Annals of Agricultural & Crop Sciences

Open Access

Austin Publishing Group

Research Article

Evaluation of Chickpea Varieties Growing on Residual Moisture of Vertisols in Southern Ethiopia

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Received: August 25, 2021; **Accepted:** September 29, 2021; **Published:** October 06, 2021

Abstract

Vertisols are suited to dry-land crop production in semi-arid environments since the residual moisture in the soil can support crop growth after the end of the rainy season. However, traditional cropping systems seldom utilize residual moisture of Vertisols for crop production. Farmers need suitable crop species to sustain and enhance their production under such soil and climatic conditions. Chickpea is the strategic crop well adapted to Vertisols and derives most of its water requirements from the residual soil moisture. Yet, different chickpea varieties found to adapt and produce different yields at different locations. The experiments were conducted for two consecutive years (2016 and 2017) on farmers training centers in two districts of Southern Ethiopia. Six released varieties; Arerti, Habru, Yelibe, Naatolii, Fetenech, Kutaye and a Local check were used for the experiment. The trials were laid in a randomized complete block design with four replicates. Data were collected on phenological traits, growth and yield attributes, and grain yield. The results showed that there was significant variation among the tested chickpea varieties in all the agronomic traits recorded. Varieties Arerti and Habru revealed superiority in grain yield, pod setting, hundred seed weight and biomass over the Local check across locations. Based on yielding performance and farmers' preference, varieties Arerti and Habru are recommended for production in the selected districts and similar agro-ecologies in southern Ethiopia.

Keywords: Chickpea; Residual moisture; Variety; Vertisols

Introduction

Climate change related insidious, particularly erratic and unreliable rainfall has considerable negative effect on livelihood of smallholder farmers in semi-arid tropics. In these regions, average annual rainfall seems enough to produce one or two crops per year; but, rainfall pattern is highly erratic with frequent dry periods within the rainy season [1]. The shift in the timing and amount of rainfall interrupt agricultural production and food security [2]. Vertisols are suited in semi-arid tropics as the soil can provide the residual moisture for the crop after the cessation of the rainy season. However, traditional cropping systems seldom utilize residual moisture for crop production in the region. Farmers need suitable cropping system to fully exploit the productive potential of Vertisols under such climatic conditions.

Chickpea is one of the main food legumes in Ethiopia [3] usually grown toward the end of the main rainy season using residual moisture in Vertisols. The crop is widely grown in the semi-arid regions of the country by subsistence farmers under rain-fed conditions [4]. Chickpea production gives smallholder farmers the opportunity to be engaged in double cropping for intensive and productive land use [5]. The crop is also known for its soil nitrogen enrichment and rotational advantages as well as cheaper cost of production than other field crops. In addition, the growing demand of chickpea in both domestic and export markets provides income for smallholder producers and contributes to the country's foreign exchange earnings [6]. Smallholder farmers are well-positioned to earn better income while improving soil fertility on their limited land. Furthermore, the crop enhances livestock productivity as its residue is rich in digestible crude protein [7].

Since its inception, chickpea research in Ethiopia has focused on landrace evaluation and germplasm enhancement from which various chickpea varieties have been developed and released for production [8]. To fully exploited production potential, the varieties should be productive and match the growing conditions in the country. Several research findings [9-14] indicated that chickpea varieties produce significantly different yields at different locations emphasizing the need for their evaluation under various climatic and soil conditions. The participation of small-scale farmers is also limited during improved variety development. Thus, there is a considerable gap in identifying appropriate and adapted chickpea varieties for different agro-climatic conditions in Ethiopia. The aims of this research were to: (1) evaluate chickpea varieties for yield performance and adaptability, and (2) assess farmers' preference criteria for selecting chickpea varieties in two districts, Southern Ethiopia.

Materials and Methods

The experimental sites

The experiments were conducted under field condition in two districts (Borricha and Dalle) in southern Ethiopia during the main cropping season (August-December) of the years 2016 and 2017. Two locations, Dilla-Arfe and Darara-Goribe, in Borricha district and two locations, Debub-Kege and Semen-Mesenkela, in Dalle district were selected for field experiments. Samples were cored to a depth of 20cm from 20 random spots of the entire experimental

Citation: Allito BB and Geda GG. Evaluation of Chickpea Varieties Growing on Residual Moisture of Vertisols in Southern Ethiopia. Ann Agric Crop Sci. 2021; 6(6): 1096.

field and composited for determination of soil chemical and physical properties using standard laboratory methods [15]. Textural class of the surface soil of the study locations was classified as clay with the bulk density varied from 1.21 to 1.42 gcm^{-3}. The soil pH ranged from slightly alkaline (pH = 7.8) to alkaline (pH = 8.5) [16] with low organic carbon (1.02-1.71%) and total nitrogen contents (0.077-0.122%) [17]. Cation exchange capacity of the soils ranged from 34.41-47.4 cmol(+) kg^{-1} were within the very high range [17]. Exchangeable K and Mg in the study sites varied from 0.90-1.08 and 7.16-10.15 cmol(+) kg^{-1}, respectively whereas exchangeable Ca ranged from 23.31-34.37 cmol(+) kg^{-1}. Soil available phosphorus contents were low (less than 1.46mgkg^{-1}) suggesting that supplementary phosphorus is mandatory for optimum crop production. The soils of the study sites were classified as Vertisols.

Treatments and experimental design

A randomized complete block design with four replications was used to conduct the experiments. The trials included six released chickpea varieties, Arerti (FLIP 89-84C), Habru (FLIP 88-42C), Yelibe (ICCV-14808), Naatolii (ICCX-910112-6), Fetenech (ICCV-92069), Kutaye (ICCV-92033) and a Local check.

Land preparation was done following conventional practices to make the field suitable for planting. Each variety was planted in 10 rows of 4m length per plot. The inter-row and intra-row spacing was maintained at 40cm and 10cm, respectively. The crop was planted in mid to late August. Fertilizer was applied to all plots in the form of NPS at the recommended rate of 100kgha^{-1} at planting.

Data collection and analysis

Data were collected on the number of days to flowering and maturity, pods plant^{-1}, plant height, hundred seed weight, straw weight and grain yield. At physiological maturity, ten plants were sampled randomly from each plot leaving two border rows on both sides. The height of each sampled plant was measured and pods were counted. The number of seeds per pod was determined from 20 pods randomly selected from the sample plants.

The final plant stand of the eight central rows per plot was counted leaving 0.5m on both sides of each row. The pods were removed, sun dried and threshed by hand. The grain was further dried and weighed with sensitive balance. The moisture content was determined with portable moisture tester and adjusted to 10% stand moisture content. Hundred seed weight was measured from randomly counted 100 seeds per plot in three replicates. Ten plants per plot were randomly selected and cut at collar. The straws were cut into small pieces, placed in pre-marked paper bags, and then oven dried at 70^{0}C to constant weight. The above-ground biomass yield was obtained by adding the grain and straw yields.

The data collected were subjected to Analysis of Variance using SAS (2010) computer software (SAS Institute Inc.). Mean separation and comparison were done by using Duncan's Multiple Range Test. A Pearson correlation test was conducted to determine association among treatment means using a p <0.05 probability level.

Preference ranking

A total of 60 farmers, 15 farmers from each village, were invited to visit the experimental sites at pod filling, maturity, and harvesting stages. Participant farmers set selection criteria and used matrix ranking to identify the most suitable chickpea varieties for their locations. The participants were provided with rating sheet and asked to place the scale for each variety. A scale of 1-5 was used to assess traits with definitions as: 5 = not preferred, 4 = less preferred, 3 = moderately preferred, 2 = highly preferred and 1 = excellent. The scales were added to get total for each trait per variety and the smallest sum was assigned as first in rank.

Result and Discussion

Growth and yield attributes

The tested chickpea varieties revealed significant variations in all agronomic traits recorded except number of seeds per pod and harvest index despite the variations were slight among experimental locations (Figure 1). Days to flowering varied among chickpea varieties, and the varieties matured within 96 and 140 days. Chickpea varieties Yelibe and Fetenech showed the lowest (42 and 42) days to flowering and the shortest (96 and 109) days to maturity, respectively; whereas Ararti and Habru showed the highest (140 and 132) days to maturity, respectively. This variation might be due to the genetic variation as reported by Goa et al. [14]; Alemu et al. [9]; Gonzales and Gonzales [10].

Mean values for plant height among the tested chickpea varieties were significantly (p ≤0.05) different, ranging from 34.7 to 47.8 cm (Figure 2). The tallest variety was Habru (47.8cm) followed by Arerti (45.30cm) and Naatolii (45.0cm) whereas Fetenech was the shortest (34.7cm). These results are in line with the reports of Alemu et al. [9], Goa and Ashemo [13]. The result also revealed significant (p ≤0.05) variation in pod number per plant among the evaluated chickpea varieties ranging from 38.5 to 55.4 (Figure 2). Variety Arerti

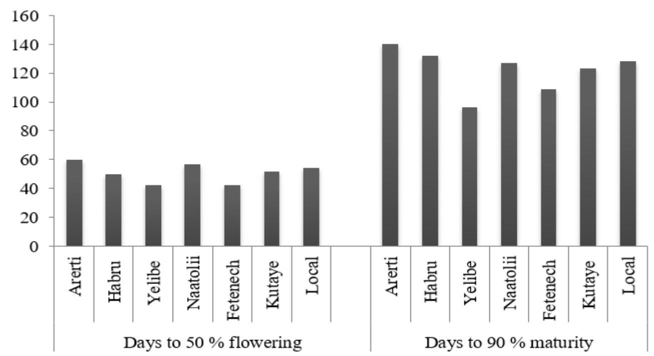

Figure 1: Days to flowering and physiological maturity.

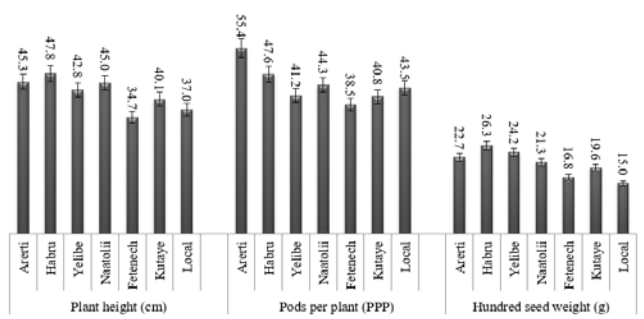

Figure 2: Average plant height, pods per plant and hundred seed weight over the study locations.

Table 1: Physico-chemical properties of soils at the experimental locations.

Parameters	Dilla-Arfe	Darara-Goribe	Debub-Kege	Semen-Mesenkela
pH (1:2; Soil:H_2O)[a]	8.2	7.8	8.1	8.5
Total nitrogen (%)[c]	0.08	0.11	0.09	0.12
Organic carbon (%)[d]	1.02	1.71	1.14	1.2
Available phosphorus (mg kg^{-1})[b]	1.38	1.12	1.26	1.46
Exchangeable bases ($cmol_{(+)}$ kg^{-1})[e]				
K	1.08	0.98	0.9	1.04
Ca	23.31	30.29	26.04	34.37
Mg	8.43	7.16	10.15	8.94
Na	0.88	0.97	0.85	1.13
CEC ($cmol_{(+)}$ kg^{-1})[e]	34.41	40.26	38.14	47.4
Bulk density (BD) (g cm^{-3})[f]	1.42	1.21	1.4	1.32
Textural class[g]	clay	clay	clay	clay

Method: [a]Carter and Gregorish [26]; [b]Olsen et al., [27]; [c]Bremner and Mulvaney [28]; [d]Walkley and Black [29]; [e]van Reeuwijk [15]; [f]Black and Hartge [30]; [g]Bouyoucos [31].

Table 2: Straw yield of the chickpea varieties at the study locations.

Varieties	Dilla-Arfe (t ha^{-1})		Darara-Goribe (t ha^{-1})		Debub-Kege (t ha^{-1})		Semen-Mesenkela (t ha^{-1})		Mean (t ha^{-1})
	I	II	I	II	I	II	I	II	
Arerti	5.09^{a}	4.61^{ab}	4.97^{a}	4.58^{ab}	4.88^{ab}	4.75^{ab}	5.11^{a}	4.88^{a}	4.86
Habru	5.27^{a}	5.25^{a}	4.81^{ab}	5.06^{a}	5.17^{a}	5.18^{a}	5.09^{a}	5.49^{a}	5.17
Yelibe	4.19^{b}	4.80^{a}	4.20^{bc}	4.81^{ab}	4.92^{ab}	4.47^{abc}	4.67^{ab}	4.83^{a}	4.61
Naatolii	3.87^{bc}	3.85^{bc}	3.88^{cd}	3.97^{bc}	4.10^{bc}	3.98^{bcd}	4.20^{bc}	3.59^{b}	3.93
Fetenech	4.11^{b}	3.65^{c}	3.46^{d}	3.60^{c}	3.72^{c}	3.85^{cd}	3.99^{bc}	3.68^{b}	3.76
Kutaye	3.59^{bc}	3.64^{c}	3.44^{d}	3.64^{c}	3.60^{c}	3.51^{d}	3.81^{c}	3.44^{b}	3.58
Local	3.27^{c}	3.63^{c}	3.25^{d}	3.50^{c}	3.55^{c}	3.38^{d}	3.72^{c}	3.36^{b}	3.46
CV (%)	12	12.4	11.6	14.3	13.3	13.2	11.6	13	4.2

Means within each column followed by the same superscript letter (s) are not significantly different at 5% as determined by Duncan's multiple range test; I = First year (2015); II = Second year (2016).

produced the highest (55.4) number of pods per plant, while Fetenech has the lowest (38.5) pods per plant. Similarly, Goa et al. [14] and Alemu et al. [9] reported remarkable variation in pod number per plant among chickpea varieties. Varietal differences in Hundred Seed Weight (HSW) were significant ($p \leq 0.05$) ranging from 15.0g (Local check) to 26.3g (Habru) (Figure 2). Variety Habru had the highest hundred seed weight followed by Yelibe and Ararti, whereas the Local Check and variety Fetenech had the lowest hundred seed weight. Comparably, Goa [11]; Ketema et al. [18] revealed significant variations of hundred seed weight among chickpea varieties. The results confirm the existence of significant genetic differences for the traits among the chickpea genotypes.

Straw yield

The mean straw yield of the chickpea varieties across locations and years was 4.20t ha^{-1}. Habru had the highest straw yield (5.17t ha^{-1}) followed by Ararti and Yelibe with the biomass yield of 4.86t ha^{-1} and 4.61kg ha^{-1}, respectively (Table 2). High biomass yielding varieties were those with longer maturity periods, which could be associated with their longer exposure and higher investment in vegetative growth. Genotype with the longer maturity period might have a better comparative advantage to assimilates, mobilize and use assimilates more efficiently having adequate period of time [19].

Grain yield

Analysis of variance indicated highly significant ($p \leq 0.01$) grain yield differences among the tested chickpea varieties at the study locations (Table 3). In Agreement with this finding, Alemu et al. [9]; Goa and Ashamo [13]; Gonzales and Gonzales [10] reported considerable variation among chickpea varieties indicating that grain yield potential of chickpea varied from variety to variety. The average grain yield of the chickpea varieties across locations ranged from 1.26t ha^{-1} for the Local Check to 1.91t ha^{-1} for Arerti. The promising varieties Arerti and Habru produced 1.91t ha^{-1} and 1.81t ha^{-1} of grain yields with 52% and 44.2% superiority over the Local Check, respectively. The yield differences indicate the possibility of obtaining high yielding varieties with proper selection in the fields.

Association of yield related traits with grain yield

The yield components exhibited varying degree of association with grain yield (Table 4). The straw yield had a highly significant and positive correlation with grain yield (0.97). Agreed with findings of Singh [20] and Bicer [21], the results herein demonstrated that increasing the straw yield would be an efficient way to boost up chickpea grain yield. Contrary to Khan [22] finding, harvest index and pods per plant had non-significant correlations with grain yield at 5% significance level, whereas the hundred seeds weight and plant

Table 3: Mean grain yield of the chickpea varieties at the study locations.

Varieties	Dilla-Arfe (t ha^{-1})		Darara-Goribe (t ha^{-1})		Debub-Kege (t ha^{-1})		Semen-Mesenkela (t ha^{-1})		Mean (t ha^{-1})
	I	II	I	II	I	II	I	II	
Arerti	1.90^{a}	1.83^{a}	2.02	1.83^{a}	1.92^{a}	1.92^{a}	1.92^{a}	1.93^{a}	1.91
Habru	1.79^{ab}	1.83^{a}	1.72^{a}	1.82^{a}	1.81^{ab}	1.86^{ab}	1.76^{ab}	1.89^{a}	1.81
Yelibe	1.53^{bc}	1.76^{ab}	1.62^{ab}	1.79^{a}	1.79^{ab}	1.70^{abc}	1.68^{bc}	1.73^{a}	1.7
Naatolii	1.46^{cd}	1.48^{bc}	1.54^{abc}	1.56^{ab}	1.56^{bc}	1.56^{bcd}	1.46^{cd}	1.39^{b}	1.5
Fetenech	1.35^{cd}	1.33^{c}	1.34^{bc}	1.33^{b}	1.32^{c}	1.45^{cd}	1.46^{cd}	1.33^{b}	1.36
Kutaye	1.26^{cd}	1.32^{c}	1.29c	1.32^{b}	1.26^{c}	1.26^{d}	1.25^{d}	1.27^{b}	1.28
Local	1.17^{d}	1.32^{c}	1.25^{c}	1.32^{b}	1.25^{c}	1.25^{d}	1.24^{d}	1.25^{b}	1.26
CV (%)	13.3	12.4	12.9	12.9	13.98	13.2	10.5	13.5	

Means within each column followed by the same superscript letter (s) are not significantly different at 5% as determined by Duncan's multiple range test; I = First year (2015); II = Second year (2016)

Table 4: Association of different independent variables to the dependent variable (yield) of chickpea varieties.

Independent variables	Grain yield	
	r	r^{2}
Straw yield hectare^{-1}	0.97**	0.93
Plant height	0.80*	0.64
Pods per plant	0.75	0.56
Hundred seed weight	0.85*	0.72
Harvest index (HI)	0.17	0.03

*Significant difference at $p \leq 0.05$; **Significant difference at $p \leq 0.01$.

height showed significant and positive correlation. Contrary to Ali et al. [23], Sharma and Saini [24] findings, stepwise correlation analysis indicated that straw yield and hundred seed weight were the most important traits which greatly contributed to the variation in grain yield. Ninety three percent of the total variations in grain yield of chickpea varieties were explained by straw yield. Similarly, Belete et al. [25] reported that straw yield contributed 97% of the variation in grain yield in chickpea varieties. In general, higher grain yield in chickpea varieties appears to be associated with the production of a higher biomass.

Farmers' preference ranking

Grain yield, biomass, pod number per plant, seed size and marketability were selection criteria set by farmers for ranking and selection of the best-fit chickpea varieties (Table 5 and 6). Overall assessment results in both study districts showed that, chickpea varieties Arerti, Habru and Yelibe were preferred as 1st, 2nd and 3rd, respectively.

Table 5: Matrix ranking of chickpea varieties based on farmers perception on various characters at Debub-Kege (DK) and Semen-Mesenkela (SM) villages.

Preference Criteria	Arerti		Habru		Yelibe		Naatolii		Fetenech		Kutaye		Local	
	DK	SM	DK	SM	DK	SM	DK	SM	DK	SM	DK	SM	DK	SM
Grain yield	1	1	1	2	2	3	3	3	4	3	4	4	5	4
Biomass	2	2	1	1	2	2	3	3	4	4	4	4	4	4
Pod number	1	1	2	2	4	4	3	2	5	3	4	3	3	2
Maturity/Earliness	3	4	3	4	1	1	3	3	1	1	2	2	2	2
Seed size	1	1	1	1	1	2	2	2	4	4	3	3	5	5
Market demand	1	1	1	1	2	2	2	2	4	3	3	3	5	4
Average score	1.5	1.7	1.5	1.8	2	2.3	2.7	2.5	3.7	3	3.3	3.2	4	3.5
Rank	1	1	1	2	2	3	3	4	5	5	4	6	6	7

Table 6: Farmers' chickpea variety preference ranking at Dilla-Arfe (DA) and Darara-Goribe (DA) villages.

Preference Criteria	Arerti		Habru		Yelibe		Naatolii		Fetenech		Kutaye		Local	
	DA	DG	DA	DG	DA	DG	DA	DG	DA	DG	DA	DG	DA	DG
Grain yield	1	1	2	2	2	2	3	3	4	4	4	4	5	5
Biomass	1	1	1	1	1	3	2	2	3	3	2	2	3	3
Pod number	1	1	2	2	4	4	2	2	4	4	3	3	3	3
Maturity/Earliness	5	4	5	4	1	1	3	3	2	2	2	2	2	2
Seed size	2	2	1	1	3	3	3	3	4	4	4	5	5	5
Market demand	1	1	1	1	2	3	2	2	3	3	3	3	4	5
Average score	1.8	1.7	2	1.8	2.2	2.7	2.5	2.5	3.3	3.3	3	3.2	3.7	3.8
Rank	1	1	2	2	3	4	4	3	6	6	5	5	7	7

Conclusion and Recommendation

Chickpea varieties, Arerti and Habru demonstrated superiority in grain yield, pod setting, hundred seed weight and straw yield over the Local Check, and they are best adapted to the test locations. Farmers' selection criteria in both districts were grain yield, biomass, pod setting, seed size and market demand. The best performing chickpea varieties, Arerti and Habru produced high, stable and consistent yield across locations and fulfilled all other farmers' requirements. Therefore, based on yielding performance and farmers' preference, varieties Arerti and Habru are recommended for production in the selected districts and similar agro-ecological zones in southern Ethiopia.

Acknowledgement

Hawassa University is gratefully acknowledged for financial support.

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