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Assessment of genetic variation and heritability of agronomic traits in chickpea (*Cicer arietinum* L)

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Abstract

The objective of this study was to evaluate the genetic variation and heritability of selected agronomic traits among chickpea genotypes. Replicated field experiments were conducted for 60 genotypes during the long and short rain seasons of 2013 at Kabete and Juja using alpha lattice design. Data were collected for days to 50 % flowering, plant height, days to 75 % maturity, pods plant $^{-1}$, yield ha $^{-1}$ and 100 seed weight and analysed using SAS 2013. Genotypes and genotype by environment interactions showed highly significant ($p < 0.0001$) variations for all studied traits. Genotypes were classified as early (< 50 days), moderate (50 – 55 days), late (55 – 60 days) and very late (> 60 days) in flowering. Fifteen genotypes were early (< 115 days) and 14 were late (> 120 days) in maturity. Genotypes took longer in flowering and maturity during the long rains in comparison with short rains in both sites. Genotypes further varied with respect to yield traits and categorized as low, moderate and high. The highest yield ha $^{-1}$ was recorded by ICC 9636 while ICC 9002 recorded the lowest. Broad sense heritability was high for most traits except days to 75 % maturity during long rains and pods plant $^{-1}$ in long rain Kabete. Characters with high broad sense heritability would be used as selection criterion for better yield. Promising, early flowering and maturing genotypes with reasonable yield traits from this study can be exploited for genetic improvement of chickpea.

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Introduction

Chickpea (*Cicer arietinum* L.) is the 3rd most important pulse crop in the world, after dry beans and field peas (FAOSTAT, 2008). It is grown mainly in the arid and semi-arid regions of the world with a total annual production of 9.6 million ton from 11.5 million hectares and an average yield of 0.84 ton ha $^{-1}$ (FAOSTAT, 2009). Chickpea is an important source of human food and animal feed due to its high protein, vitamins, minerals and fibre content. The total seed yield production is quite low in most chickpea growing countries and a wide gap exists between the potential (5 ton ha $^{-1}$) and actual (0.8 ton ha $^{-1}$) yields (FAOSTAT, 2008). The low yields have been attributed to several factors among which include low genetic diversity of cultivated chickpea and several biotic and abiotic stresses (Gaur *et al*., 2012).

Evaluation of crop genetic resources is a pre-requisite for which the future breeding work is based. The value of germplasm relies not only on the number of accessions it possesses, but also upon the genetic variability present in those accessions for agronomic and yield components (Reddy *et al*., 2012). Previous studies in chickpea have reported substantial variation for days to maturity; number of pods plant $^{-1}$, seed yield, biomass yield, 100 seed weight (Malik *et al*., 2009; Aslamshad *et al*., 2009), plant height, number of primary and secondary branches plant $^{-1}$ (Aslamshad *et al*., 2009; Ali *et al*., 2008). In addition to genetic variation, heritability of economically important characters is essential for effective breeding programme and selection of specific traits. High broad sense heritability has been reported in chickpea for 100 seed weight and number of seeds plant $^{-1}$ (Ali and Ahsan, 2012), number of secondary branches plant $^{-1}$ and seed yield (Malik *et al*., 2009), days to flowering and plant height (Khan *et al*., 2011). In other legumes, Okonkwo and Idahosa (2013) reported high broad sense heritability for yield and some agronomic traits in soybean.

Heritability act as predictive tool in expressing the reliability of phenotypic traits and thus high heritability could assist in effective selection of particular characters and devise future breeding programme of chickpea.

In Kenya, chickpea is a relatively new crop and preliminary studies show that chickpea is adapted to varied agro-ecological-zones of the country (Kibe and Onyari, 2006; ICRISAT, 2008) and its cultivation is gradually expanding in the Rift Valley and dry highlands. Limited information is available on the performance of important agronomic traits and breeders lack baseline information needed to effectively improve chickpea productivity in the country and in the region. The objective of this study was to evaluate the genetic variation and heritability of selected agronomic traits currently being evaluated for adoption in the country.

Materials and methods

Sites

The experiment was conducted at the University farm of Jomo Kenyatta University of Agriculture and Technology, Juja and the field station of the University of Nairobi, Kabete, Kenya during the long and short rain seasons of each site. Juja is located about 36 km North East of Nairobi at 1°11´ 0´´S, 37° 7´ 0´´E with an altitude of 1530 m above sea level. It is in upper midland zone 4, semi-humid to semi-arid. It receives an annual rainfall of 600 – 800 mm and mean annual temperature of 18.9 °C and clay soils (Kaluli *et al*., 2011). Kabete is located about 15 km to the West of Nairobi and lies at a latitude of 1°15' S, longitude 36° 41' E with an altitude of 1940 m above sea level and is in upper midland zone 3 (Sombroek *et al*.,1982). It is semi - humid with mean annual rainfall of 1000 mm and mean annual temperature of 18°C and deep and friable reddish or brown, friable clay soils ((Karuku *et al*., 2012). Both experimental sites have bimodal rainfall pattern with peaks in April (long rain season) and November (short rain season).

Plant Materials and Experimental Details

Fifty eight *desi* genotypes and two checks were used in this study (Table 1). The genotypes were obtained from ICRISAT gene bank, Nairobi, Kenya. Prior to planting, the experimental fields were ploughed and manually leveled with the help of spade and fork jembe.

The genotypes were evaluated in the field using alpha lattice design with three replications. Each plot comprised of two rows with a gross area of 2.5 m^2. Genotypes were randomly assigned to entire plots in each block within replication at both sites. All genotypes were sown in two rows with inter row spacing of 50 cm.

Seeds were sown by hand drilling on 14th of May (long rain Kabete), 28th of May (long rain Juja), 18th of November (short rain Kabete) and 29th of December (short rain Juja), 2013 for season I and II, respectively. Two weeks after emergence, plants were thinned to maintain intra-row spacing of 10 cm.
The field experiment was rain-fed and supplementary irrigation was provided when necessary. All the cultural practices were performed as recommended for chickpea production.

Data Collection
Data were recorded based on the available descriptors for chickpea (*Cicer arientinum* L) (IBPGR, ICRISAT and ICARDA, 1993). Days to 50 % flowering, days to 75 % maturity and seed yield ha $^{-1}$were recorded on plot $^{-1}$ basis while other characters were recorded on six randomly selected and pre-tagged plants from the middle two rows of each plot.

The main parameters recorded were as follows:
Days to 50 % Flowering (DF)
Number of days from emergence to the time when 50 % of the plants in the plots produced at least one open flower.

Plant Height (PH)
The height (cm) of the plant was measured from the ground level to the tip of the plant using a ruler at 75 % physiological maturity.

Days to Maturity (DM)
Number of days from emergence to the time when 75 % of the plants in the plot reached physiological maturity.

Number of Pods Plant $^{-1}$ (PP $^{-1}$)
The total number of pods plant $^{-1}$ were counted on six randomly selected and pre-marked plants and recorded as pods plant $^{-1}$.

Seed Yield (SY)
This parameter was recorded after harvesting, threshing and winnowing (in g or kg). The seed yield was weighed using electronic balance on net plot $^{-1}$ basis and later converted into kilo gram ha $^{-1}$ for each genotype.

Hundred Seed Weight (HSW)
100 seeds were counted in triplicate and weighed using electronic balance and recorded in gram plot $^{-1}$of each genotype in three replications.

Data Analysis
Data were analysed using SAS Insitute Inc. 2013 and broad sense heritability (H^2) was calculated according to Johnson *et al.* (1955) as below;

Broad Sense Heritability (H^2) = $\frac{\sigma^2 G}{\sigma^2 P} \times 100$

Where σ^2G and σ^2P - genotypic and phenotypic variances respectively.

Results
Days to 50 % Flowering (DF)
The genotypes and genotype by environment interactions showed highly significant ($p < 0.0001$) variations in their response to flowering in all environments (Table 2). All genotypes took longer to flower during the long rain seasons in comparison to short rains in both sites (Table 2). Some of the earliest (ICC 1356, ICC 16915, ICC 15614) and latest (ICC 791, ICC 12928, ICC 11944, ICC 2242) flowering genotypes in Juja consistently flowered early and late respectively under Kabete conditions.

The results further displayed that many genotypes flowered earlier than the check varieties ICCV 00108 and ICCV 97105, which indicated a good potential of obtaining even earlier flowering genotypes from the evaluated germplasm. Overall, the results classified 13 genotypes as early (< 50 days), 17 as moderate (50 – 55 days) and 17 as late (55 – 60 days) and 13 very late (> 60 days) in their response in flowering. The earliest flowering genotypes were ICC 8318 (45.8 days) and ICC 1398 (45.9 days) closely followed by ICC 506 (46.3 days) and ICC 16915 (46.8 days) while genotypes ICC 12928 (70.8 days) and ICC 791 (70.7 days) were the latest in flowering (Table 2). The check varieties were grouped as moderate in flowering. The grand means of days to 50 % flowering were 62.7 days, 50.7 days, 61.6 days and 48.4 days in the long rain Juja, short rain Juja, long and short rain season Kabete respectively.

Table 1. Chickpea Genotypes used in this Study and their Country of Origin.

Name	*Origin*	*Name*	*Origin*	*Name*	*Origin*
Annigeri	India	ICC 6294	Iran	ICC 6877	Iran
ICC 1052	Pakistan	ICC 15614	Tanzania	ICC 7326	Unknown
ICC 10685	Turkey	ICC 16261	Malawi	ICC 7413	India
ICC 11198	India	ICC 16524	Pakistan	ICC 7867	Iran
ICC 1164	Nigeria	ICC 16915	India	ICC 791	India
ICC 11903	Germany	ICC 1715	India	ICC 8318	India
ICC 11944	Nepal	ICC 2242	India	ICC 8522	Italy
ICC 12851	Ethiopia	ICC 2580	Iran	ICC 9002	Iran
ICC 12928	India	ICC 3325	Cyprus	ICC 9636	Afghanistan
ICC 13124	India	ICC 4093	Iran	ICC 9702	Afghanistan
ICC 1356	India	ICC 4182	Iran	ICC 9712	Afghanistan
ICC 1392	India	ICC 4463	Iran	ICC 9862	Afghanistan
ICC 1397	India	ICC 4657	India	ICC 9872	Afghanistan
ICC 8200	Iran	ICC 4872	India	ICC 9895	Afghanistan
ICC 1398	India	ICC 4991	India	ICCV 07102	ICRISAT
ICC 4918	India	ICC 506	India	ICCV 00108 (Check)	ICRISAT
ICC 14051	Ethiopia	ICC 5504	Mexico	ICCV 07111	ICRISAT
ICC 1422	India	ICC 5613	India	ICCV 10	ICRISAT
ICC 14815	India	ICC 5639	India	ICCV 00104	ICRISAT
ICC 1510	India	ICC 6579	Iran	ICCV 97105 (Check)	ICRISAT

Plant Height (PH)

There were highly significant (p < 0.0001) differences among the evaluated genotypes and genotype by environment interactions for plant height (Table 2). The evaluated genotypes recorded the highest plant height in Juja (long and short rains) as compared with Kabete (long and short rains). Genotypes with the highest plant height during long and short rain season at Juja (ICC 6877, ICC 4182 ICC 7867) recorded the highest plant height in Kabete except changing of their rank. Some of the shortest (ICC 11194, ICC 4657, ICC 11198) genotypes for plant height in Juja recorded the shortest under Kabete conditions. The results noticed a crossover genotype by environment interactions among the genotypes except for ICC 11944 which consistently recorded the shortest plant height across environments.

The current findings further indicated that many genotypes were shorter and taller than the check varieties ICCV 00108 and ICCV 97105 for plant height. Overall, the studied genotypes differed in plant height and could be classified as follows: 12 genotypes were short (< 40 cm), 44 as medium (40.1 – 55 cm) and 4 genotypes were tall (> 55 cm) which indicated that there was a good potential of the acquiring genotypes with modest plant height from the evaluated germplasm (Table 2). The check varieties were classified as medium plant height. Referring the grand means, the performance of evaluated genotypes in ascending order for plant height ranked as follows: short rain Juja (39.5 cm) < short rain Kabete (41.0 cm) < long rain Kabete (46 cm) < long rain Juja (52 cm).

Table 2. Means and Standard Error of Days to 50 % Flowering and Plant Height for the Highest(15) and the Lowest (5) Seed Yielding Genotypes at Juja and Kabete Table 2: Means and Standard Error of Days to 50 % Flowering and Plant Height for the Highest(15) and the Lowest (5) Seed Yielding Genotypes at Juja and Kabete.

	Days to 50 % Flowering					*Plant Height (cm)*					
	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	P. value
Genotypes	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	
ICC 9636	65.7±3.0	53.8±1.0	77.0±3.2	55.0±0.9	62.9	53.2±3.0	43.2±2.3	39.3±3.0	41.5±1.8	44.3	< 0.0001
ICCV 97105 (Check)	56.4±3.0	49.0±1.0	59.4±3.2	47.0±0.9	52.9	56.0±3.0	49.1±2.3	41.6±3.0	39.6±1.8	46.6	< 0.0001
ICCV 00108 (Check)	59.3±3.0	49.0±1.0	54.0±3.2	49.9±0.9	53.0	52.6±3.0	46.3±2.3	41.7±3.0	41.3±1.8	45.5	< 0.0001
ICC 6579	59.3±3.0	53.2±1.0	55.5±3.2	49.6±0.9	54.4	48.1±3.0	42.5±3.0	38.0±3.0	40.4±1.8	42.2	< 0.0001
ICC 5639	66.9±0.3	58.9±1.0	69.6±3.2	53.4±0.9	62.2	50.6±3.0	41.3±2.3	37.8±3.0	39.1±1.8	42.2	< 0.0001
ICC 1052	64.8±3.0	47.1±1.0	54.0±3.2	51.5±0.9	54.4	61.7±3.0	50.7±2.3	44.5±3.0	45.9±1.8	50.7	< 0.0001
ICC 15614	51.5±3.0	48.8±1.0	53.5±3.2	42.0±0.9	49.0	49.7±3.0	39.9±2.3	38.2±3.0	35.3±1.8	40.8	< 0.0001
ICC 3325	53.5±3.0	47.0±1.0	57.4±3.2	44.3±0.9	50.5	48.4±3.0	35.8±2.3	32.8±3.0	35.5±1.8	38.1	< 0.0001
ICC 16915	51.3±3.0	38.5±1.0	54.1±3.2	43.2±0.9	46.8	59.0±3.0	50.4±2.3	45.8±3.0	43.9±1.8	49.8	< 0.0001
ICC 4182	63.6±3.0	44.8±1.0	56.2±3.2	48.6±0.9	53.3	63.8±3.0	59.1±2.3	49.5±3.0	49.9±1.8	55.6	< 0.0001
ICC 7867	69.8±3.0	55.6±1.0	62.9±3.2	51.4+0.9	59.9	65.9±3.0	62.2±2.3	50.5±3.0	51.7±1.8	57.6	< 0.0001
ICC 1356	49.0±3.0	45.6±1.0	51.1±3.2	43.6±0.9	47.3	45.5±3.0	36.9±2.3	30.8±3.0	37.6±1.8	37.7	< 0.0001
ICC 1422	51.7±3.0	43.4±1.0	53.1±3.2	44.9±0.9	48.3	51.9±3.0	45.0±2.3	38.6±3.0	39.6±1.8	43.8	< 0.0001
ICC 4093	61.3±3.0	48.4±1.0	55.6±3.2	49.2±0.9	53.6	53.9±3.0	48.2±2.3	41.2±3.0	41.1±1.8	46.1	< 0.0001
ICC 16261	69.3±3.0	55.9±1.0	67.1±3.2	46.9±0.9	59.8	54.0±3.0	41.1±2.3	41.3±3.0	39.8±1.8	44.0	< 0.0001
ICC 8522	52.6±3.0	47.9±1.0	51.5±3.2	47.2±0.9	49.8	51.4±3.0	44.6±2.3	39.5±3.0	43.2±1.8	44.7	< 0.0001
ICC 11944	73.4±3.0	60.4±1.0	80.9±3.2	56.4±0.9	67.8	38.2±3.0	31.8±2.3	24.4±3.0	31.0±1.8	31.4	< 0.0001
ICC 9862	68.5±3.0	52.7±1.0	65.3±3.2	48.1±0.9	58.7	60.4±3.0	56.3±2.3	43.4±3.0	46.4±1.8	51.6	< 0.0001
ICC 791	76.2±3.0	65.3±1.0	88.4±3.2	53.0±0.9	70.7	46.0±3.0	38.7±2.3	30.4±3.0	40.3±1.8	38.9	< 0.0001
ICC 9002	64.1±3.0	57.9±1.0	73.0±3.2	49.1±0.9	61.0	44.1±3.0	38.8±2.3	28.1±3.0	35.5±1.8	36.6	
Mean	62.3	50.7	61.4	48.4	55.7	52.8	46.0	39.5	41.0	44.8	
Minimum	49.0	34.6	45.5	40.8	45.8	38.2	31.8	24.4	31.0	31.4	
Maximum	76.5	65.3	88.5	62.6	70.8	68.8	62.7	52.0	51.7	57.6	

Days to Maturity (DM)

The genotypes and genotype by environment interactions exhibited highly significant ($p < 0.0001$) differences for days to 75 % physiological maturity (Table 3). The evaluated genotypes took longer time to mature during the long rain season in comparison with the short rains in both sites. Genotypes showed inconsistency in response to their maturity which indicated a crossover genotype by environment interactions.

The results discovered many genotypes matured earlier than the check varieties ICCV 00108 and ICCV 97105, which indicated the potential generating genotypes with early maturity from the evaluated germplasm. Overall, the current findings indicated different groups genotypes in maturity such as early, moderate and late matured genotypes and hence 15 genotypes could be classified as early (< 115 days) and 14 genotypes were late (> 120 days) in maturity. Genotypes ICC 2580 (111.1 days) and ICC 15614 (111.3 days) closely followed by ICC 14815 (111.5 days), ICC 3325 (112.1 days) and ICC 1397 (112.4 days) were the earliest in maturity and genotypes ICC 5639 (126.5 days) ICC 4463 (124.4 days) and ICC 7867(12.4 days) were late in maturity (Table 3). The check varieties were grouped as moderate in maturity. The grand means for days to 75 % maturity during the long and short rain season at Juja, long and short rain season at Kabete were 124.6 days, 97.9 days, 141.8 days and 105.3 days respectively.

Number of Pods Plant $^{-1}$(PP $^{-1}$)

There were highly significant ($p < 0.0001$) differences among evaluated genotypes and genotype by environment interactions for number of pods plant $^{-1}$ (Table 3). Majority of the assessed genotypes recorded the highest number of pods plant $^{-1}$ during the long rain season in comparison with short rain season in both sites (Table 3). Genotypes recorded the highest number of pods plant during long rain season at Juja as compared with long rain season at Kabete. The grand means for number of pods plant $^{-1}$ were 210.0, 125.3, 121.3 and 110.9 in long rain season at Juja, short rain season at Juja, long and short rain season at Kabete respectively. Genotypes perform and respond differently across environments for number of pods plant $^{-1}$.

Table 3. Means and Standard Error of Days to 75 % Maturity and Number of Pods Plant $^{-1}$ for the Highest (15) and Lowest (5) Seed Yielding Genotypes at Juja and Kabete.

	Days to 75 % Maturity					*Number of Pods Plant $^{-1}$*					
	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	
Genotypes	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	P. value
ICC 9636	125.0±2.6	98.9±1.6	144.5±2.4	101.9±1.6	117.6	271.5±31.4	173.2±3.4	168.3±3.4	125.4±4.0	184.6	< 0.0001
ICCV 97105 (Check)	122.1±2.6	97.9±1.6	144.4±2.4	98.5±1.6	115.7	173.6±31.4	131.2±3.4	118.4±3.4	89.0+4.0	128.1	< 0.0001
ICCV 00108 (Check)	120.4±2.6	94.3±1.6	144.3±2.4	113.4±1.6	118.1	175.8±31.4	70.6±3.4	114.2+3.4	87.1±4.0	111.9	< 0.0001
ICC 6579	122.8±2.6	102.9±1.6	135.6±2.4	97.5±1.6	114.7	206.3±31.4	96.8±3.4	150.0±3.4	150.4±4.0	105.9	< 0.0001
ICC 5639	127.9±2.6	107.9±1.6	147.1±2.4	123.0±1.6	126.5	246.3±31.4	137.1±3.4	136.5±3.4	216.3±4.0	184.0	< 0.0001
ICC 1052	124.9±2.6	105.3±1.6	141.6±2.4	123.2±1.6	123.8	194.9±31.4	196.3±3.4	104.5±3.4	132.1±4.0	157.0	< 0.0001
ICC 15614	121.7±2.6	89.4±1.6	147.1±2.4	86.8±1.6	111.3	189.5±31.4	139.0+3.4	167.3±3.4	76.8±4.0	143.0	< 0.0001
ICC 3325	121.5±2.6	96.3±1.6	144.6±2.4	85.9±1.6	112.1	199.3±31.4	82.3±3.4	190.5±3.4	136.4±4.0	152.1	< 0.0001
ICC 16915	121.0±2.6	92.1±1.6	144.4±2.4	105.3±1.6	115.7	205.5±31.4	157.0±3.4	122.5±3.4	105.1±4.0	147.5	< 0.0001
ICC 4182	129.6±2.6	103.2±1.6	141.1±2.4	123.2±1.6	124.3	302.2±31.4	346.4±3.4	145.0±3.4	182.7±4.0	244.1	< 0.0001
ICC 7867	125.5±2.6	107.2±1.6	141.1±2.4	123.9±1.6	124.4	299.0±31.4	272.9±3.4	135.0±3.4	195.5±4.0	225.6	< 0.0001
ICC 1356	121.9±2.6	96.3±1.6	138.3±2.4	98.1±1.6	113.7	219.2±31.4	92.4±3.4	105.2±3.4	83.7±4.0	125.1	< 0.0001
ICC 1422	125.6±2.6	92.6±1.6	143.3±2.4	89.4±1.6	112.7	238.4±31.4	71.1±3.4	131.5±3.4	76.9±4.0	129.5	< 0.0001
ICC 4093	121.1±2.6	101.2±1.6	143.9±2.4	117.6±1.6	120.9	216.9±31.4	147.6±3.4	118.3±3.4	111.1±4.0	148.5	< 0.0001
ICC 16261	128.1±2.6	97.3±1.6	145.8±2.4	94.8±1.6	116.5	202.3±31.4	131.0±3.4	141.1±3.4	97.7±4.0	143.0	< 0.0001
ICC 8522	128.7±2.6	93.3±1.6	138.8±2.4	105.6±1.6	116.6	204.1±31.4	137.0±3.4	117.4±3.4	141.4±4.0	150.0	< 0.0001
ICC 11944	126.3±2.6	99.2±1.6	148.1±2.4	94.1±1.6	116.9	186.9±31.4	67.7±3.4	89.7±3.4	98.3±4.0	110.6	< 0.0001
ICC 9862	125.4±2.6	102.7±1.6	139.3±2.4	111.9±1.6	119.8	208.6±31.4	233.4±3.4	99.3±3.4	168.6±4.0	177.5	< 0.0001
ICC 791	130.1±2.6	100.7±1.6	146.6±2.4	115.5±1.6	123.2	189.3±31.4	78.2±3.4	119.7±3.4	182.8±4.0	142.5	< 0.0001
ICC 9002	122.8±2.6	96.4±1.6	138.7±2.4	102.5±1.6	115.1	178.6+31.4	75.4±3.4	79.9±3.4	76.2±4.0	102.5	
Mean	124.6	97.9	141.8	105.3	117.4	210.0	125.3	121.3	110.9	141.9	
Minimum	119.2	88.6	135.6	85.9	111.1	151.3	49.0	65.7	58.9	101.1	
Maximum	132.1	107.9	148.3	123.9	126.5	321.4	346.4	190.5	247.0	244.1	

The present findings displayed several genotypes out-yielded the check varieties ICCV 00108 and ICCV 97105 for number of pods plant $^{-1}$. These indicated the potential of acquiring genotypes with high number of pods plant $^{-1}$ from the evaluated germplasm. Overall, the findings discovered that 16, 26 and 18 genotypes had low (< 120 pods), moderate (120 -150) and high (> 150) for number of pods plant $^{-1}$. The highest number of pods plant $^{-1}$ were recorded in genotype ICC 4182 (224.1), ICC 7867 (225.6), ICC 7326 (190.0), ICC 9636 (184.6) and ICC 7872 (184.1). While genotypes ICC 13124 (101.1) and ICC 9002 (102.5) recorded the lowest number of pods plant $^{-1}$(Table 3). The check varieties ICCV 00108 and ICCV 97105 had 101.1 and 128.1 pods plant $^{-1}$ respectively. Referring the grand means, the order of evaluated genotypes performance from low number of pods to high number of pods plant $^{-1}$ ranked as follows short rain Kabete (110.9.) < long rain Kabete (121.3) < short rain Juja (125.3) < long rain Juja (210.0). The results further indicated the immense potential of obtaining high pod yielding genotypes from the germplasm and thus could be utilized in future breeding of chickpea.

Table 4. Means and Standard Error of Seed Yield and 100 Seed Weight of the Highest Yield (15) and the Lowest(5) Seed Yielding Genotypes at Juja and Kabete.

	Seed Yield (ton ha $^{-1}$)					*Hundred Seed Weight (g)*					
	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	
Genotypes	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	P. value
ICC 9636	3.19±0.3	0.82±0.2	2.09±0.3	1.27±0.2	1.84	20.1±0.9	21.0±0.7	17.1±1.0	23.9±0.6	20.6	< 0.0001
ICCV 97105 (Check)	2.75±0.3	0.87±0.2	2.13±0.3	1.38±0.2	1.78	27.7±0.9	25.4±0.7	28.9±1.0	22.8±0.6	26.2	< 0.0001
ICCV 00108 (Check)	2.54±0.3	0.79±0.2	2.35±0.3	1.41±0.2	1.77	28.0±0.9	21.3±0.7	29.3±1.0	26.4±0.6	26.2	< 0.0001
ICC 6579	2.72±0.3	1.18±0.2	1.52±0.3	1.56±0.2	1.74	20.0±0.9	22.7±0.7	17.2±1.0	23.9±0.6	20.9	< 0.0001
ICC 5639	2.51±0.3	1.09±0.2	1.82±0.3	1.28±0.2	1.68	18.5±0.9	19.5±0.7	15.6±1.0	19.3±0.6	18.2	< 0.0001
ICC 1052	2.33±0.3	1.62±0.2	1.29±0.3	1.33±0.2	1.64	18.8±0.9	22.3±0.7	17.5±1.0	18.0±0.6	19.1	< 0.0001
ICC 15614	2.54±0.3	0.71±0.2	1.92±0.3	1.39±0.2	1.64	20.1±0.9	21.2±0.7	18.5±1.0	28.0±0.6	22.0	< 0.0001
ICC 3325	2.78±0.3	0.83±0.2	1.49±0.3	1.42±0.2	1.63	22.0±0.9	22.2±0.7	19.8±1.0	22.1±0.6	21.5	< 0.0001
ICC 16915	2.49±0.3	0.87±0.2	1.69±0.3	1.33±0.2	1.60	24.5±0.9	26.5±0.7	23.0±1.0	25.1±0.6	24.8	< 0.0001
ICC 4182	2.05±0.3	1.61±0.2	1.31±0.3	1.39±0.2	1.59	21.3±0.9	26.6±0.7	16.4±1.0	20.6±0.6	21.2	< 0.0001
ICC 7867	2.34±0.3	1.50±0.2	1.08±0.3	1.37±0.2	1.57	23.8±0.9	20.8±0.7	21.2±1.0	26.2±0.6	23.0	< 0.0001
ICC 1356	2.15±0.3	0.72±0.2	1.51±0.3	1.86±0.2	1.56	22.2±0.9	21.1±0.7	20.2±1.0	22.6±0.6	21.5	< 0.0001
ICC 1422	2.58±0.3	0.76±0.2	1.78±0.3	1.14±0.2	1.56	24.3±0.9	22.2±0.7	22.2±1.0	29.7±0.6	24.6	< 0.0001
ICC 4093	2.50±0.3	0.90±0.2	1.69±0.3	1.05±0.2	1.53	17.7±0.9	22.2±0.7	15.2±1.0	22.1±0.6	19.3	< 0.0001
ICC 16261	2.42±0.3	0.60±0.2	1.65±0.3	1.46±0.2	1.53	19.7±0.9	25.3±0.7	17.5±1.0	23.2±0.6	21.4	< 0.0001
ICC 8522	1.62±0.3	0.55±0.2	0.96±0.3	0.62±0.2	0.94	20.3±0.9	27.2±0.7	18.4±1.0	23.2±0.6	22.3	< 0.0001
ICC 11944	1.45±0.3	0.47±0.2	0.87±0.3	0.86±0.2	0.91	17.5±0.9	26.0±0.7	15.8±1.0	26.1±0.6	21.4	< 0.0001
ICC 9862	1.49±0.3	0.63±0.2	0.71±0.3	0.70±0.2	0.88	22.6±0.9	20.1±0.7	19.8±1.0	22.2±0.6	21.2	< 0.0001
ICC 791	1.63±0.3	0.42±0.2	0.81±0.3	0.60±0.2	0.87	19.5±0.9	24.0±0.7	16.9±1.0	21.1±0.6	20.4	< 0.0001
ICC 9002	1.66±0.3	0.49±0.2	0.73±0.3	0.52±0.2	0.85	20.2±0.9	25.6±0.7	16.6±1.0	21.2±0.6	20.9	
Mean	2.09	0.77	1.32	1.05	1.30	22.4	23.3	20.3	24.5	22.6	
Minimum	1.45	0.42	0.71	0.52	0.85	17.1	18.6	13.3	18.0	18.2	
Maximum	3.19	1.62	2.35	1.86	1.84	34.7	31.5	34.5	36.1	33.8	

Seed Yield (SY)

The genotypes and genotype by environment interactions exhibited highly significant variations ($p < 0.0001$) for seed yield ha $^{-1}$(Table 4).

All genotypes studied recorded the highest seed yield ha $^{-1}$ during the long rain season in comparison to short rain season at Juja and some genotypes recorded the highest seed yield ha $^{-1}$ during short rain season at Kabete. The grand means for seed yield ha $^{-1}$ were 2.1 ton, 0.8 ton, 1.3 ton and 1.1 ton in long rain season at Juja, in short rain season at Juja, in long and short rain seasons at Kabete respectively. The results detected that some genotypes exceeded check varieties ICCV 00108 and ICCV 97105 for seed yield ha $^{-1}$ which indicated the importance of the evaluated germplasm for direct selection of genotypes for this particular trait. Overall, genotype ICC 9636 gave the highest seed yield ha $^{-1}$ (1.84 ton) followed by check varieties ICCV 97105 (1.78 ton), ICCV 00108 (1.77 ton). Genotypes ICC 3325 (1.63 ton), ICC 15614 (1.64 ton), ICC 1052 (1.64 ton), ICC 5639 (1.68 ton), ICC

6579 (1.74 ton), ICCV 00108 (1.77 ton), ICCV 97105 (1.78 ton) and ICC 9636 (1.84 ton) recorded greater than 1.60 ton ha $^{-1}$ for seed yield (Table 4). The lowest seed yield ha $^{-1}$ was recorded for genotypes ICC 9002 (0.85 ton), ICC 791 (0.87 ton) and ICC 9862 (0.88 ton). Results indicated the potential of generating high seed yielding varieties from the evaluated germplasm. Based on the grand means, the order of genotypes performance from low to high for seed yield in tons ha $^{-1}$ ranked as follows short rain Juja (0.8) < short rain Kabete (1.1) < long rain Kabete (1.3) < long rain Juja (2.1).

Table 5. Broad Sense Heritability(H^2) of Six Studied Traits at Juja and Kabete.

Characters	*Long rain Juja*	*Short rain Juja*	*Long rain Kabete*	*Short rain Kabete*
Days to 50 % Flowering	0.62	0.95	0.84	0.88
Plant Height (cm)	0.52	0.76	0.53	0.56
Days to 75 % Maturity	0.06	0.71	0.25	0.94
Number of Pods Plant $^{-1}$	0.48	0.99	0.16	0.97
Seed Yield (ton ha $^{-1}$)	0.57	0.99	0.45	0.99
Hundred Seed Weight (g)	0.83	0.85	0.85	0.92

Hundred Seed Weight (HSW)

There were highly significant ($p < 0.0001$) differences among evaluated genotypes and genotype by environment interactions for 100 seed weight (Table 4). All the evaluated genotypes, except check varieties recorded the highest 100 seed weight during short rains in comparison to long rains at Kabete and some genotypes recorded the highest 100 seed weight during long rain season at Juja. The grand means for hundred seed weight were 22.4 g, 23.3 g, 20.3 g and 24.5 g during long and short rain season at Juja, in long and short rain season Kabete respectively.

The current results detected that many genotypes surpassed the check varieties ICCV 00108 and ICCV 97105 for 100 seed weight which noticed that the immense potential for obtaining genotypes with high 100 seed weight from the germplasm.

Overall, the results detected that 10 genotypes recorded high (> 25 g), 22 genotypes moderate (22.1 – 25.0 g) and 28 genotypes recorded low (< 22 g) for 100 seed weight. Overall, genotype ICC 13124 (33.8 g) followed by ICC 6877 (28.6 g), ICC 11903 (28.1 g) and ICCV 07111 (26.2 g) recorded the highest for 100 seed weight. While genotype ICC 5639 (18.2 g) followed by ICC 4991 (19.1 g), ICC 1052 (19.1 g) and ICC 4093 (19.3 g) recorded the lowest for 100 seed weight (Table 4). The results also grouped the check varieties (26.2 g each) as high for 100 seed weight. The results further indicated the potential of generating varieties from the evaluated germplasm with large seed size and thus high seed weight.

Heritability of the Traits

The highest broad sense heritability estimates for days to 50 % flowering was recorded in short rain season at Juja followed by short rain season at Kabete and long rain season at Juja . Broad sense heritability estimates for seed yield ha $^{-1}$ and 100 seed weight varied from 0.45 to 0.99 and 0.83 to 0.99 respectively. The highest broad sense heritability for 100 seed weight was recorded in the short rain season Kabete (0.92) while the lowest broad sense heritability was recorded in long rain season Juja (0.83). Estimates of broad sense heritability for days to 75 % maturity varied from 0.06 (long rain Juja) to 0.94 (short rain Kabete). Broad sense heritability estimates for plant height and number of pods plant $^{-1}$ ranged from 0.52 to 0.76 and 0.48 to 0.99 respectively. Overall, all the studied traits had medium to high broad sense heritability estimates except for days to 75 % maturity in the long rain season at Juja and long rain season at Kabete. Likewise the number of pods plant $^{-1}$ in the long rain season at Kabete recorded low broad senseheritability (Table 5).

Discussion

Crop germplasm including chickpea represents a valuable source of genetic diversity that is anticipated to be highly useful for direct and future breeding programmes. The evaluated genotypes differed significantly for all studied traits while most traits exhibited high broad sense heritability.

Early flowering trait is useful in crops with indeterminate growth habit such as chickpea, in which vegetative growth, flowering, podding and pod filling period occur concurrently. Earliness enables the genotypes to escape from biotic and abiotic stresses that occur late in the growing season and to utilize the available soil moisture and nutrients. The current findings indicated wide diversity among the studied genotypes (Table 2). In chickpea, earlier studies (Khan *et al.,* 2011; Gul *et al.,* 2013) have reported significant genetic variability for days to 50 % flowering but their genotypes took longer to flower (141.0 – 156.7 days and 90 – 122 days respectively) in comparison to these results. In other legumes, Imani *et al.* (2013) and Oladejo *et al.* (2011) reported high genetic variability for days to 50 % flowering in lentil and cowpea germplasm. The present results were in disagreement with those of Zelalem (2014) who reported non-significant variations for days to 50 % flowering in haricot bean. The recorded wide variation among assessed genotypes for days to 50 % flowering could be due to variations in their genetic makeup, environmental factors and genotype by environment interactions. This critical stage is highly sensitive and may influence by fluctuation of temperatures due to adverse effect on viability of pollen and pollination which could results poor fertilization and low seed set. Extra early genotypes from this study could assist breeders for genetic improvement of chickpea in the region.

The results showed great genetic variability for plant height among evaluated genotypes (Table 2). Similar results were reported in previous studies by Kayan and Saitadak (2012) and Khan *et al.* (2011) in chickpea and Imani *et al.* (2013) in lentil. The current results were in disagreement with those of Roy *et al.* (2013) who reported non-significant variation for plant height in lentil germplasm. The wide range of variation for plant height could be due to genetic, environment and genotype by environment interactions. Plant height is one of the desirable characters in chickpea which reduces lodging effect and enhance ultimate seed yield. The results detected the potential of evaluated germplasm in obtaining genotypes with modest plant height along with other yield traits. Hence genotypes with modest plant height and reasonable yield traits could be used for genetic enhancement of chickpea varieties.

Crop phenology (flowering and maturity) contributes a key role in increasing seed yield of chickpea. Breeding for earliness is one of the prime breeding objectives of chickpea as most end users and farmers usually seek for early maturing varieties in order to enable the crop to mature within the rainy season and utilize the available moisture and nutrients. In addition early maturity could give sequential merit like excess nitrogen fixation and enhancement of soil organic matter. The findings for days to 75 % maturity displayed highly significant differences among evaluated genotypes (Table 3). These findings were in agreement with results reported by Khan *et al.,* (2011) in chickpea, Oladejo *et al.*, (2011) in cowpea and Imani *et al.*, (2013) in lentil. The results were contradictory to the results reported by Malik *et al.*, (2010) in chickpea and Zelalem (2014) in haricot beans. The recorded great variation for days to 75 % maturity could be attributed to pod filling duration and pod size because early flowered genotype might not be early matured while in some genotypes early flowering trait is correlated to early maturity. Overall, the main reasons for significant great variation among evaluated genotypes could be due to genetic, environment and genetic makeup combined with environmental factors. Thus early genotypes along with those medium reproductive duration and reasonable yield traits can be candidates for potential breeding material in future improvement of chickpea in various regions.

Plant growth behavior and yield performance of chickpea could be determined by the number of pods plant $^{-1}$. Genotypes varied with respect to number of pods plant $^{-1}$ and showed existence of genetic variation (Table 3). Similar results have been reported by many researcher (Kayan and Saitadak, 2012, Malik *et al.,* 2010; Qureshi *et al.*, 2004; Gul *et al.*, 2013) in chickpea germplasm, (Hegde and Mishra, 2009) in cowpea, (Latief *et al.*, 2011) in lentil germplasm. The differences for number of pods plant $^{-1}$ could be due to genotypes, environment and genotype by environment interactions. In addition, high productive secondary branches plant ^{1} could be attributed for the increment of pods plant ^{1}. Therefore genotypes with remarkably high number of pods plant $^{-1}$ (> 150) can be utilized in hybridization of chickpea with early flowering and maturing traits for better yield.

Yield is a quantitative character, the result of various physiological and biochemical processes. Yield and yield contributing traits could have dynamic correlation with environmental effects. The findings displayed wide genetic variability among studied genotypes for seed yield ha $^{-1}$ (Table 4). Significantly high variation for seed yield ha $^{-1}$indicated the potential of the germplasm to determine the best genotypes for specific and broad adaptation across environments. In chickpea germplasm, previous studies have reported substantial variation for seed yield (Farshadfar and Farshadfar, 2008; Malik *et al.,* 2009). In other legumes, earlier studies (Roy *et al.,* 2013; Hegde and Mishra, 2009; Furat and Uzun, 2010) have reported substantial variation for seed yield in lentil, cowpea and sesame germplasm respectively. However, the findings contradict the previous results by Oladejo *et al.* (2011) who reported non-significant differences for seed yield in cowpea cultivars. General facts short growth duration gives low yields in comparison to medium and long growth duration. In chickpea, Namvar and Sharifi (2011) reported high biomass and seed yield production obtained from longer growth period in comparison to shorter growth. However, this findings discovered some early matured genotypes such as ICC 15614 (1.64 ton) and ICC 3325 (1.63 ton) (Table 4) recorded high seed yield ha $^{-1}$ which indicated the potential of the aforementioned genotypes in utilization the available moisture and nutrients and converted into economic yields. The presence of significant variation among evaluated genotypes for seed yield could be due to genetic, environment and genetic makeup combined with environmental effect. Best performance and high seed yield ha $^{-1}$ is one of the basic criteria for identifying and selecting superior varieties for end users and farmers. Besides, the presence of wide variation for seed yield ha $^{-1}$ could be attributed to high number of pods plant $^{-1}$, high biomass yield enables to converted final seed yield and heavier 100 seed weight. A crossover genotype by environment interaction indicated inconsistent performance of genotypes across environments for seed yield. Hence promising, high yielding potential genotypes can concurrently be combined with enhancement of diverse traits such as flowering, maturity and yield related traits for better economic yield.

Seed weight is one of the most important traits in seed consumed pulse crops including chickpea. The findings exhibited highly significant differences for 100 seed weight among studied genotypes (Table 4), which indicated considerable diversity. In chickpea, earlier studies have reported significant and wide range of variations for 100 seed weight Qureshi *et al.* (2004) (12.3 – 28.7 g); Khan *et al.* (2011) (13.0 – 39 g), and Malik *et al.* (2009) (22.38 – 38.6 g) relatively low and high minimum and maximum values respectively compared to current results. The significant great variability could be attributed to the use of diverse genotypes which differed in pod size, pod filling period which affect the seed size (weight) for the reason that late occurring biotic and abiotic stresses. Also number of pods plant $^{-1}$ can be a factor due to competition for available soil moisture and nutrients and reduce seed size. It was evident from this study, genotype ICC 13124 (33.8 g) with the lowest number of pods plant $^{-1}$ (101.1) recorded consistently the highest 100 seed weight (Table 4). Overall, genetic, environment and genetic makeup combined with environment could affect seed set, pod filling and thus seed weight. The results indicated the potential of evaluated germplasm in obtaining genotypes with high 100 seed weight and considerable yield and related traits. Hence genotypes with high 100 seed weight from this study could be utilized in future chickpea breeding in the region.

Heritability estimates showed high broad sense heritability among studied traits (Table 5). In line with these results, previous studies in chickpea have been reported high broad sense heritability for days to 50 % flowering, plant height, 100 seed weight, seed yield (Khan *et al.*, 2011), number of secondary branches plant $^{-1}$,harvest index (Malik *et al.*, 2009), branches plant $^{-1}$, days to maturity and number of pods plant $^{-1}$ (Sharma and Saini, 2010). In chickpea, Sharma and Saini (2010) reported heritability in broad sense estimates and grouped as highly heritable (> 0.5) moderately heritable (0.2 – 0.5) and less heritable (< 0. 2) traits. The estimated high broad sense heritability for 100 seed weight, days to 50 % flowering and plant height could be due to high genetic effect than that of the environment. Broad sense heritability was low for days to 75 % maturity during long rains and number of pods plant $^{-1}$ in long rain season Kabete indicated that non-genetic factors were more important than the genetic and hence not suitable for direct selection. High genetic variations combined with high heritability could provide effective selection of phenotypic trait for future chickpea improvement through hybridization.

Conclusion

Genotypes in this study were classified as early, moderate and late on the basis of their flowering and maturity. The genotypes varied with respect to seed yield ha $^{-1}$ and number of pods plant $^{-1}$ which grouped as low, moderate and high. Plant height variability was also detected and categorized the germplasm into short, medium and tall genotypes. Genotypes further differed in 100 seed weight and classified as low, moderate and high. Overall the highest seed yield ha $^{-1}$ was recorded in genotype ICC 9636 and the lowest by ICC 9002. Genotypes ICC 2580, ICC 15614 and ICC 14815 were early in maturity while ICC 5639, ICC 4463 and ICC 7867 were late in maturity. The highest pod yielding genotypes were ICC 4182; ICC 7867 and ICC 7326 while ICC 13124 and ICC 9002 recorded the lowest number of pods plant $^{-1}$. The highest and lowest 100 seed weight belonged to genotypes ICC 13124 and ICC 5639 respectively. The highest estimates of broad sense heritability were recorded for 100 seed weight followed by days to 50 % flowering and plant height. Character with high broad sense heritability could be selected for future chickpea breeding. Promising, early flowering and maturing genotypes with reasonable yield traits from this study can be exploited for genetic improvement of chickpea in various regions.

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