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Yield and agronomic performances of desi type chickpea genotypes against acidic soil of Western Ethiopia

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Currently, 40% of arable land in Ethiopia is affected by acidity and particularly the soil acidity problem that occurs in central and western zones of Oromia deserves immediate intervention for crop production. The objective of the present study was to examine responses of Desi type chickpea varieties against acidic soil of western Ethiopia. Pooled analysis of variance (ANOVA) indicated significant difference among genotypes indicating differential response of chickpea genotypes to acidic soil. The combined mean of genotypes indicates that Natoli and DZ-2012-CK-20113-2-0042 were top yielders. Differential response of chickpea genotypes indicates the possibilities of designing better chickpea breeding strategies that aim at screening large germplasms of chickpea genotypes for soil acidity tolerance and thereby developing a cultivar(s) with wider adaptations.

Key words: Chickpea (*Cicer arietinum* L.), yield, soil acidity, liming.

INTRODUCTION

Pulses play a significant role in sustaining food security, balancing ecosystem, and generating revenue in Ethiopia. Chickpea (*Cicer arietinum* L.) is the most important food legumes grown in Ethiopia. Although the ecological and economic contribution of chickpea is high, its productivity is by far below its potential because of the several biophysical and socioeconomic constraints in Ethiopia (Keneni et al., 2012).

Biotic and abiotic stresses cause significant economic losses to this crop (Datta et al., 2008). Among these factors, abiotic stresses due to soil acidity were one of the major factors that hamper chickpea productivity with worldwide distribution. Acidic soils limit crop production on 30-40% of the world's arable land and up to 70% of the world's potentially arable land. In Ethiopia 40% of arable land is currently affected by acidity and particularly the soil acidity problem that occurs in central and western zones of Oromia deserves immediate intervention and amelioration for crop production (Batjes, 1995; Abdenna et al., 2007; Abebe, 2007).

Soil pH is probably the most important principal chemical soil parameter and it mirrors the overall chemical status of the soil and influences a whole range of chemical and biological processes occurring in the soils. Most plants and soil organisms prefer pH range between 6.0 and 7.5 (Hazelton and Murphy, 2007; Hall,

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Table 1. Passport description of the test genotypes.

Genotype codes	Genotype names	Status	Year of release
G1	Akaki	Released	1995
G2	Dalota	Released	2013
G3	Dimtu	Released	2012
G4	Dubie	Released	1978
G5	Local	Local variety	-
G6	Mariye	Released	1985
G7	Minjar	Released	2010
G8	Natoli	Released	2007
G9	Teketay	Released	2013
G10	DZ-2012-CK-0032	Advanced line	-
G11	DZ-2012-CK-0034	Advanced line	-
G12	DZ-2012-CK-0233	Advanced line	-
G13	DZ-2012-CK-0237	Advanced line	-
G14	DZ-2012-CK-0312	Advanced line	-
G15	DZ-2012-CK-0313	Advanced line	-
G16	DZ-2012-CK-20113-2-0042	Advanced line	-

2008). Different scholars reported the pH of the soils in western Ethiopia is in acidic range and it needs immediate intervention and ameliorations for crop production (Chimdi et al., 2012; Deressa et al., 2013). Under such low pH, the availability of essential nutrients is critically affected. Moreover, the activities of microorganisms, which play pivotal roles in nutrient cycling in agro ecosystems, are affected (Addisu, 2007).

Several strategies have been pursued to manage acid soils including an application of lime (calcium carbonate) to raise soil pH to less toxic forms. Nevertheless, because of a topographic feature of the lands, affordability and logistics reasons, application of lime is not practicable for resource-poor farmers. Furthermore, soil pH below plow layer is raised very slowly by liming (Dall'Agnol et al., 1996).

Consequently, these reasons direct a need of developing cultivars that are adapted to acid soil complexes as a promising alternative for resource-poor farmers. Therefore, morphological characterization of plants that better tolerate acidity under the usual condition and give rise better yield and economic turn for poor farmers is a promising alternative to liming and related agronomic practices.

The present study was, therefore, conducted with the objective of examining the responses of Desi type chickpea genotypes against the acidic soils of western Ethiopia.

MATERIALS AND METHODS

Plant material and site description

Field experiment was conducted at five locations *viz.,* Shambu, Hawa Galan, Mata, Alaku Belle and Badesso, Western Ethiopia, during the 2016/2017 main cropping season. A total of 16 Desi type chickpea varieties *viz.,* 8 cultivars released over three decades, 1 local variety and 7 advanced lines introduced from Debre Zeit Agricultural Research Center (DZARC) were used (Table 1).

The experiment was laid out in a randomized complete block design (RCBD) with three replicates. The plot size was six rows of three-meter length (5.4 m^2). The central four rows were harvested to determine seed yield. Diammonium phosphate fertilizer (DAP) with a rate of 100 kg/ha was used and all other crop management and protection practices were applied uniformly as recommended.

Soil samples were collected and composited from each of the experimental sites at the depth of 0 to 20 cm using an auger to analyze the chemical properties of the soil. Description of the test locations for geographical position and the chemical properties of the soils in the study area are presented (Table 2).

Data collection and statistical analysis

Days to 50% flowering, days to 90% maturity, grain filling duration, number of pods per plant, number of seeds per pod, plant height, number of branches per plant, hundred seed weight, and grain yield data were collected based on chickpea (*Cicer arietinum* L.) descriptor (IBPGR, ICRISAT and ICARDA, 1993) and were subjected to analysis using statistical analysis software (SAS Inc., 2003).

RESULTS AND DISCUSSION

Analysis of variance

Pooled analysis of variance indicated highly significant differences for genotypes, environments and genotype × environment interaction (G×E). Variance component of sum squares were 55% for environments, 11% for genotypes and 12% for G×E. This indicated that

Table 2. Description of the test locations for geographical position and soil chemical properties.

Parameters	Sites				
	Shambu	H. Galan	Mata	A. Belle	Badesso
Latitude	09° 32'N	08° 38' N	08° 34' N	08° 37'N	08° 40' N
Longitude	037° 04'E	034° 50'E	034° 44'E	034° 42'E	034°47'E
Altitude (m.a.s.l.)	2776	1905	2016	2050	2054
Organic C (%)	4.01	3.27	3.64	3.95	3.61
TN (%)	0.40	0.22	0.33	0.33	0.37
pH (H_2O 1:2:5)	4.59	4.96	5.3	5.19	5.26
pH (KCl 1:2:5)	4.09	4.3	4.59	4.44	4.65
Exchangeable acidity	1.35	0.3	0.07	0.24	0.14
Exchangeable Al^{+3}	0.66	ND	ND	ND	ND
EC (S/m)	0.27	0.06	0.06	0.17	0.09
CEC	41.53	28.52	36.16	35.74	36.07
Na	0.16	0.1	0.13	0.24	0.09
K	0.34	0.81	0.06	1.13	1.26
Ca	8.1	11.55	16.69	19.11	11.77
Mg	4.6	3.85	7.7	5.46	9.42

Key: ND =Not detected.

Table 3. Combined analysis of variance of grain yield (t/ha) of chickpea genotypes tested across five environments.

Source of variation	DF	SS	MS
Environments (E)	4	79.62	19.9***
Block (B)	10	10.62	1.06***
Genotypes (G)	15	15.89	1.05***
G×E	60	17.56	0.29***
Error	150	19.76	0.13
Total	239	143.45	-
CV (%)	21.7	-	-
LSD	0.262	-	-
R^2	87%	-	-
Grand mean	1.67	-	-

environmental factors played a leading role for the variability observed among chickpea genotypes in western Ethiopia. In addition to the environmental factors, the contribution of G×E was also appreciable. The significant G×E suggests that grain yield of chickpea genotypes varied across environmental conditions (Table 3).

Yield performance

The mean grain yield of the sixteen genotypes tested at five environments of Western Ethiopia indicated statistically significant difference among genotypes. At Alaku Belle, genotype DZ-2012-CK-20113-2-0042 and Natoli were better performers while Dubie was the worst performer where the best performer genotypes exceeded it by more than two-fold.

At Badesso, genotype DZ-2012-CK-0237 performed better than any other genotype and Akaki was found to be the poorest of all at this location. At Hawa Galan and Shambu, genotype DZ-2012-CK-0032 out-performed the other genotypes while local variety was the poorest performer at both the locations. At Mata, genotype, DZ-2012-CK-20113-2-0042 was the best performer as in Alaku Belle and the performance of the local variety was the poorest in a similar fashion it displayed in Shambu and Hawa Galan (Table 4). This result is in agreement with the report of Getachew et al. (2015) who showed inconsistent performances of chickpea genotypes in central and eastern Ethiopia.

Tolessa (2015) conducted multi-locational studies of seventeen Faba bean varieties and reported that the varieties responded differentially in southeastern and central Oromia. Similar result was noted on sesame in northern Ethiopia (Tadesse and Abay, 2011). The combined mean of genotypes indicates that Natoli and DZ-2012-CK-20113-2-0042 were top yielders though they did not differ in a statistically significant manner from Minjar, Teketay, DZ-2012-CK-0032, and DZ-2012-CK-0237 (Table 4).

Agronomic performance

Differences among the genotypes were significant for a number of characters (Table 5). A local variety included in this investigation flower early (60) and relatively mature intermediary. This indicated that local landraces had a relatively longer grain filling period.

Table 4. Pooled mean grain yields (t/ha) of chickpea genotypes tested in five environments.

Genotypes Code	Environments					
	AB	BD	HG	MT	SH	Mean
G1	1.44	0.49	1.34	2.26	0.59	1.23[e]
G2	1.76	1.31	1.48	2.51	0.73	1.56[dc]
G3	1.94	1.88	1.49	2.62	0.75	1.74[bc]
G4	1.22	1.24	1.46	2.25	0.68	1.37[de]
G5	1.25	1.80	1.17	2.15	0.40	1.35[de]
G6	1.55	2.13	1.25	2.33	0.49	1.55[dc]
G7	2.06	2.11	1.60	2.75	0.86	1.88[ab]
G8	2.46	2.20	1.65	2.95	0.94	2.04[a]
G9	1.81	2.45	1.80	2.74	1.03	1.97[ab]
G10	1.40	2.39	1.85	2.58	1.04	1.85[ab]
G11	1.47	1.25	1.39	2.33	0.64	1.42[de]
G12	1.66	2.43	1.42	2.48	0.66	1.73[bc]
G13	1.87	3.07	1.38	2.59	0.63	1.91[ab]
G14	1.28	1.53	1.30	2.21	0.53	1.37[de]
G15	1.50	1.98	1.66	2.51	0.88	1.7[1bc]
G16	2.48	1.97	1.71	2.98	0.99	2.02[a]
Mean	1.69	1.89	1.49	2.52	0.74	1.67

N.B. Different letters within a column indicate significant differences among genotypes at (P>0.05) significance level.

Similarly, Summerfield and Roberts (1988) reported early flowering genotypes do not certainly mature early and some late flowering genotypes have a short reproductive period and mature concurrently with earlier flowering ones. Wakeyo (2012) also tested 155 chickpea germplasms including landraces, improved varieties and some introduced pipelines indicating that landraces had a relatively shorter period of vegetative growth and longer grain filling periods. Except DZ-2012-CK-0032 and DZ-2012-CK-0233, all other advanced lines and improved varieties included within this study showed delayed flowering. This might be due to higher asset they employ at vegetative growth.

In contrast to this, though Natoli was late to flower (71.60); it pays its late flower by filling the grain as short as possible (64.3). Mariye (72.33), Minjar (72.47), DZ-2012-CK-20113-2-0042 (73.80) and Teketay (74.07) were also acquired a short grain filling period, whereas DZ-2012-CK-0312 was the late maturing genotype with accompanied long grain filling period (78.27). Minjar, Mariye and local landrace developed relatively higher number pods than other genotypes. Even though improved genotypes display small difference among themselves for seeds per pod; the difference with landraces was very high.

On the other hand, in terms of plant height, Mariye, Akaki, Natoli and local landraces were the shortest, whereas DZ-2012-CK-0313, Teketay, DZ-2012-CK-0312, Dubie and Dimtu were comparatively taller genotypes. Nevertheless, the pod bearing character of the local landrace, Natoli, Mariye and Minjar may not emanate from their branches. The local landraces included in this study were by far inferior by their seed weight. Wakeyo (2012) also reported that the seed size of landraces was not comparable to improved genotypes and released varieties. However, among released and advanced genotypes there were differential seed weights. Some of the released varieties namely Akaki, Dubie and Minjar also possess small seed weights. In the contrary, DZ-2012-CK-0312 and Dimtu showed higher seed weight than all the tested materials.

Overall, Natoli, Minjar, Teketay, DZ-2012-CK-0032, DZ-2012-CK-0237 and DZ-2012-CK-20113-2-0042 were the best performing genotypes. Akaki, a variety released two decades ago, was the poorest performing variety across all test environments, followed by Dubie, Local variety, DZ-2012-CK-0034 and DZ-2012-CK-0312 (Table 5).

Conclusion

This study revealed that chickpea genotypes differ in tolerance to soil acidity. Although some genotypes exhibited an outstanding performance in terms of grain yield and yield related traits, soil fertility improvement through lime application would still be very important if economical chickpea production is to be practiced in places with strong acid soil as the one used in this study and other similar growing environments. Generally, differential response of chickpea genotypes indicates the

Table 5. Pooled mean of phenological traits, yield and yield components of chickpea genotypes grown across five locations in western Ethiopia.

Genotype	Traits							
	DF	DM	GFP	NPPP	SPP	PH	BRN	HSW
1	63.47^{bcd}	138.33^{abcde}	74.87^{cde}	29.67^{cd}	1.34^{ab}	46.41^{ef}	3.78^{c}	23.64^{g}
2	62.87^{cde}	139.13^{abc}	76.27^{abcd}	28.07^{cd}	1.24^{b}	53.39^{abc}	4.04^{bc}	33.64^{b}
3	60.73^{fg}	138.73^{abcd}	78.00^{ab}	26.59^{cd}	1.16^{b}	55.47^{ab}	4.16^{bc}	36.56^{a}
4	61.53^{efg}	138.93^{abcd}	77.40^{abc}	32.15^{bcd}	1.15^{b}	54.04^{abc}	4.19^{bc}	23.46^{g}
5	60.07^{g}	138.07^{abcde}	78.00^{ab}	41.74^{a}	1.47^{a}	46.81^{def}	4.25^{bc}	14.01^{h}
6	64.87^{b}	137.20^{cde}	72.33^{e}	39.17^{ab}	1.23^{b}	44.35^{f}	4.52^{ab}	26.20^{f}
7	64.20^{bc}	136.67^{de}	72.47^{e}	42.60^{a}	1.26^{b}	52.11^{abc}	4.95^{a}	23.10^{g}
8	71.60^{a}	135.93^{e}	64.33^{f}	33.41^{bc}	1.28^{ab}	46.68^{def}	3.89^{bc}	32.40^{bcd}
9	64.87^{b}	138.93^{abcd}	74.07^{de}	29.36^{cd}	1.20^{b}	56.14^{a}	4.09^{bc}	31.70^{cd}
10	60.67^{fg}	138.60^{abcd}	77.93^{abc}	31.97^{bcd}	1.18^{b}	52.80^{abc}	4.13^{bc}	29.05^{e}
11	61.73^{defg}	139.80^{ab}	78.07^{ab}	26.05^{cd}	1.22^{b}	50.17^{cde}	3.88^{bc}	33.77^{b}
12	60.93^{fg}	138.47^{abcd}	77.53^{abc}	29.09^{cd}	1.22^{b}	53.94^{abc}	4.07^{bc}	31.10^{d}
13	64.80^{b}	139.93^{ab}	75.13^{bcde}	30.08^{cd}	1.16^{b}	51.15^{bcd}	4.36^{abc}	33.21^{bc}
14	62.20^{def}	140.47^{a}	78.27^{a}	26.37^{cd}	1.18^{b}	56.08^{a}	4.29^{bc}	38.35^{a}
15	61.8^{defg}	139.07^{abcd}	77.27^{abc}	29.46^{cd}	1.24^{b}	56.51^{a}	4.39^{abc}	32.47^{bcd}
16	64.07^{bc}	137.87^{bcde}	73.80^{de}	25.12^{d}	1.18^{b}	53.02^{abc}	3.75^{c}	31.47^{cd}
CV	4.02	2.43	5.75	32.78	21.82	11.96	21.71	8.55
R	90%	74%	80%	53%	33%	83%	45%	92%
LSD	1.83	2.43	3.12	7.4	0.19	4.47	0.65	1.83

Key: -DF=Days to flower, DM = Days to mature, GFP=Grain filling period, NPPP=Number of pods per plant, SPP=Number of seeds per pod, PH =Plant Height (cm), BRN=Number of branches, HSW=Hundred seed weight (g), GYLD=Grain yield (t/ha).

possibilities of designing better chickpea breeding strategies that aim at screening large germplasm of chickpea for soil acidity tolerance and thereby developing a cultivar(s) with wider adaptations.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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