as well as the common bean genotypes in both lime treated and untreated soils. However, number of soaked and unsoaked seeds, and cooking residue were influenced by the main effects in lime untreated and treated soil except for number of unsoaked seeds in lime treated soil. The mean cooking time values for the two genotypes decreased as the amount of aluminum applied increased in both lime untreated and lime treated soil. Thus, higher cooking time was recorded for the control (no aluminum) in both soil conditions. Roba 1 presented the highest cooking time than new BILFA 58, however, no statistically significant difference was found among them in lime treated soil. On the other hand new BILFA 58 has short cooking time at all aluminum levels, but the first two aluminum levels (0 and 12.5 mg Al/kg soil) did not differ statistically for this parameter (Figure 4).

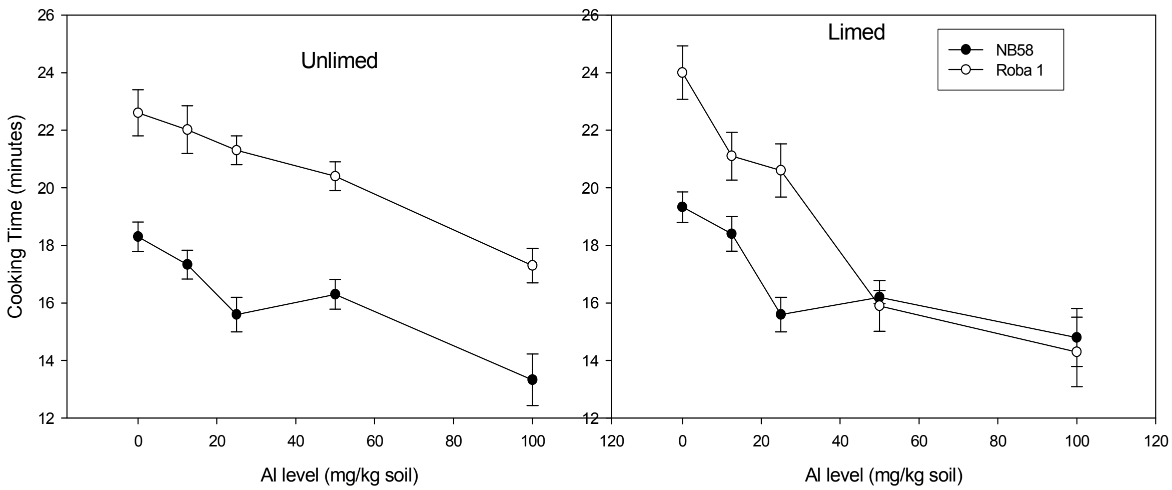

Figure 4: Cooking time of two common bean seeds as affected by aluminum levels and genotypes under lime treated and untreated soils.

After soaking the seeds for 16 hours in distilled water for both genotypes from each treatment and both soil types the result obtained indicate the variation among aluminum levels, and genotypes. On average lime application reduces number of unsoaked seeds by 26.5 % and the ratio of unsoaked to soaked seeds by 39 %, and increases number of soaked seeds by 7.64 % in this study (Table 5). Thus, lime application decreases the hard shell of common bean seeds for water uptake. Among the two genotypes new BILFA 58 had higher water uptake (less hard seed) as compared to Roba 1 (sensitive genotype) in both unlimed and limed soil. In addition the number of soaked beans for new BILFA 58 was higher in both unlimed and limed at each aluminium levels applied than Roba 1. Similarly, the ratio of unsoaked seeds to soaked seeds were more than 69 %, and 40 % for Roba 1, and 8.8 and 7.2 % for new BILFA 58 when the two genotypes grown under different aluminum levels with and without lime treated, respectively. Lime application improves the soaking ability of the sensitive genotypes roba 1 than new BILFA 58. Thus, aluminium toxicity has a negative impact on soaking of the seeds with higher effect on the sensitive genotype (Roba 1) than the tolerant genotype (new BILFA 58).

Table 5: Weight of soaked seeds, number of unsoaked, number of soaked and ratio of unsoaked to soaked seeds of the two common bean genotypes grown with lime treated and untreated soil

Al Level	**Wt. Soaked (g)**		**No. unsoaked**		**No. Soaked**	
(mg Al/kg soil)	**Unlimed**	**Limed**	**Unlimed**	**Limed**	**Unlimed**	**Limed**
0	53.5±13^{a}	62.1±14.7^{a}	21.2±6^{b}	14.9±0.6.8^{ns}	78.8±7^{a}	85.1±5.3^{a}
12.5	54.3±10^{a}	52.5±11.5^{bc}	28.3±9^{a}	17.3±4.4^{ns}	71.7±9^{b}	82.7±4.4^{ab}
25	51.5±9.9^{a}	56.6±14.5^{b}	18.2±6^{b}	18.8±5^{ns}	81.8±6^{a}	81.2±5.2^{b}
50	48.8±11.8^{ab}	51.9±12.5^{c}	28.6±7^{a}	19.2±5^{ns}	71.4±7^{b}	80.9±4.6^{b}
100	42.5±8.8^{b}	47.4±11.6^{d}	22.9±9^{ab}	17.5±4.6^{ns}	77.1±9^{ab}	82.5±5.5^{ab}
Genotypes						
NB58	72.9±3.2^{a}	82.9±2.3^{a}	7.9±1.2^{b}	6.7±0.7^{b}	92.2±1.2^{a}	93.3±0.7^{a}
Roba 1	27.2±0.9^{b}	25.3±0.9^{b}	39.9±2.2^{a}	28.4±0.9^{a}	60.2±2.2^{b}	71.6±0.9^{b}
Mean	**50.1**	**54**	**23.9**	**17.6**	**76.2**	**82.5**
CV (%)	**14.3**	**6.5**	**22.8**	**16.9**	**7.2**	**3.6**

Means followed by the same letter in a column are not significantly different at 5% significant level

DISCUSSION

Many studies have reported on large genotypic variations in plant growth, physiology, and quality in response to aluminum (Liu *et al*., 2004). Two common bean genotypes in this study exhibited some of these variations. Aluminum toxicity have a detrimental effect on seed physical quality parameters of common bean genotypes grown on lime treated and untreated soils. However lime application reduces the toxicity of aluminum and improves the some of the physical quality of the seeds as compared to lime untreated soil. Several studies have reported substantial gains in growth and yield in acid soils treated with lime (Fageria, 2001). The positive effects of liming on acid soils are numerous, and the reduction of Al toxicity is certainly one of the most beneficial.

Low water absorption by hard-shell can be due to low permeability of the seed coat to water. Agbo *et al*. (1987) showed differences in micropyle size and in other micro-structural differences that were related to seed coat permeability and water uptake by the seed. The higher seed coat proportion of Roba 1 resulted in poor water absorption of the seeds and had lower soaked seeds than new BILFA 58. The seed coat proportion is important in consumer nutrition and physiology, because the chemical composition of the grain coat, cotyledon, and embryonic axis is highly contrasting (Reynoso-Camacho *et al*., 2006). These results confirmed that if the grain size increases, as occurring during common bean domestication (Celis-Vela´zquez *et al*., 2010), then the grain coat relative weight decreases. Furthermore, physical and chemical grain coat characteristics are important in processes like the hard-to-cook defect and the grain water uptake during cooking and germination (Pena-Valdivia *et al*., 1999).

Cooking time is one of the most important parameters in evaluating beans for processing quality. Fast and uniformly cooking beans are required both for processing and for traditional consumption of beans by local producers where firewood is the major source of fuel (Elia *et al*., 1996). The lower cooking time recorded for new BILFA 58 in this study in addition to its better agronomic performance make this genotype better acid soil tolerant as it saves the time taken and cost saved for cooking. On the other hand Roba 1 took higher cooking time when grown under acid than reported before by other researchers with 19.2 minutes on average. Shimelis and Rakshit (2005) evaluated the effect of cooking time on different bean varieties after 24 hours of soaking. They found out that cooking times varied from 19.50 min (*Awash 1)* to 41.70 min (*Gofta*), with water absorption percentages between 227.29 and 124.94 %, respectively. These values are much higher than the result obtained for the two genotypes in this study. The need for prolonged cooking can be related to either hard-shell, which does not allow adsorb enough water or adsorbed water failed to soften during soaking and cooking (Hohlberg and Stanley, 1987). Kigel (1999) reported hard-to-cook problem of bean seeds. The culinary quality of common bean grains is defined by several desirable attributes, among which the cooking time may be the most important one (Pena-Valdivia *et al*., 2011).

In this study as the applied aluminum level increases cooking time of the genotypes decreases with shortest time recorded at 100 mg Al applied. The suggested reason for the lower cooking time as the applied aluminum increases is due to the lower nutrient content of seeds including calcium and magnesium which are important for seed coat development, at higher aluminum levels. In line this result cooking time and seed hardness were increased by growing beans in a location with soils rich in Ca and Mg and higher average annual temperature (15–24°C), compared to a location with lower temperature (11–18°C) and soils poor in Mg and P (Paredes-Lopez *et al*., 1989). Similarly, Seeds produced on a calcic chernozem in Bulgaria needed a longer cooking time compared to those produced in soils with lower Ca levels (Stoyanova *et al*., 1992).

Considerable differences were also observed among genotypes and aluminum levels for fresh cooked weight of seeds and percent residue (solid loss) in this study. New BILFA 58 had higher fresh cooked weight of seeds and low percent residue as compared to Roba 1 in both lime-treated and lime untreated soils. At each aluminum level percent residue was higher in lime untreated soil as compared to lime treated soil, with the maximum average value where recorded from the maximum aluminum applied. Thus, aluminum treatment affects the quality of cooking by increases the amount of solid loss. The result obtained in this study was by far higher than the results reported by Supradip and his co-investigators for 35 common bean genotypes, according to the result obtained cooking loss was ranged between 5.3 –15.0 % (Supradip *et al*., 2009).

The grain weight of both genotypes was reduced than the weight obtained under screening of these genotypes for soil acidity tolerance. Thus, as the amount aluminum applied in the soil increases the productivity and the quality in terms of hundred seed weight and germination were affected as observed in this study. In line with Alamgir and Sufia (2009), reported that aluminum affected seed germination of different varieties of wheat (*Triticum aestivum* L.), and the inhibitory effect increased with the increase of Al^{3+} concentration. Similarly different researchers has been reported that Al^{3+} at different concentrations showed differential inhibitory effect on seed germination of white spruce (Nosko *et al.,* 1988), pigeon pea (Narayanan and Syamala, 1989).

CONCLUSIONS

The result of this work have clearly shown that, the dry seed density, seed length and seed width were affected by aluminum treatment and genotypes, in both lime treated and untreated soils. Seed swelling ratio, hydration ratio and water absorption by the seed were influenced by aluminum level and genotype; water absorption by seeds of the genotypes was increased as the applied aluminum increases. Cooking quality parameters, number of soaked seed, cooking time, and percent residue (solid loss) were significantly affected by aluminum treatment and genotypes on both soil types. Number of soaked seeds decreased and percent residue (solid loss) increased as the applied aluminum increases. Cooking time decreased as the aluminum applied increases in both lime treated and untreated soil. Roba 1 had high percent residue, cooking time and number of unsoaked seeds in both soil conditions than new BILFA 58. Aluminum treatment had increased the seed coat proportions of the seeds that means less storage of food in cotyledon which resulted in poor germination of the seed as observed in this study. Hundred seed weight and germination percentage of the seeds in both genotypes affected by aluminum application on both soil types with more effect seen on lime untreated soil.

Therefore, growing common bean genotypes with tolerant genotype with the application of lime improves the physical quality of the seed. Thus, for sustainable production of common bean on acid soil of western and south western Ethiopia one has to identify the tolerant genotype for this stress to obtain higher yield with improved bean seed physical quality.

Conflict of Interest

Authors declared no conflict of interest.

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