Quantifying Genetic Advance of Kabuli Chickpea Varieties for Yield and Yield Related Traits in Ethiopia

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Abstract
Fourteen Kabuli chickpea varieties released since 1974 were evaluated in 2017 cropping season at Akaki, Chefe Donsa, Debre Zeit, and Jari stations to determine genetic progress in yield and yield associated traits of Kabuli chickpea varieties. The varieties were laid out in a randomized complete block design with three replications. The average rate of increase in grain yield per year over the past 42 years period was 22.35kgha^{-1}yr^{-1} with a relative genetic gain of 1.04% year^{-1}, which was not significantly different from zero. The regression of hundred seed weight against the years of release showed significant increase for the last 42 years of improvement in Ethiopia. It showed an annual rate of genetic gain of 0.56 g yr^{-1} with a relative annual genetic gain of 4.37%. Number of pods per plant and number of seeds per pod revealed a significant decreasing trend over the past 42 years, which could be a reciprocate to the increased seed size. Plant height, days to flowering, and days to maturity showed non-significant trend in the current study. Grain yield showed non-significant positive association with plant height, days to flowering, number of pods per plant and non-significant negative association with days to maturity, number of seed per pod and hundred seed weight. Hundred seed weight was positively and significantly correlated with days to maturity but negatively and significantly correlated with number of pods per plant and number of seeds per pod. Therefore, the Kabuli chickpea improvement program needs special attention to compliment seed size and grain yield by using integrated breeding approach to make rapid progress in developing superior Kabuli chickpea varieties.
Keywords: Kabuli chickpea, Grain yield, hundred seed weight, Genetic gain
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1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an annual diploid with 16 chromosomes and genome of 740 Mbp (Jain *et al*., 2013). It is a member of genus Cicer, tribe Cicereae, subfamily Papilionoideae, and family fabaceae (vander Massen, 2007). Chickpea is grown in 54 countries with nearly 90% of its area covered in developing countries (Guar *et al*., 2012). Evidence have confirmed that Ethiopia is considered as a secondary center of genetic diversity for chickpea (Kanouni *et al*., 2011, Rajeev et al, 2019). In Ethiopia, chickpea production area and volume ranks third following Faba bean and haricot bean, while its productivity (2058kgha^{-1}) follows Soybean and Faba bean, respectively (CSA,2018).

Globally chickpea is a highly sought after pulse due to its nutritional value and as an inexpensive source of protein. In addition to having higher protein content, as compared to cereals, it has also essential amount of carbohydrates and oil, minerals like calcium, magnesium, potassium, phosphorous, iron, zinc and manganese (Ibrikci *et al*., 2003). Chickpea is considered less labor-intensive crop and its production requires less external inputs as compared to cereals .It plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. Mostly, chickpea is consumed as food in several different forms and preparations are determined by ethnic and regional factors (Ibrikci *et al*., 2003). In the Indian subcontinent, chickpea is split (cotyledons) as ‘dhal’ and ground to make flour (‘besan’) that is used to prepare different snacks (Hulse, 1991). In other parts of the world, especially in Asia and Africa including Ethiopia, chickpea is used in stews and soups/salads, and consumed in roasted, boiled, salted and fermented forms. Chickpea seeds are also consumed at green pods stage without any processing. These different forms of consumption provide consumers with valuable nutritional and potential health benefits. Additionally, the straw is an important animal feed supplementing cereal straw.

Chickpea yield improvement is challenging due to the influences of the environment, agronomic practices and genetic factors (Wood and Grusak, 2007). Despite the challenges, breeders have been developing improved varieties over the last several decades. Understanding the changes produced by crop breeding on grain yield and its determinants is important to evaluate the efficiency of past improvement works on the advances in genetic yield potential, and to define future strategies to facilitate further progress. Thus, estimation of genetic progress is a useful indicator that helps breeders to make decisions about what future breeding strategy they should follow;

whether they ought to pursue or if changes are required.

Chickpea breeding in Ethiopia was started in the 1950 (Gemechu *et al*., 2011). Since then, a number of locally collected and newly introduced germplasm have been evaluated to develop high yielding and widely adaptable varieties. Some work has been done on the genetic progress in Ethiopian chickpea breeding. The current initiative was aimed at critically assessing the rate of genetic gain achieved in Ethiopian Kabuli chickpea breeding program at diverse agro-ecological locations so as to devise effective breeding strategy for further improvement. Therefore, the purpose of present study was to determine genetic progress in yield and yield related traits of Kabuli chickpea varieties. Though, there appear one oldest type variety release from local sources, a full-fledged breeding program for Kabuli type chickpea has mainstreamed in the early1980s.

2. Material and Methods

The experiment was conducted in 2017 cropping season at four locations, namely Akaki, Chefe Donsa, DZARC and Jari sub stations. The specific descriptions of the sites are given in Table 1 below. The experiment consisted of fourteen Kabuli chickpea varieties released since 1974 (Table 2). The experiment was planted in a Randomized Complete Block Design (RCBD) with three replications. The experimental plot size of 4 rows each 4m long and 1.2m wide (4.8m^2) with spacing of 30cm between rows, 10cm between plants and 1m between blocks was used. Two hundred seeds were planted to each row. Field management and protection practices were applied based on research recommendation at each location. Data were recorded on: days to flowering, days to maturity, plant height, number of pods per plant, number of seed per pod, hundred seed weight and grain yield.

Table 1**.** Descriptions of the study sites

Experimental stations	Distance from Addis Ababa (km)	Longitude(E)	Latitude(N)	Altitude (masl)	Soil Type	Annual Average rainfall (mm)	Mean Min. Tem. (°c)	Mean Max. Temp. (°c)
Akaki	20	38°47’	08°52’	2200	Black	1025	7.0	26.5
Chefe Donsa	84	38°37’	08°58’	2450	Black	909	7.0	26
DZARC	47	38°58’	08°44’	1900	Black	851	8.9°c	28.3
Jari	449	39o 38ʻʻ	11° 21’	1680	Vertisol	NA	NA	NA

Source: Debre zeit Agricultural Research Center (Abera and Kebede, 2014) and Sirinka Agricultural Research Centers for altitude, rain fall and soil type; Wikipedia for global position. NA= not available

Table 2**.** Kabuli chickpea varieties released in Ethiopia from 1974 to 2016

No	**Variety**	**Pedigree**	**Source**	**Year of released**	**Released research center**
1	DZ-10-4	-----	Ethiopia	1974	DZARC
2	Arerti	X87TH186/ICC14198XFLIP 82-150C	ICARDA	1999	DZARC
3	Shasho	ICCC33X(L144XE1004Y(M)	ICRISAT	1999	DZARC
4	Chefe	(ICCV2XSURUTATO77)ICC-7344	ICRISAT	2004	DZARC
5	Habru	X85TH230/ILC3395XFLIP 83-13C)	ICARDA	2004	DZARC
6	Ejerie	X94TH71/FLIP87-59CX4C-15	ICARDA	2005	DZARC
7	Teji	X94TH75/FLIP87-58CX4C-15	ICARDA	2005	DZARC
8	Yelibie	ICC-14808	ICRISAT	2006	SARC
9	Acos dubie	ICC 13XANNIGERI	Mexico	2009	DZARC
10	Kasech	FLIP 95-31C	ICRISAT	2011	SARC
11	Akuri	ICC-03402	ICRISAT	2011	SARC
12	Kobo	ICCV-01308	ICRISAT	2012	SARC
13	Hora	X2000TH50/FLIP 98-52C X FLIP 98-12C	ICARDA	2016	DZARC
14	Dhera	X98TH30/FLIP-93-55C X S-96231	ICARDA	2016	DZARC

2.1. Statistical Analysis

All measured parameters were subjected to analysis of variance (ANOVA) using PROC GLM of SAS software version 9.0 to assess the difference among the tested varieties. The homogeneity of error mean squares between the four locations was tested by Bartlett’s chi-square test and combined analyses of variance were performed for the traits whose error mean squares were homogenous. Mean separation was carried out using Duncan’s Multiple Range Test (DMRT). The breeding effect was estimated as a genetic gain for grain yield and associated traits; by regressing the mean of each character of each variety against the year of release of the variety using PROC REG procedure. The coefficient of linear regression gives the estimate of genetic gain in kg ha^{-1} yr^{-1} or in % per year

(Evans and Fisher, 1999). For this study, the year of release was expressed as the number of years since 1974 for the varieties; the year when the first chickpea variety was released. Calculation was done as follows.

Annual rate of gain (b) =CovXY/VarX
Where: Cov= Covariance, Var= Variance, X= the year of variety release and Y= the mean value of each character for each variety
The relative annual gain achieved over the last 42 years (1974-2016) was determined as a ratio of genetic gain to the corresponding mean value of oldest variety and expressed as percentage. Stepwise regression analysis was carried out on the varietal mean to determine those traits that contributed much for yield variation among varieties. To compute Pearson's product moment correlation coefficients among all characters using means of each variety, PROC CORR in SAS was used.

3. RESULT AND DISCUSSION

3.1. Analysis of Variance

The analysis of variance for individual locations revealed highly significant (P<0.01) differences among tested varieties for all traits (Table 3). Combined analysis of variance across the four locations also revealed highly significant effects of location, variety and variety x location interaction for all traits studied (Table 4). Similarly, Fikre *et al*. (2012); Tamene *et al*. (2015); Mekuria *et al*. (2018) in ground nut, faba bean and durum wheat varieties reported significant (p ≤ 0.01) interaction effects for grain yield, though, this is in contrast to the finding of Hailu *et al*. (2009); wondimu *et al*. (2011) and Ersullo *et al*. (2016) in soybean, barley and linseed respectively.
Table 3.Mean squares from separate analysis of variance for grain yield and other traits of Kabuli chickpea at four locations

traits	**Mean squares (MS) at each location**							
	Debre Zeit		**Chefe Donsa**		**Akaki**		**Jari**	
	Variety	Error	Variety	Error	Variety	Error	Variety	error
DF	47.47**	2.06	54.57**	1.35	32.88**	1.88	34.55**	1.99
DM	11.47**	1.81	80.70**	2.30	8.32**	2.31	17.72**	2.30
PTH	74.44**	5.61	91.39**	4.73	31.28**	5.60	77.19**	7.53
NPPP	110.79**	22.27	544.83**	71.91	225.04**	16.99	419.03**	103.98
NSPP	0.036**	0.007	0.029**	0.009	0.064**	0.006	0.12**	0.007
HSW	339.53**	1.49	236.37**	1.52	411.62**	2.86	481.06**	3.35
GY	1938657.3**	165439.3	2926413.15**	215338.3	993572.96 **	242119.3	3364198.35**	291574.13

**, *, ns= Significant at P ≤ 0.01, significant at P ≤ 0.05 and non-significant respectively€= DF= days to flowering, DM=days to physiological maturity, PTH= plant height (cm), NPPP= number of pods per plant, NSPP= number of seeds per pod, HSW= hundred seed weight (g) and GY= grain yield (Kg ha^{-1}).

3.2. Grain Yield Potential

The grain yield performance of all Kabuli chickpea varieties averaged over locations was 3264.48 kg ha^{-1}, which ranged from 1541.3 kg ha^{-1} for the variety Acos dubie to 4074.2kg ha^{-1} for the variety Arerti (Table 5). The variety Acos dubie, showed lower grain yield than all varieties represented in the current study. The variety Arerti, which was released in 1999, was the highest yielding variety among the tested varieties. The recently released variety Hora was the second best yielder among the varieties next to Arerti (Table 5). The poor relative yield of Acos dubie in this study may be due to its super bold seed size (Table 6), which presumably has compromised for the gain in yield.

Table 4. Mean squares from combined analysis of variance for yield and other traits of Kabuli chickpea evaluated over four locations in 2017 Cropping Season

Trait€	Location(3) ¥	Variety(13)	Location x Variety(39)	Error(104)	Mean	CV	R^2
DF	1159.75**	130.38**	13.07**	1.80	56.61	2.37	0.97
DM	4891.33**	57.91**	20.10**	2.18	129.52	1.14	0.99
PTH	1639.68**	181.22**	31.021**	5.87	49.70	4.87	0.93
NPPP	6442.27**	918.92**	126.93**	53.79	41.47	17.68	0.87
NSPP	0.039**	0.177 **	0.033**	0.0078	1.198	7.39	0.81
HSW	1386.14**	1423.06 **	15.17340 **	2.30	32.86	4.62	0.99
GY	66187429.2 **	5913044.3**	1115687.6 **	223897.7	3264.48	14.49	0.93

¥= Numbers in parenthesis represent degrees of freedom
€=Abbreviations of traits, refer to Table 3, CV= Coefficient of variation, R^2= Proportion of total variation explained by the model (i.e., by location, replications within location, variety, and variety x location interaction effects), **, *, ns= Significant at $P \leq 0.01$, significant at $P \leq 0.05$ and no significant respectively

Table 5. Mean grain yield (Kg/ha) of Kabuli type chickpea varieties at four locations

	Location				
Variety	**Akaki**	**Debre Zeit**	**Chefe Donsa**	**Jari**	**Mean**
DZ-10-4	2948.7^{cd}	1268.7 ^{g}	642.0 ^{f}	3821.0 ^{e}	2153.4 ^{g}
Arerti	4701.7^{a}	2305.7^{def}	3057.3^{bc}	6232.0 ^{a}	4074.2 ^{a}
Shasho	3390.0^{bc}	2502.3 ^{cd}	2173.7 ^{cd}	5483.7^{abcd}	3387.4^{cde}
Chefe	4205.7^{ab}	2600.3 ^{cd}	1767.0^{de}	5169.7^{bcd}	3435.7^{cde}
Habru	3289.7^{bcd}	2674.7^{cd}	2727.0^{bc}	5858.3 ^{ab}	3637.4^{bcd}
Ejere	3613.7^{bc}	3174.3^{abc}	2886.0^{bc}	4823.7^{cd}	3624.4^{bcd}
Teji	3494.0^{bc}	3020.0^{bcd}	1263.7^{ef}	5279.0^{a-d}	3264.2 ^{de}
Yelibie	3207.7^{cd}	1603.3^{fg}	3012.3^{bc}	4801.7^{cde}	3156.3^{ef}
Acos dubie	2378.0^{d}	1042.3 ^{g}	621.0 ^{f}	2123.7 ^{f}	1541.3 ^{h}
Kasech	3541.3^{bc}	2384.7 ^{de}	3190.7 ^{b}	6076.3^{ab}	3798.3^{abc}
Akuri	3214.3 ^{cd}	1674.3^{efg}	1619.7^{de}	4627.7^{cde}	2784.0 ^{f}
Kobo	2782.3 ^{cd}	3791.7^{a}	2449.7^{bcd}	5619.7^{abc}	3660.8 $^{a-d}$
Hora	2995.7 ^{cd}	3432.3^{ab}	3994.7 ^{a}	5580.7^{abc}	4000.8 ^{ab}
Dhera	3531.7^{bc}	2396.0^{de}	2291.7^{cd}	4519.3 ^{de}	3184.7^{ef}
CV	14.57	16.81	20.50	10.80	14.49
Mean	3378.17	2419.33	2264.02	5001.17	3264.48
R^2	0.72	0.86	0.88	0.85	0.93

Means followed by the same letter with in a column are not significantly different from each other at $P \leq 0.05$.

Table 6. Mean Values of Different Traits from Combined Analysis of Variance for Kabuli Type Chickpea Varieties in the Yield Potential Trials at Four Locations.

	Trait					
Variety	**DF**	**DM**	**PTH**	**NPPP**	**NSPP**	**HSW**
DZ-10-4	57.83^{c}	128.17^{e}	44.70^{g}	51.80^{b}	1.54^{a}	12.91^{h}
Arerti	59.17 ^{b}	129.50^{d}	48.23^{ef}	50.85^{b}	1.09^{g}	27.25^{g}
Shasho	59.58^{b}	130.42^{cd}	49.47^{c-f}	58.05^{a}	1.15^{efg}	29.68^{f}
Chefe	55.58^{d}	130.58^{cd}	50.83^{bcd}	48.02^{bc}	1.20^{cde}	31.57^{de}
Habru	54.25^{e}	127.58^{e}	50.38^{cde}	39.783^{de}	1.22^{bcde}	31.21^{e}
Ejere	53.92^{e}	128.17^{e}	50.35^{cde}	38.650^{de}	1.29^{b}	32.83^{bcd}
Teji	55.08^{de}	131.50^{bc}	47.42^{f}	40.750 ^{de}	1.23^{bcd}	33.74^{b}
Yelibie	54.00^{e}	127.50^{e}	49.12^{def}	37.367^{de}	1.26^{bc}	32.08^{cde}
Acosdubie	54.25^{e}	133.50^{a}	50.03^{cde}	21.933 ^{f}	1.08^{g}	65.89^{a}
Kasech	54.42 ^{e}	127.83^{e}	52.73^{b}	42.72^{cd}	1.18^{def}	31.02^{e}
Akuri	52.08^{f}	125.42^{f}	41.55^{h}	34.967^{e}	1.25^{bcd}	32.39^{cde}
Kobo	59.42^{b}	130.67 ^{cd}	50.82^{bcd}	36.967^{de}	1.10^{fg}	33.33^{bc}
Hora	58.67^{bc}	129.92^{d}	51.45^{bc}	38.917^{de}	1.11^{fg}	32.26^{cde}
Dhera	64.25^{a}	132.42^{ab}	58.72^{a}	39.867 ^{de}	1.08g	33.84^{b}
Cv	2.37	1.14	4.87	17.68	7.39	4.62
Mean	56.61	129.51	49.70	41.47	1.198	32.86
R^2	0.97	0.99	0.93	0.87	0.81	0.99

3.3. Genetic Progress for Yield and other Traits

3.3.1. Grain yield

The mean grain yield of varieties released in 1970s, 1990s and 2000s were 2153.4, 3730.8 and 3280.7 kg ha^{-1} (Table 8), respectively. These result indicated an increase of 1577.4 (73.25%) and 1127.3 kg ha^{-1} (52.35%) over the first released variety (Table 8), respectively. The average grain yield of the varieties released in 2000s was greater than that of the first released variety in 1974 (DZ-10-4), but less than the mean yield of the varieties released in 1990s by 450.1 kg ha^{-1} (12.06%) Table 8). In this context we learnt the breeding program has made strategic shift in its objective from merely yield deriver to some other market traits deriver like seed size. For example, releasing Acos Dubie 2009, we can see a big compromise on the count of yield progress measurement in time.

Table 7. Genetic Progress Trend in Grain Yield and Hundred Seed Weight (HSW) for Kabuli Type Chickpea Varieties Released from 1999 to 2016 over the Older Variety (DZ-10-4) Released in 1974

Variety	Year of release	Mean grain yield (Kg/ha)	Increment over DZ-10-4		Mean HSW(g)	Increment over DZ-10-4	
			Kg	%		g/HSW	%
DZ-10-4	1974	2153.4	---	--	12.91	--	
Arerti Shasho	1999 1999	3730.8	1577.4	73.25	28.47	15.56	120.53
Chefe Habru	2004 2004	3536.5	1383.15	64.23	31.39	18.48	143.14
Ejere Teji	2005 2005	3444.3	1290.9	59.94	33.28	20.37	157.81
Yelibie	2006	3156.3	1002.9	46.57	32.08	19.17	148.49
Acosdubie	2009	1541.3	-612.1	-28.42	65.89	52.98	410.37
Kasech Akuri	2011 2011	3291.15	1137.75	52.83	31.70	18.79	145.58
Kobo	2012	3660.8	1507.4	70.00	33.33	20.42	158.17
Hora Dhera	2016 2016	3592.75	1439.35	66.84	33.05	20.15	156.08

Table 8. Genetic Progress Trend in Grain Yield and Hundred Seed Weight (HSW) For Kabuli Type Chickpea Varieties Released in 1990s and 2000s over the Older Variety DZ-10-4 Released in 1974

Variety	Year of release	Mean grain yield	Increment over DZ-10-4		Mean HSW (g)	Increment over DZ-10-4	
			Kg	%		ghsw^{-1}	%
DZ-10-4	1974	2153.4	-	-	12.91	-	-
Arerti Shasho	1990s	3730.8	1577.4	73.25	28.47	15.56	120.53
Chefe Habru Ejere Teji Yelibie Acosdubie Kasech Akuri Kobo Hora Dhera	2000s	3280.7	1127.3	52.35	35.39	22.48	174.13

Varieties derived from introductions yielded an average of 3349.96 kg/ha, and surpassed the varieties developed from local collections by 1196.56 kg ha^{-1} (55.57%) (Table 9). Similarly, Sanchez-Garcia *et al.* (2013) revealed that the introduction of improved bread wheat varieties in Spain during the 20th century enhanced bread-making quality. The results of the present study indicated that the Kabuli chickpea improvement program that employed selection from introductions as major breeding methods was successful in improving grain yield, though the rate of gain is negatively accelerated in time. Similarly, Kebere. (2006); Mekuria *et al.* (2018); have indicated that introduced materials contributed a lot to the improvement of the genetic yield potential of durum wheat and haricot bean varieties in Ethiopia, respectively.

Table 9. Average Increments in Grain Yield and Hundred Seed Weight (HSW) for Kabuli Type Chickpea Varieties Derived from Introduction over Variety Derived from Local Collection

Variety	Grain yield (kg/ha)	Grain yield increment over local collection		Mean HSW (g)	HSW increment over local collection	
		Kgha^{-1}	%		ghsw^{-1}	%
Local collection derived	2153.4	---	--	12.91	-	-
Introduction derived	3349.96	1196.56	55.57	34.39	21.38	165.61

The genetic gain analysis revealed an average rate of increase of 22.35 kg ha^{-1} yr^{-1} in yield potential over the last 42 years since 1974 (Figure 1) in Kabuli chickpea, which is not significantly different from zero (P≤0.05). The average relative annual gain in grain yield was 1.04 % per year or about 43.68% for the whole period (Table 11). This evidently showed that chickpea breeders have made efforts over the last 42 years to improve the yield of Kabuli type chickpea in Ethiopia, however, hardly in leap progressive. Similarly, Alisson *et al.* (2010) reported in the period ranging from 1997 to 2007, the estimate of genetic progression was null. Likewise, Ersullo *et al.* (2016) reported in the first era (since 1984), the relative rate of genetic gains in grain yields of linseed was 4.15 kg ha^{-1}yr^{-1} of the modern cultivars over that of the older ones was non-significant. Similarly, Wondimu *et al.* (2013) in grain yield of malt barley reported that slope of regression since 1973 was not significantly different from zero at each location as well as across locations. In contrary, Follmann *et al.* (2017) reported annual genetic progress of sunflower during the period of 10 years (2005-2014) was 132.46 kgha^{-1}year^{-1} for grain yield was significant.

The genetic progresses made in grain yield of Kabuli chickpea breeding (1.04%) in this study is much lower than the progresses made in grain yields from breeding of other crops like haricot bean (3.24% ha^{-1} year^{-1}) (Kebere *et al.*, 2006) , barley (1.34% ha^{-1} year^{-1}) (Wondimu *et al.*, 2011), groundnut (1.89% ha^{-1} year^{-1}) (Fikre *et al.*, 2012)and linseed (4.33, 9.78 and 10.45% ha^{-1} year^{-1} since 1984, 1992 and 1997 respectively) (Ersullo *et al.*, 2016) but little higher than that of malt barley(0.88% ha^{-1} year^{-1})(Wondimu *et al.*,2013) ,faba bean (0.26 % ha^{-1} year^{-1}) (Tamene *et al.*, 2015), more or less during the same period in Ethiopia and in other countries, 0.58% ha^{-1} year^{-1} from breeding soybean in Northeast China (Jin *et al.*, 2010), 0.45% ha^{-1} year^{-1} from breeding soybean in Canada (Morrison, *et al.* 2000) and 0.39% ha^{-1} year^{-1} from hundred years of barley breeding in England (Riggs, *et al.*, 1981).

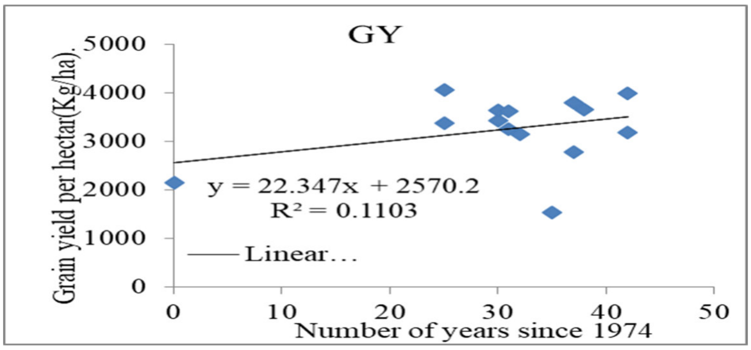

Figure 1. Relationship between year of Kabuli chickpea variety releases and grain yield across location in Ethiopia

3.3.2. Hundred Seed Weight

Mean hundred seed weight ranged from 12.91g (DZ-10-4) to 65.89g (Acos duie) with across location average of 32.86 g (Table 6). Acos dubie, which was released in 2009, had significantly higher seed size (hundred seed weight) than all of the varieties in this study. It surpassed the first older variety (DZ-10-4) by 52.98 g (410.37%) in hundred seed weight. The mean hundred seed weight of varieties that released in 1974, 1999, 2004, 2005, 2006 , 2009,2011,2012 and 2016 were 12.91, 28.47, 31.39, 33.28, 32.08, 65.89, 31.7, 33.33 and 33.05g, respectively (Table 7). This indicated an increase of 15.56g (120.53%), 18.48g (143.14%), 20.37g (157.81%), 19.17g (148.49%) and 52.98g (410.37%), 18.79g (145.58 %), 20.42(158.17%), and 20.15g (156.08 %) in hundred seed weight, respectively, over the older varieties (Table 7).

The regression of hundred seed weight against the years of release showed annual rate of genetic gain of 0.56 g yr^{-1} (Figure 2) ,reflecting a significant increase in the trait over the last 42 years of Kabuli type chickpea improvement in Ethiopia with a relative annual genetic gain of 4.37% (Table 11). Generally, this experiment clearly revealed that improved genetic progress was obtained from breeding kabuli chickpea in Ethiopia for seed size than it was for grain yield. Similarly, Wych and Rasmusson (1983) in malting barley; Cox *et al.* (1988) in hard red winter wheat; Amsal (1994) in durum wheat , Ortiz *et al.* (2002) in two-row Nordic spring barley, Tamene *et al* .(2015) in faba bean and Ersullo *et al.* (2016) in linseed found that thousand seed weight of modern varieties were heavier than the older ones. Similar results with more dramatic increments in seed size than in grain yield, was also reported from chickpea breeding in Ethiopia (Gemechu *et al.*, 2011).

Like to the grain yield, varieties derived from introductions gave higher hundred seed weight, which was 34.39 g on average, and exceeded the mean of the varieties developed through local collection by 21.38g (165.61%) (Table 9). This result is contrary to the finding of Tamene *et al.* (2015) in faba bean.

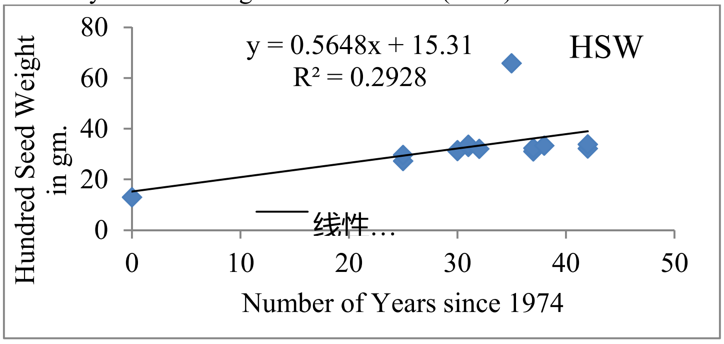

Figure 2. Relationship between year of variety release and hundred seed weight across

Table 10. Estimation of mean values and regression coefficient (b) of various agronomic traits from linear regression of the mean value of each character for each variety against the year of release

Character	Mean	R^2	b	Intercept
Days to flowering	56.61	0.0002	0.0045	56.47
Days to maturity	129.52	0.0419	0.0431	128.17
Plant height	49.7	0.2429	0.1836	43.997
Number of pod per plant	41.47	0.3204	-0.4748*	56.23
Number of seed per pod	1.20	0.6046	-0.0091**	1.48
Hundred seed weight	32.86	0.2928	0.5648*	15.31
Grain yield	3264.48	0.1103	22.347	2570.2

Table 11. Annual Relative Genetic Gain and Correlation Coefficients for Grain Yield and Different Attributes Of Kabuli Type Chickpea Varieties

Characters	Mean of the older variety (DZ-10-4)	Relative genetic gain (% $year^{-1}$)	Correlation coefficient(r)	
			GY/ha	HSW
Days to flowering	57.83	0.01	0.21	-0.23
Days to maturity	128.17	0.03	-0.22	0.54*
Plant height	44.7	0.41	0.31	0.22
Number of pod per plant	51.80	-0.92	0.40	-0.78**
Number of seed per pod	1.54	-0.59	-0.33	-0.59*
Hundred seed weight	12.91	4.37	-0.42	--
Grain yield	2153.4	1.04	--	-0.42

3.3.3. Plant height

Among the recently released varieties, the tallest plant height was observed in variety 'Dhera' (58.72 cm) that was of course released for mechanized harvesting purpose, while 'Akuri', which was released in 2011 (41.55cm) had the shortest plant height (Table 6). The regression of plant height against the years of release showed annual rate of genetic gain of 0.1836 cm ha^{-1} $year^{-1}$ (Table 10) with a relative annual genetic gain of 0.41%, though it was not significantly different from zero (Table 11). Similarly, Yifru and Hailu (2005) reported that plant height was taller for the modern Tef varieties than the older ones, even though the relative genetic gain over the 35 years period of breeding was low (0.42) cm per year, and was not significantly ($P<0.05$) different from zero. In contrary to this study, Nurberdy *et al.* (2015) and Mekuria *et al.* (2018) observed a significant reduction in plant height in winter wheat in turkey and durum wheat in Ethiopia, respectively. Mihret *et al.* (2015) reported a negatively non-significant annual rate of gain in plant height against year of release with the average annual genetic gain and annual relative percentage gain of -0.39 cm year^{-1} and -0.16% per year.

3.3.4. Number of Pods per plant and seeds per pod

Mean number of pods per plant and number of seeds per pod average across location were 41.47 and 1.198 respectively (Table 6). From this study, the number of pods per plant and number of seeds per pod followed a decreasing trend over 42 years of Kabuli chickpea improvement program as seen from the significant and highly significant negative linear regression coefficients(Table 10) with relative annual gains of -0.92 and -0.59, respectively(Table 11). In contrast, kebere *et al*. (2006) reported there was an increasing tendency in the number of pods plant^{-1}.

3.3.5. Days to flowering and maturity

The recently released variety, Dhera was the latest to reach flowering and maturity (Table 6), while 'Akuri' (released in 2011) was the earliest (52.08 days) to flower and 125.42 days to mature (Table 6). The regression analysis of days to flowering against the year of release indicated a non- significant increase in annual genetic gain of 0.0045 days yr^{-1} (Table 10) with the relative genetic gain of 0.01 % (Table 11). In contrast, Ribeiro *et al*. (2008); Fikre *et al*. (2012) reported a negative genetic gain for the number of days to 50% flowering in common bean. In addition, days to physiological maturity showed a non- significant positive increase in annual genetic gain of 0.043 days per year (Table 10), with relative genetic gain of 0.03% (Table 11). Similarly, Kebere *et al*. (2006); Tamene (2008), Demissewu (2010) and Mekuria *et al*. (2018) found a non-significant increase in days to maturity in haricot bean, faba bean, soybean and durum wheat breeding, respectively. In contrast, Wondimu *et al*. (2013) reported non-significant negative trends for days to flowering and maturity in food barley.

3.4. Correlation between traits

The correlation coefficients of grain yield and hundred seed weight with all the traits studied are presented in (Table 12). The result showed that non-significant positive association between grain yield and plant height. It is often common to see high chickpea plants with pod bearing parts raising above shade zone, means small area for pod production. Yifru and Hailu (2005); Wondimu *et al*. (2013); Mihret *et al*. (2015) ; also reported statistically non- significant association between grain yield and plant height in teff, malt barley and lowland sorghum, respectively. In contrast, Demissew (2010) reported a highly significant increase and significant positive correlation of plant height with grain yield in soybean. Jin *et al*. (2010) on soybean observed negative correlation between plant height and grain yield.

Non-significant positive correlation was observed between grain yield and the number of pods plant^{-1}, while number of seeds pod^{-1} and hundred seed weight showed negative and non-significant association with grain yield (Table 12). Kulwal and Mhase (2016) reported yield which is influenced by seed weight is the enhanced assimilation of metabolites and their transformation to yield components. Hundred seed weight showed significantly negative associations with number of pods plant^{-1} and number of seeds pod^{-1} (Table 12). According to Dewey and Lu (1959), more seeds per pod might cause a reduction of the average seed size because of competition among seeds for limited food reserves. According to Sharma and Saini (2010), days to maturity and days to flowering showed non-significant negative and positive correlations with grain yield, respectively in chickpea. On the contrary, Singh *et al*. (1990) in chickpea, and Hailu *et al.* (2009) and Demissew (2010) in soybean reported strong positive correlations of grain yield with days to flowering and days to maturity.

Table 12. Estimates of correlation coefficient among traits of Kabuli chickpea varieties

	YOR	DF	DM	PH	NPPP	NSPP	HSW	GY
DF	0.014	1						
DM	0.204	0.53	1					
PH	0.49	0.57*	0.54*	1				
NPPP	-0.56*	0.39	-0.17	-0.08	1			
NSPP	-0.78**	-0.34	-0.54*	-0.56*	0.29	1		
HSW	0.54*	-0.23	0.54*	0.22	-0.78**	-0.59*	1	
GY	0.33	0.21	-0.22	0.31	0.40	-0.33	-0.42	1

Stepwise regression analyses using grain yield as dependent variable indicated that, hundred seed weight and number of seed per pod were traits which contributed to grain yield. Particularly, 79% by hundred seed weight and 87% was contributed together by hundred seed weight and number of seed per pod (Table 13). This illustrates that the improvement in grain yield was achieved by combination of different factors.

Amsal (1994) reported number of grain per meter square alone accounted for most of the variation (>68%) in grain yield while number of gain per meter square, 1000-seed weight, plant height, biomass yield collectively contributed for more than 93% variation in wheat grain yield. Similarly, Tamene (2008) reported that 96% of the variation in faba bean grain yield was explained by economic growth rate, whereas economic growth rate, number of pod plant^{-1}, harvest index and biomass together accounted for 99 % of the variation in grain yield. Tafese *et al.* (2016) also reported that 84% of the variation in grain yield of sesame was explained by seed yield per plant, 12% by harvest index and 96% was contributed altogether by harvest index and seed yield per plant.

Stepwise regression analyses showed using hundred seed weight as dependent variable, which is contributed an economic trait in Kabuli type chickpea: number of pods per plant had a declining effect, contributed to the variation among the varieties in hundred seed weight. About 60% of the variation in Kabuli chickpea seed size was explained by number of pods per plant. Similarly, Tamene (2008) was reported 88.48% of the variability in thousand seed weight was accounted for by number of pods per plant alone and 92.56% when both number of pods and grain filling period together.

Table 13. Summary result of selection from stepwise regression analysis of mean grain yield and hundred seed weight as dependent variable and the other traits as independent variable

	Grain Yield	
independent Variable	Regression coefficient (b)	R^2 (%)
Hundred seed weight	-51.37*	0.79
Number of seed per pod	-4234.56 *	0.87
	Hundred seed weight	
Number of pods per plant	-0.97**	0.60

4. Conclusion

Estimation of the genetic progress achieved through crop breeding helps breeders evaluate the strengths and weaknesses of the breeding program and accordingly devise more efficient strategies for further improvement. This experiment clearly revealed that improved genetic progress was obtained from breeding Kabuli chickpea in Ethiopia for seed size than it was for grain yield. Hundred seed weight was negatively correlated with number of pods per plant and number of seeds per pod. For that reason, the negative relationship between hundred seed weight and with these traits indicates that a compensatory relationship between them. Selection from introductions and hybridization as major breeding methods was successful in improving grain yield as well as different agronomic practices rather than selection from landrace. Therefore, the Kabuli chickpea improvement program needs special attention to compliment seed size and grain yield by using integrated breeding (conventional- crossing works than landrace selection with molecular breeding) approach to make rapid progress in developing chickpea varieties.

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