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Breeding Progress for Grain Yield and Yield Related Characters of Kabuli Chickpea (*Cicer arietinum* L.) in Ethiopia Using Regression Analysis

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Abstract

The progress made to improve kabuli chickpea varieties through breeding in Ethiopia has not been assessed so far. Therefore, in this study genetic gain in seed yield and yield related characters of 10 kabuli chickpea varieties (8 released and 2 elite lines) developed by the Chickpea Research Program from 1974 to 2015 during main cropping season was assessed. The varieties were evaluated in the Randomized Complete Block design at Debrezeit Agricultural Research Center experimental research farm. The overall increase in seed yield over the local check, DZ-10-4, was estimated to be 739 kg/ha (38.9%). Grain yield was increased from 1900 to 3250 kg/ha during the last 41 years and the overall increase in seed yield of the Arartie variety over the oldest variety DZ-10-4 was estimated to be 1350 kg/ha or 71.1%. Based on the regression analysis, the estimated average annual rate of increase in grain yield potential was 10.87 kg/ha/year with an annual relative genetic change of 0.57%/year. Genotypic change was an important source for increased grain yield potential during the studied period. Positive genetic gains were observed for the yield traits (grain yield and yield components).The average cumulative gains over 41 years of breeding was, therefore, 445.67 kg (23.37%) for seed yield, and 30.26 g for hundred seeds weight (297.7%). Hundred seed weight revealed the most dramatic response to breeding for the last 41 years. It is, therefore, strategically advisable that breeding efforts in the future should give due attention to yield related traits of kabuli chickpea varieties.

Keywords: chickpea, kabuli, regression, relative genetic gain, yield potential

1. Introduction

Chickpea, an important grain legume crop, is grown in over 50 countries of the world in diverse climatic regions. Among grain legumes, it acquires fourth position based on both cultivated area and production in the world (FAOSTAT, 2014). It is an excellent source of protein and carbohydrate and its protein is of high quality as compared to other pulse crops (Ercan et al., 1995). The average seed yield of chickpea in Ethiopia is 1.91 tons/ha. The total land coverage and yield of chickpea in Ethiopia are estimated to be 239,747.51 hectares and 458,682 tons, respectively (CSA, 2015).

The crop has a great economic merit in Ethiopia providing a cheap source of protein for human diet and animal feed, source of alternative cash income to the farmers and foreign currency to the country. Despite its high economic importance, the national average yield of chickpea is very low, 1.91 tons/ha (CSA, 2015). This yield is far less than the attainable yield (5 tons/ha) under good management condition, yet it is also very low compared to the average yield of 2,200 kg/ha in Egypt. However, it is higher than the world average yield (962 kg/ha) or some countries like India (920 kg/ha) (FAOSTAT, 2014). Lack of compatible improved varieties for different agro-ecological zones has been one of the major reasons for the low chickpea yield.

Chickpea breeding in Ethiopia was started in the 1970's with the prime objectives of improving seed yield, seed size and resistance to important diseases, particularly fusarium wilt and aschocyta blight. From the hitherto breeding efforts in Ethiopia, a number of improved chickpea varieties have been developed and released for general production under different recommendation domains, including the mid and high altitude agro-ecologies and the waterlogged vertisol areas. For the last 41 years of Kabuli type chickpea improvement, grain yields and hundred seed weight (seed size) showed significant increment. Breeding efforts on kabuli type chickpea to improve its yield was relatively less marked probably owing to stringent seed size requirements. However, better genetic progress was obtained from breeding for its hundred seed weight than seed yield for the last four decades.

Systematic research in the country on Kabuli type chickpea was started during 1970s. Since then, several efforts have been made to identify its major production constraints. Accordingly, prevalence of diseases, insect pests, absence or limited use of modern inputs and inappropriate agronomic practices were found to be constraints of chickpea productivity. Furthermore, progress in chickpea breeding in the country has also been constrained by lack of good early maturing variety with ability to resist known chickpea diseases. Understanding the amount of genetic gain realized through past crop breeding efforts is absolutely essential to improving the efficiency and effectiveness of future breeding endeavors (Evans, 1993; Ustun et al., 2001; Waddington et al., 1987). Besides quantifying the progress obtained in a certain period, the genetic gain analysis also enables aggregation of other information, such as comparison of the gains obtained with the use of different breeding strategies or in different environments (Specht & Williams, 1984). This kind of information contributes to the understanding of past events, allows elaboration of new strategies, adoption of corrective methods and more efficient resource allocation that together result in an increase in the breeding programs efficacy.

The accurate estimation of genetic progress realized from long-term breeding efforts is a difficult task but various procedures may be used. Among the available procedures, the performance of genotypes in common environments regressed over years of varietal release of a given crop as a continuous quantitative variable provided the most direct estimate of genetic gain from breeding and has widely been used in different crops (Cox et al., 1988). For example, genetic progresses using the same procedure were reported in barley (Martintello et al., 1987), groundnut (Mozingo et al., 1987), sunflower (Pereira et al., 1999), wheat (Brancourt-Hulmel et al., 2003; Parveen & Khalil, 2011; Rodrigues et al., 2007; Shearman et al., 2005), soybean (Jin et al., 2010; Liu et al., 2012; Morrison et al., 2000; Ustun et al., 2001) and maize (Luque et al., 2006). Genetic gain achieved over time from breeding of different crops in Ethiopia have also been studied using the same procedure and documented in haricot bean (Bezawuletaw et al., 2006), maize (Worku & Zelleke, 2007), barley (Fekadu et al., 2011), groundnut (Hagos et al., 2012) and faba bean (Tolessa et al., 2015). The magnitude of genetic progress of chickpea for hundred seed weight and grain yield in association with changes in resistance to adzuki bean beetle (*Callosobruchus chinensis*) was reported (Keneni et al., 2011). However, information on the amount of genetic gain made over time from breeding chickpea in Ethiopia is limited. Therefore, the purpose of present study was to estimate the amount of genetic gain made over-time in seed yield and yield related traits of kabuli chickpea.

2. Materials and Methods

The experiment was conducted at the experimental field of Debrezeit Agricultural Research Center (DZARC). The center is located at 8°44′ N latitude and 38°58′ E longitude at an altitude of 1900 m.a.s.l. Ten varieties, representing eight kabuli chickpea varieties released between 1974 and 2015 and two elite lines being proposed as variety for release**,** were used (Table 1). The experiment was set using randomized complete block design with three replications since 1974. Each gross plot size was 4.8 m^2 and consisted of 4 rows of 4 m in length. The two middle-rows, with net plot of 2.4 m^2, were considered in recording data. The spacing between rows and between plants within row was 30 cm and 10 cm, respectively. Pesticides were also applied to control major diseases and insects prevailing in the area. Hand weeding was practiced as frequently as needed. Data were recorded on days to 50% flowering, maturity, plant height (cm), hundred seed weight (g) and seed yield (kg/ha). To estimate the annual genetic gain achieved in seed yield and changes produced on associated agronomic traits, the mean values of each character for each variety were regressed against the year of release. The year of release was expressed as the number of years since 1974, the period when coordinated chickpea improvement program started.

Table 1. Description of the 10 kabuli chickpea varieties used in the experiments

No	Name of Variety	Pedigree	Year of release	Source	Seed rate	Recommendation domain (m.a.s.l)
1	DZ-10-4	DZ-10-4	1974	Selection	65-75	1800-2300
2	Shasho	ICCV-93512	1999	Hybridization	100-125	1800-2600
3	Arartie	FLIP 89-84c	1999	Hybridization	110-115	1900-2600
4	Chefe	ICCV-92318	2004	Hybridization	110-140	1800-2000
5	Habru	FLIP 88-42C	2004	Hybridization	110-140	1800-2600
6	Ejere	FLIP 92-263c	2005	Hybridization	120-140	1800-2600
7	Tjie	FLIP 97-266C	2005	Hybridization	120-140	1800-2700
8	Monino	ACOS DUBIE	2006	Introduction	150-160	1600-2400
9	DZ-2012-CK-001	FLIP 04-9C	Candidate	Hybridization	130-140	1800-2600
10	DZ-2012-CK-0009	FLIP 0163	Candidate	Hybridization	130-140	1800 - 2800

2.1 Statistical Analysis

Genetic gain of grain yield was estimated from the trials "Final Assessment of kabuli chickpea lines and Cultivars" conducted between the 1974 and the 2015 growing seasons, at several locations. Linear regression analysis was used to calculate the genetic gain for each trait considered in the study. The breeding effect was estimated as a genetic gain for grain yield and associated traits in chickpea improvement by regressing mean of each character for each variety against the year of release of that variety. The magnitude of genetic progress from breeding was estimated by regressing the mean performances of the genotypes on years of varietal release using 1974, when the first variety was released, as the base year (Cox et al., 1988). The linear relationship between a dependent variable Y and independent variable X is represented by the equation:

$$Y = bx + a \tag{1}$$

where, Y = the mean value of the dependent variable, x = the mean value of the independent variable, a = the intercept of the line, and b = the regression coefficient (slope of the line), or the changes in y per unit change in x.

A straight line was fitted through the points using simple linear regression and the resultant coefficients of regression of genotype mean performances on the years of varietal release were used as estimates of the annual genetic progress calculated as:

$$\text{Annual rate of gain (b)} = \frac{\text{Cov (X,Y)}}{\text{Var (X)}} \tag{2}$$

where, X = the year of variety release, Y = the mean value of each character for each variety, Cov (X,Y) = the covariance of X and Y; and Var (X) = the variances of x.

The relative annual gain achieved over the last 41 years (1974-2015) for *Kabuli* chickpea was determined as a ratio of genetic gain to the corresponding mean value of oldest variety and expressed as percentage. Simple linear relationship among all characters were calculated using means of each character. Correlation coefficients for the traits under consideration were computed using means of varieties. Correlation coefficient between Y and X was computed as:

$$r_{xy} = \frac{\text{Cov (X,Y)}}{\sqrt{\text{Var (X)}\cdot\text{Var (Y)}}} \tag{3}$$

where, Cov (X,Y) = Covariance between X and Y, Var (X) = Variance of X and Var (Y) = Variance of Y.

The data were analyzed using the R software version 2.15.2.

3. Results and Discussions

The mean values for grain yield ranged from 1900 to 3400 kg/ha with an average yield of 2650 kg/ha. Table 2 shows the mean seed yield of varieties released in 1974, 1999, 2004, 2005, 2006 and proposed for release in 2016. The least and highest increases were 325 kg/ha (18.4%) and 1350 kg/ha (71.1%) for the variety released in 2006 and Arartie variety, respectively, over the local check, DZ-10-4. The overall increase in grain yield over the local variety was estimated to be 821.11 kg/ha (43.22%) considering all varieties in the trial, whereas 857.14 kg/ha (45.11%) was obtained excluding varieties proposed for release (Table 2). Hence, grain yield increased substantially with the release of improved varieties. This was in agreement with other findings on soybean (Karmakar & Bhatanagar, 1996), which reported a significant increase in grain yield of new soybean cultivars over the older ones. It was also reported that the average grain yield of soybean ranged from 1.117 to 1.710 tons/ha for the period of 1980 to 1996 (Tefera et al., 2009). Furthermore in another similar study, better seed yield of new soybean cultivars over that of the first old variety was reported (Demissew, 2010). This gives an insight for possible future opportunities to exploit the genetic potential of the crop for enhanced chickpea production.

Table 2. Mean value of traits obtained from analysis of grain yield and yield components of kabuli chickpea varieties

Variety	Grain yield and yield components					
	Grain yield (kg/ha)	Days to flowering	Days to maturity	Plant height (cm)	100 SW (kg/ha)	Seed rate (kg/ha)
DZ-10-4	1900	49.50	123.0	36.90	10.20	70.00
Shasho	3100	60.50	122.5	49.60	29.90	117.50
Arartie	3400	58.50	130.0	45.20	25.70	107.50
Chefe	2450	48.50	121.5	46.05	33.45	125.00
Habru	2850	59.50	120.5	46.05	32.20	125.00
Ejere	2500	49.00	123.5	40.00	37.20	130.00
Tjie	2750	53.50	126.0	36.60	38.10	130.00
Acos Dubie	2250	43.00	121.5	44.00	64.00	155.00
DZ-2012-CK-001	2730	60.5	133.0	48.05	31.36	135.00
DZ-2012-CK-009	2460	60.75	133.8	60.99	33.24	135.00
Mean	**2609.23**	**54.33**	**125.53**	**45.34**	**33.54**	**123.00**
CV %	**16.18**	**11.90**	**3.96**	**15.58**	**39.61**	**18.27**

Plotting mean grain yields of the 10 tested kabuli chickpea varieties versus the year of release (Figures 1 and 2) showed an upward trend since the mid 1970s (a year when the first improved varieties was released). The estimated average annual rates of increase in seed yield potential were 10.87 kg/ha/year (Figure 1) and 17.18 kg/ha/year (Figure 2) for all varieties and for the released ones, respectively. This indicated that past kabuli chickpea breeding efforts in Ethiopia have resulted in an average grain yield increment of 445.67 kg ha-1 when the local check variety, DZ-10-4, was used as a reference (Table 3). Similarly, previous work on durum wheat (Waddington et al., 1987), Australian spring wheat (Perry & D'Antuono, 1989), soybean (Voldeng et al., 1997), and tef (Teklu, 1998) reported an increase in yield potential of the tested varieties over years of variety release.

The mean relative annual gain in grain yield of kabuli chickpea varieties since 1974 was 0.57% increase per year (39% improvement of yield), or about 23.37% for the whole period of 41 years (Table 5). Present results indicated that the plant breeders made substantial progress during the last 41 years in improving the yields of kabuli chickpea varieties in Ethiopia. Besides, there was no indication of yield potential plateau in kabuli chickpea varieties over the period of the study (Figure 1) which indicates that further improvement is possible to increase yield and this provides clues for breeders to further exploit (increase) the yield potential of the existing kabuli chickpea varieties.

Table 3. Average seed yield (kg/ha) of kabuli chickpea varieties and increment over the first released variety, DZ-10-11

Name of Variety	Year of release	Average Seed Yield (Kg/ha)	Increment over DZ-10-4		100 Seed Weight (g)	Increment over DZ-10-4	
			Kg/ha	%		gram	%
DZ-10-4	1974	1900	-	-	10.20	-	-
Shasho							
Arartie	1999	3250	1350	71.1	27.80	17.6	172.6
Chefe							
Habru	2004	2650	750	39.5	32.83	22.6	221.9
Ejere							
Tjie	2005	2625	725	38.2	37.65	27.5	269.1
Acos Dubie	2006	2250	350	18.4	64.00	53.8	527.5
DZ-2012-CK-001							
DZ-2012-CK-009	Candidate	2595	695	36.6	32.30	22.1	216.7

The genetic progresses made in seed yield (0.57% ha^{-1} $year^{-1}$) from kabuli chickpea breeding in Ethiopia is much lower than the progresses made in seed yields from breeding of other crops like barley (1.34% ha^{-1} $year^{-1}$) (Fekadu et al., 2011), groundnut (1.89% ha^{-1} $year^{-1}$) (Hagos et al., 2012) and haricot bean (3.24% ha^{-1} $year^{-1}$) (Bezawuletaw et al., 2006) and higher than faba been (0.26% ha^{-1} $year^{-1}$) (Tolessa et al., 2015). In other countries, reports also revealed higher annual yield increases of 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). Even though genetic gain in grain yield from chickpea breeding in Ethiopia indicate the progress, the progress made was lower than other crops and the actual yield is also lower than potential yield. The major reason for this low yield could be related to lack of high-yielding, disease-resistant genotypes with adaptability to different ecological zones. It could also be related to lack of varieties with high response to high inputs and other management practices.

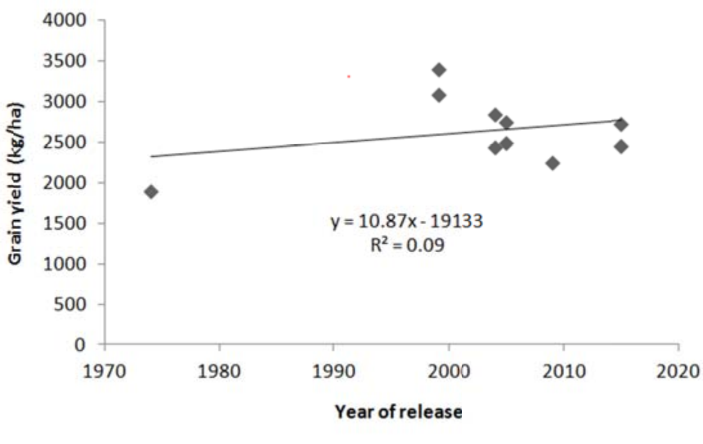

Figure 1. Association between mean seed yield of 10 kabuli chickpea varieties and the year of release since 1974 (the year when coordinated kabuli chickpea improvement program started)

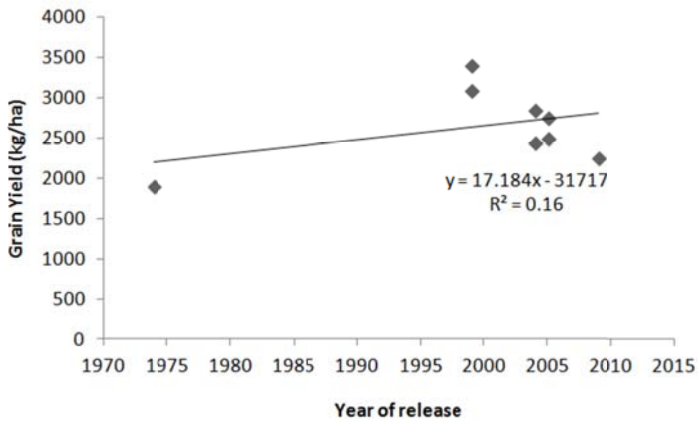

Figure 2. Relationship between average seed yield of 8 kabuli chickpea varieties (only released ones) and the year of release since 1974 (the year when coordinated kabuli chickpea improvement program started)

The 100 seed weight levels varied significantly from 10.2 to 64 grams among the 10 varieties (Table 2). Regression analysis revealed that a positive association and significant trend between mean 100 seed weight and years of varietal releases (Figure 3), which was in contrary with finding from soybean reported earlier in Canada (Voldeng et al., 1997). The annual rate of genetic progress from breeding kabuli chickpea was estimated to be 0.738 g 100 $seeds^{-1}$ as indicated in (Figure 3). This means that increment of 7.26% 100 $seeds^{-1}$ $year^{-1}$ or 30.26 g 100 $seeds^{-1}$ (297.7%) for over four decades of breeding period was gained using the oldest variety, DZ-10-4, as a reference. Therefore, it was clearly indicated that better genetic progress was gained from breeding kabuli chickpea for 100 seed weight than it was for seed yield. One hundred seed weight was also significantly affected with the release of improved varieties. Similarly, a significant annual increase in a hundred seed weight occurred in USA in all the maturity groups of soybean released during the period 1902 to 1977 (Specht & Williams, 1984). Based on the relative comparison of different varieties for the temporal changes made through breeding, 172.6-527.5% hundred seed weight increment was obtained for kabuli chickpea varieties when compared with reference variety, DZ-10-11 (Table 3). Similar findings with more increments in 100 seed weight than in seed yield, was also reported from chickpea breeding in Ethiopia (Keneni et al., 2011; Tolessa et al., 2015). This could be attributed to the fact that, while seed yield is the primary character of interest and a prime objective in most of the Ethiopian crop breeding programs for the last many decades, hundred seed weight/seed size also received a special attention recently both at national and international levels, in response to the current move towards meeting the export-market demand for large seed size (EARO, 2000).

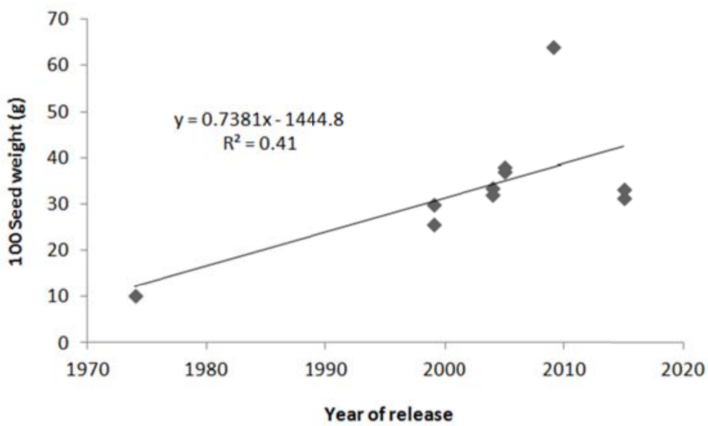

Figure 3. Scatter plot of 100 seed weight (g) against years of variety release starting from 1974-2015

Table 4. Estimation of mean values, coefficient of determination (R^2) and regression coefficients (b) of some yield attributing characters against the year of release for the varieties

Character	Mean (1974)	Mean (1974-2015)	R^2	b
Grain yield	1900	2639.00	-	10.87
Days to flowering	49.5	54.33	0.06	0.14
Days to maturity	123	125.53	0.18	0.18
Plant height	36.9	45.34	0.32	0.34
100 seed weight	10.2	33.54	0.41	0.74**

Note. ** = Significant at 5 % level.

The mean rate of increase in total grain yield per year of release, estimated from the slope of the graph was 10.87 (Figure 1). The relative annual gains of grain yield was 0.57% over the 41 years (Table 5), indicating that genetic improvement for this trait was important for seed yield enhancement in kabuli chickpea varieties during the study period.

Table 5. The annual relative genetic gain and correlation coefficients for grain yield and yield contributing traits of kabuli chickpea varieties

Character	Relative genetic gain (% year^{-1})	Correlation Coefficient (r)
Grain yield(kg/ha)	0.57	-
Days to flowering	0.28	0.65**
Days to maturity	0.15	0.25
Plant height (cm)	0.92	0.22
100 Seed Weight	7.26	-0.05

Note. ** = Significant at 5 % level.

However, unlike other attributes, a significant relative gain per year was obtained for the 100 seed weight during the whole period of yield improvement program. There were challenges to improve the number of days to flowering, days to maturity and plant height during the given period of time (Table 5).

3.1 Phenological Traits

Days to flowering obtained in this study ranged from 43 to 60.75 with a mean of 51.9 (Table 2). In the present study Acos Dubie variety has lower days to flowerings and proposed variety, DZ-2012-CK-009 va has longer days to flowering. The regression of the mean days to flowering of kabuli chickpea variety on the year of release indicated that there was 0.14 days/year average annual rate of increase (Table 6). This was not significantly different from zero, revealing that there was a non-significant improvement from the old to the modern varieties in days to flowering. The relative gain in terms of annual days to flowering in kabuli chickpea varieties was estimated to be 0.28% per year for the 41 years (Table 5). This gain is mainly due to late flowering of some variety such as Shasho and the two candidate varieties (DZ-2012-CK-001 and DZ-2012-CK-009).The present result was in contrary with the results of others (Bezawuletaw et al., 2006; Hagos et al., 2012), which reported negative and insignificant regression coefficient in days to flowering of haricot bean and groundnut. This indicate that the breeding program had failed to reduce the days to flowering of kabuli chickpea, and the grain yield improvement was solely due to the result of higher 100 seed weight. Days to maturity obtained in this study ranged from 120.5 to 133.8 with a mean of 127.15 (Table 2). From the present study DZ-2012-CK-009 variety takes long days to maturity and the Habru variety has short days to maturity (Table 2). Like days to flowering, the regression analysis indicated a positive regression coefficient in days to maturity which was 0.18. It can be seen from the table that there was no significant trend of increasing in days to maturity over 41 years. This insignificant increase occurred due to late flowering character of some released and proposed varieties such as Arertie, DZ-2012-CK-001 and DZ-2012-CK-009. Hence, the change in days to maturity was not associated with the time of release of the varieties. This was in agreement with the report on haricot bean varieties released in Ethiopia from 1972 to 1996 (Bezawuletaw et al., 2006). Similar result has also been reported on groundnut varieties released from 1976 to 2009 (Hagos et al., 2012). However, our result seems to be to reports from soybean cultivars released in India from 1969 to 1993 (Karmakar & Bhatanagar, 1996). The present study shows that kabuli chickpea varieties did not show significant differences for days to maturity over the period of the genetic improvement.

3.2 Plant Height and Hundred Seed Weight

In this current study, there was a non-consistent gradual increase in plant height from the older to the newer varieties. As it was estimated from regression of variety means against year of release, the annual rate of gain, 0.34cm/ha/year, was not different from zero (Table 4). This implied that yield potential improvement program did not markedly affect this trait. In contrast, a conspicuous reduction in plant height was reported (Karmakar & Bhatanagar, 1996). Since 1974, the relative annual change of hundred seed weight was found to be high, 7.26%, per year or 297.7% over 41 years period (Table 5). The estimated annual rate of changes was in the same direction with that of all other traits; however, it was significant (b = 0.738), as it was not observed for plant height (Table 4). This result was in agreement with finding of other similar works which found positive change in hundred seed weight (Bezawuletaw et al., 2006; Hagos et al., 2012; Tolessa et al., 2015). This change of hundred seed weight may be attributed to reduction of yield potential from optimum level. On the other hand, there was indications of 100 seed weight increment in kabuli chickpea cultivars over the period of the study (Figure 3), which indicates that further improvement is possible to increase this trait and this provides clues for breeders to exploit (increase) the hundred seed weight and other traits of the existing kabuli chickpea varieties.

3.3 Correlation Analysis

Grain yield was significantly and positively ($P \leq 0.05$) associated with days to flowering ($r = 0.65$) but showed no significant association with days to maturity($r = 0.25$), plant height ($r = 0.22$) and 100 seed weight($r = -0.05$) (Table 6). It was observed that grain yield was significantly and positively related with number of pods per plant in their study with soybean (Faisal et al., 2006). It was indicated that the correlations between the number of seeds per pod and the number of pods per plant with chickpea grain yield were highly significant (Savitha, 2008), which indicates that these characters can contribute to yield increment.

In this study, significant and positive relationship was obtained for seed yield and days to flowering. Contrary to the present result, no association was recorded for seed yield with days to flowering on teff (Teklu, 1998) and haricot bean (Bezawuletaw et al., 2006). Similarly, it was shown that yield was negatively correlated with days to 50% flowering (Faisal et al., 2006; Hagos et al., 2012; Ramteke et al., 2010). In soybean seed yield and days to flowering didn't show correlation but positive association (Salado-Navarro et al., 1993). The lack of relationship between grain yield and days to physiological maturity (Table 6) observed herein supported the findings on tef (Teklu, 1998). On the other hand, in other studies it was reported there was positive association for grain yield with days to physiological maturity (Laing et al., 1984; Salado-Navarro et al., 1993); as opposed to significantly negative association obtained between the same in wheat (Waddington et al., 1987). (Bezawuletaw et al., 2006) also found that no correlation between grain yield and days to maturity. In contrary, negative but significant relationship between yield and days to maturity was reported on groundnut (Hagos et al., 2012).

No associate between seed yield and plant height (Table 6) observed in the current study was in agreement with results of other similar study on haricot bean (Bezawuletaw et al., 2006). Contrary to present finding, (Riggs et al., 1981) reported positive association in wheat and negative association in spring barley, respectively, between grain yield and harvest index. As shown in Table 6, insignificant association was found between seed yield and 100 seed weight ($r = -0.05$, $p > 0.05$). Similarly, several authors also observed no association between chickpea seed yield and 100 seed weight (Bezawuletaw et al., 2006; Riggs et al., 1981; Tarekegne, 1994; Teklu, 1998; Waddington et al., 1987; White & Izquierdo, 1991). In contrast, the positive correlation were recorded for grain yield with the number of seeds per pod and mean hundred seed weight in soybean (Hagos et al., 2012; Karmakar and Bhatanagar, 1996), with the number of seed per year in wheat crop.

Table 6. Correlation coefficients of mean values of yield and yield related traits of Kabuli chickpea varieties represented in the study

Character	Grain yield	Days to flowering	Days to maturity	Plant height	100 Seed weight
Grain yield	-				
Days to flowering	0.6538**	-			
Days to maturity	0.2450	0.5708	-		
Plant height (cm)	0.2154	0.5693	0.5168	-	
100 seed weight(g)	-0.0521	-0.4303	-0.1763	0.0837	-

Note. ** = Significant at $P \leq 0.05$.

Only days to flowering were positively and significantly ($P \leq 0.05$) associated with grain yield (Table 6). In contrast, it was shown that yield was negatively associated with days to 50% flowering and days to maturity (Ramteke et al., 2010). Faisal et al. (2006) also found negative association of grain yield of soybean with days to 50% flowering, days to flowering completion and days to maturity. This indicates that selection on the basis of these traits might lead to kabuli chickpea yield loss for early maturing kabuli chickpea varieties and yield gain for late maturing varieties. Thus, days to 50% flowering, days to maturity and plant height had positive association with grain yield of kabuli chickpea varieties. Maximum associations were observed for days to flowering and grain yield ($r = 0.65$) followed by days to maturity($r = 0.25$) and plant height($r = 0.22$).

Despite insignificant increase of regression coefficient ($P \leq 0.05$, $b = 0.14$) of days to flowering over the 41 years (Table 4), a positive and significant ($P > 0.05$) correlation was observed between days to flowering and grain yield (Table 6). Contrary to the present result, it was indicated that the genetic association of days to flowering with grain yield was negative and significant (Ramteke et al., 2010). Kabuli chickpea varieties have shown a significant ($P \leq 0.05$) and positive association between grain yield and days to flowering (Table 6), but the regression coefficient ($b = 0.738$) indicated that there was significant trend for hundred seed weight from the older to the newest variety. The present study has also shown a non-significant ($P > 0.05$) and positive correlation between days to flowering and days to maturity and plant height. Hundred seed weight has negative association with both days to flowering and maturity but has positive association with plant height (Table 6). Hence, based on the findings of the present study, it could be concluded that genetic yield potential improvement program of kabuli chickpea varieties over the last 41 years has been mostly correlated with a corresponding increase of days to flowering. This principal yield component was positively associated with days to maturity and plant height as well (Table 6).

4. Conclusions

During the period 1974 to 2015, substantial progress was made in improving the seed yield potential of kabuli chickpea. Moreover, changes occurred on the correlated morphophysiological characters paralleled to varietal release. The results of this study show that there was significant increase in the seed yield potential of kabuli chickpea through consecutive release of varieties over the last 41 years. The response of hundred seed weight to past kabuli chickpea breeding efforts in Ethiopia was far better than that of seed yield. The change in genetic gain from breeding kabuli chickpea for hundred seed weight, may be attributed to reduction of grain yield. The present study also revealed that the genetic yield potential improvement of kabuli chickpea over the last 41 years was significantly associated only with paralleled increases in days to flowering. However, this trait lesser responded to breeding than grain yield. It is, therefore, advisable that breeding efforts in the future variety development program should also give due attention to yield related traits and disease resistant kabuli chickpea varieties.

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