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Genetic Improvement of Desi Type Chickpea (Cicer arietinum L.) Varieties Yield Potential and Its Agronomic Trait Determinants in Ethiopia from 1974-2010

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Abstract
A set of experiment was conducted to estimate the amount of genetic gain made over time in grain yield potential and changes in morphological characters associated with genetic yield potential improvement of *Desi* type chickpea varieties. The varieties were laid down in a randomized complete block design with three replications in 2010 cropping season. Analysis of variance revealed significant differences among varieties for all traits except primary and secondary branches plant^{-1}. Grain yield was increased by 1589.70 kg ha^{-1} to 2303.30 kg ha^{-1} over the past 36 years. The average annual rate of increase per year of release for the period 1974-2010 as estimated from the slope of the graph of linear regression of mean grain yield on year of variety release was 18.42 kg ha^{-1} with a relative genetic gain of 1.16% yr^{-1}. Varieties developed from introduction demonstrate a yield improvement of 428.28kg ha^{-1} (25.79%) over varieties developed through direct selection from local collections. Grain yield potential of *Des*i type chickpea has not attained plateau in Ethiopia. Thus, development of higher yielding varieties of *Desi* type chickpea should continue to increase chickpea grain yields if past trends pretend the future. Biomass yield and primary branches plant^{-1}also showed significant increase with respective annual genetic gains of 1.16 and 0.43%. On the contrary, secondary branches plant^{-1} showed a significant trend of decreasing over years. Linear regression also indicated that significant improvements in biomass production rate, seed growth rate and grain yield day^{-1}. No marked changes were observed in phenological traits, harvest index, plant height, number of pods plant^{-1}, seeds pod^{-1}, seeds plant^{-1}, grain yield plant^{-1} and hundred seed weight which implied that *Desi* type chickpea has failed to bring a substantial progress on these traits. Grain yield was significantly and positively associated with biomass yield, number of primary branches plant^{-1}, grain yield day^{-1}, biomass production rate and seed growth rate, whereas there was no significant correlation between grain yield and phenological traits, harvest index, plant height, hundred seed weight, secondary branches plant^{-1}, pods plant^{-1}, seeds pod^{-1} and seeds plant^{-1}. Stepwise regression analysis also revealed that most of the variation in grain yield was caused by biomass yield and harvest index.
Keywords: *Desi* type chickpea, Genetic improvement, Harvest index, Hundred seed weight, Grain yield, Yield components

INTRODUCTION

Chickpea (*Cicer arietinum* L) provides multiple benefits to growers. It is consumed in various ways and plays a substantial role in subsistence farming system. It is a good source of energy, protein, minerals, vitamins, fiber and also contains potentially health-beneficial phytochemicals (Ibrikci *et al.,* 2003 and Wood and Grusak, 2007). It supplies protein to the poor and thus known as poor man's meat.

Chickpea is one of the principal food legumes in Ethiopia and it covers about 213,187 hectares of land and 2,846,398 quintals of chickpea is produced per annum with average productivity of 1.34 tons per hectare (CSA, 2010). It, therefore, ranks third in production next to faba bean and haricot bean, but it ranks second in productivity per unit of area next to haricot bean. This clearly indicates the importance of chickpea in Ethiopian agriculture. Ethiopia is the largest producer of chickpea in Africa, accounting for about 46% of the continent's production during 1994 to 2006. It is also the seventh largest producer worldwide and contributes about 2% of the total world chickpea production (Menale *et al*., 2009).

In Ethiopia, seeds are consumed raw, roasted or in 'wot'. Sometimes, the flour is mixed with other crops for preparing injera and also unleavened bread. Green pods and tender shoots are used as a vegetable. The roasted and salted chickpea is used as snack. It can also be mixed with cereals and root crops as a protein supplement in preparing "fafa" (Senait, 1990). It is also an important legume crop used in rotation with several cereals like tef or wheat on heavy soils and maintains soil fertility through nitrogen fixation (Geletu *et al*., 1996;

Kantar *et al*., 2007). However, both productivity and quality of Ethiopian chickpeas have so far remained threateningly suboptimal due mainly to traditional and inadequate agronomic management practices, low yield potentials of the types under widespread cultivation and ravages of various biotic and abiotic stresses.

About ten *Desi* type improved chickpea varieties along with their management practices have been developed and released through the national agricultural research systems (NARS) in Ethiopia since the inception of chickpea improvement program at Debre Zeit Agricultural Research Center (DZARC) about four decades ago (Tabikew *et al*., 2009). As can been seen from the annual production statistics above, the national average yield of chickpea is very low (about one tone per hectare) (CSA, 2010). On the contrary, in areas where improved chickpea technologies were adopted and used, yield levels of up to five tons per hectare have been achieved (Tabikew *et al.,* 2009). This huge productivity gap warrants wider dissemination of the improved chickpea technologies in order substantially boost up the overall productivity and production in the country.

Information on genetic progress achieved over time from a breeding program is absolutely essential to develop effective and efficient breeding strategies by assessing the efficiency of past improvement works in genetic yield potential and suggest on future selection direction to facilitate further improvement (Waddington *et al*., 1986; Cox *et al*., 1988; Donmez *et al*., 2001; Abeledo *et al*., 2003). Progress made in genetic yield potential and associated traits produced by different crops improvement program and the benefits obtained have been evaluated and documented in different countries concluded that genetic improvement in those crops have produced modern cultivars with improved yield potential (Ustun *et al*., 2001; Abeledo *et al*., 2003; Zhang *et al*., 2005; Zhou *et al*., 2007; Hailu *et al*., 2009; Jin *et al*., 2010; Khodarahmi *et al*., 2010). This is also true for some crops in Ethiopia (Amsal, 1994; Yifru and Hailu, 2005; Kebere *et al*., 2006; Tamene, 2008; Wondimu, 2010; Demissew, 2010; Ersullo, 2010).

However; despite considerable effort and devotion of resources to *Desi* type chickpea improvement, there has been no work conducted in Ethiopia and worldwide to evaluate and document the progress made in improving the genetic yield potential and associated traits of *Desi* type chickpea varieties from different years in a common environment. Therefore, there is a need to quantify genetic progress in *Desi* type chickpea to design effective and efficient breeding strategy for the future. Hence, this research was initiated with the following objectives:

- ❖ To estimate the amount of genetic gain made over time in yield potential of *Desi* type chickpea varieties, and
- ❖ To identify changes in morphological characters associated with genetic improvement in grain yield potential of *Desi* type chickpea varieties

MATERIALS AND METHODS

The experiment was conducted during the main cropping season of 2010 under rain fed condition in the experimental fields of Debre Zeit Agricultural Research Center (DZARC) and Akaki substation. DZARC is located at 08°44'N, 38°58'E and an altitude of 1900 m.a.s.l. It's mean annual rainfall of 851 mm and mean maximum and minimum temperature of 28.3°c and 8.9°c respectively. Akaki is also situated at 08°52'N and 38°47'E with an altitude of 2200 m.a.s.l and characterized by long term average annual rainfall of 1025 mm and mean maximum and minimum temperature of 26.5°c and 7.0°c respectively.

The study consisted of 10 *Desi* type chickpea varieties released since 1974. The varieties were planted in a Randomized Complete Block Design (RCBD) with three replications at each experimental location. The experimental plot area was 4.8 m^2 having 4 rows each 4 m long and 1.2 m width. Spacing of 0.30 m between rows and 0.10 m between plants were used; the two middle rows with an area of 2.4 m^2 used for data collection. The spacing between plots and blocks were 0.40 m and 1.0 m respectively. Field management and protection practices were applied based on research recommendation for each respective location.

Data on yield and yield related traits were collected on plot and plant basis, such as phenological traits [days to 50% flowering (DF), days to 90% physiological maturity (DM), grain filling period (GFP)], grain yield, biomass yield, harvest index, yield attributes(plant height, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, number of seeds per plant, grain yield per plant, hundred seed weight and productivity traits (biomass production rate, seed growth rate and, grain yield per day).

Table 12. Description of *Desi* type chickpea varieties used in the experiment

SN	Variety/Acc. №	Year of release	Breeder/maintainer€	Source	Seed color
1.	DZ-10-11	1974	DZARC/EIAR	Ethiopia	Light Brown
2.	Dubie	1978	DZARC/EIAR	Ethiopia	Grey
3	Mariye	1985	DZARC/EIAR	ICRISAT	Brown
4.	Worku (DZ-10-16-2)	1994	DZARC/EIAR	ICRISAT	Golden
5.	Akaki (DZ-10-9-2)	1995	DZARC/EIAR	ICRISAT	Golden
6.	Kutaye (ICCV-92033)	2005	SRARC/ARARI	ICRISAT	Red
7.	Mastewal (ICCV-92006)	2006	DBRARC/ARARI	ICRISAT	Golden
8.	Fetenech (ICCV-92069)	2006	SRARC/ARARI	ICRISAT	Reddish
9.	Naatolii (ICCX-910112-6)	2007	DZARC/EIAR	ICRISAT	Light Golden
10.	Minjar	2010	DZARC/EIAR	ICRISAT	Golden

Source: MoARD, 2008, Menale *et al*., 2009, Tabikew *et al*., 2009
€=Abbreviations: DZARC= Debre Zeit Agricultural Research Center, EIAR= Ethiopian Agricultural Research Institute, SRARC= Sirinka Regional Agricultural Research Center, ARARI= Amhara Regional Agricultural Research Institute, DBRARC= Debre Berehan Regional Agricultural Research Center

All measured parameters were subjected to analysis of variance (ANOVA) using PROC ANOVA of SAS software version 9.0 (Anonymous, 2002) to assess the differences among the tested varieties. The homogeneity of error mean squares between the two locations were tested by F test on variance ratio and combined analyses of variance were performed for the traits whose error mean squares were homogenous using PROC GLM procedure of SAS. Transformation could not stabilize error variances for number of primary branches plant^{-1}, secondary branches plant^{-1} and number of seeds plant^{-1}. As a result, only separate analyses of variance for the two locations were conducted for these parameters. 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 in chickpea improvement by regressing mean of each character for each variety against the year of release of that 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 both sets of experiments; the year when the first *Desi* type chickpea variety was released. The relative annual gain achieved over the last 36 years (1974-2010) was determined as a ratio of genetic gain to the corresponding mean value of oldest variety and expressed as percentage.

To compute Pearson product moment correlation coefficients among all characters using means of each variety, PROC CORR in SAS was used. Stepwise regression analysis was carried out on the varietal mean using PROC STEPWISE in SAS to determine those traits that contributed much for yield variation among varieties.

RESULTS AND DISCUSSION

Genetic Improvement in Grain Yield

Combined analysis of variance across the two locations revealed highly significant difference among the locations and the varieties for grain yield but there was no significant variety x location interaction (Table 2). Grain yield, which is an important agronomic parameter was not significantly affected by interaction effect as varieties performed nearly similarly in both test locations. This might be due to the past breeding endeavors to develop varieties that perform relatively well over wide range of environment for grain yield potential in *Desi* type chickpea and wide adaptation for these varieties with climatic conditions under many zones (locations). The highly significant variation in grain yield of varieties and among locations and the non-significant variety x location interaction for grain yield are in agreement with the findings of Alwawi *et al*. (2010). Fikru (2004) also observed that there was a highly significant difference among locations and genotypes for most traits including grain yield.

The average grain yield of all *Desi* type chickpea varieties was 2003.48 kg ha^{-1}, which ranged from 1589.70 kg ha^{-1} for the variety released in 1974 (DZ-10-11) to 2303.30 kg ha^{-1} for the variety released in 2007 (Naatolii) (Table 3). The recently released variety Minjar was the fifth best yielder among the varieties, but the difference was not significantly lower than the top four high yielder varieties (Table 3). This variety was released because of its resistance for Ascochyta blight. As indicated in Table 4, the superiority of the higher yielder variety, Naatolii represents 642.45 kg ha^{-1} or 38.68% increment over the average of the first two older varieties

(DZ-10-11 and Dubie). Nearly similar trends of genetic progress were reported in different crops in different parts of the world. In winter wheat in UK, seed yield of newly released cultivars is found to be 27.6% greater than the older cultivars (Shearman *et al*., 2005); 30% increment of modern cultivars over old cultivars in soybean in Canada (Kumudini *et al*., 2001); 53% yield progress from breeding of soybean in Nigeria (Hailu *et al.,* 2009), 41.44% in tef (Yifru and Hailu, 2005), and 67.8% in haricot bean (Kebere *et al*., 2006). Tamene (2008) also reported increment in grain yield of modern varieties as high as 907 kg ha^{-1} (37%) over the older varieties in faba bean in Ethiopia. similarly, 71.27% yield increment is observed in soybean breeding in Ethiopia (Demissew, 2010).

Mean grain yields of varieties released in 1980s, 1990s and 2000s exceeded that of the first two older varieties released in 1970s respectively by 50.45 (3.04%), 305.9 (18.42%) and 552.77 kg ha^{-1} (33.28%) (Table 7). In other words, varieties released in 1985, 1994, 1995, 2004, 2005, 2006, 2007 and 2010 exceeded that of the average of the first released two older varieties by 50.45 (3.04%), 224.25 (13.50%), 387.55 (23.33%), 625.75 (37.68%), 539.20 (32.47%), 642.45 (38.68%) and 417.25 kg ha^{-1} (25.12%) (Table 4). Hence, grain yield showed an increase from old to new varieties during the last three decades of *Desi* type chickpea breeding in Ethiopia. This implies chickpea breeders tried to a lot to improve *Desi* type chickpea grain yield potential. This is in agreement with the findings of Amsal (1994), Yifru and Hailu (2005), Kebere *et a*l. (2006), Tamene (2008), Hailu *et al*.(2010), Wondimu (2010), Demissew (2010) and Ersullo (2010) who found substantial increases in grain yield of modern varieties over the older ones.

Table 2. Mean squares from combined analysis of variance for seed yield and other traits in *Desi* type chickpea varieties evaluated over two test locations (Debre Zeit and Akaki).

Trait€	Location (1)¥	Varieties (9)	Location x Varieties(9)	Error (36)	Mean	CV (%)	R^2
DF	326. 67**	285.90**	25.37**	2.87	46.90	3.61	0.97
DM	2996.27**	44.49**	10.97**	3.04	120.90	1.44	0.97
PH	484.50**	16.94*	14.08^{ns}	7.49	29.05	9.42	0.79
NPoPP	418.70**	158.97**	47.89^{ns}	44.79	48.27	13.87	0.60
NSPPo	0.02ns	0.05**	0.0047^{ns}	0.01	1.18	8.33	0.64
GYPP	8.96ns	9.95**	3.90^{ns}	3.22	12.28	14.62	0.60
GYPha	5456716.15**	399678.01**	558896.70^{ns}	64639.11	2003.48	12.69	0.85
HSW	34.20**	98.57**	3.02**	0.64	20.57	3.89	0.98
BYPha	19159331.24**	1136907.89**	174973.46^{ns}	194655.77	3440.80	12.82	0.86
GFP	1344.27**	238.93**	35.19**	4.66	74.00	2.92	0.96
HI	0.01**	0.001**	0.00^{ns}	0.0004	0.58	3.42	0.64
BPR	2423.29**	85.87**	10.90^{ns}	13.03	28.85	12.51	0.90
SGR	1953.51**	152.84**	17.60^{ns}	11.48	27.75	12.21	0.91
GYPD	724.68**	30.50**	4.21^{ns}	4.40	16.79	12.50	0.89

¥= Numbers in parenthesis represent degrees of freedom

****, *, ^{ns}**= Significant at $P \le 0.01$, significant at $P \le 0.05$ and non-significant respectively

€= Abbreviations: BPR= biomass production rate (Kg ha^{-1} day^{-1}), BYPha= biomass yield per hectare (Kg ha^{-1}), DF= days to flowering, DM= days to physiological maturity, GFP= grain filling period (days), GYPD= grain yield per day (Kg ha^{-1} day^{-1}), GYPha= grain yield per hectare (Kg ha^{-1}), GYPP= grain yield per plant (g), HI= harvest index, HSW= hundred seed weight (g), NPBPP= number of primary branches per plant, NPoPP= number of pods per plant, NSBPP= number of secondary branches per plant, NSPP= number of seeds per plant, NSPPo= number of seeds per pod, PH= plant height (cm) and SGR= seed growth rate (Kg ha^{-1} day^{-1})

Varieties derived from introductions yielded an average grain yield of 2089.13 kg ha^{-1}, and exceeding the grain yield varieties derived from local collections by 428.28kg ha^{-1} (25.79%) (Table 6). This indicates that varieties developed from introduced germplasm are the most important sources of genetic material contributing to the genetic improvement in grain yield of *Desi* type chickpea varieties over the last 36 years and the possibility of further improvement in grain yield using this breeding method. Similarly, it was reported that introduced materials contributed a lot for the improvement of the genetic yield potential of haricot bean varieties in Ethiopia (Kebere *et al*., 2006). On the contrary, the less contribution of introduction derived materials both to grain yield and 1000 seed weight was reported in faba bean by Tamene (2008).

The average rate of increase in grain yield of *Desi* type chickpea varieties per year of release was 18.42 kg ha^{-1} yr^{-1}(Figure 1A) and it was significantly different from zero ($p \le 0.01$) (Table 7). This reveals that chickpea breeders have made best level of efforts over the last 36 years to improve the yields of *Desi* type chickpea in the country. Similar trends have been reported by Ustun *et al*. (2001) and Kumundi *et al*. (2001) with comparable genetic gains of 12 and 14 kg ha^{-1} yr^{-1} in soybean genotypes in Mid-southern USA and Canada respectively. Grain yield potential of successively released haricot bean and faba bean varieties in Ethiopia increased at a rate of 65.54 and 18.10 kg ha^{-1} yr^{-1} (Kebere *et al*., 2005 and Tamene, 2008), respectively. Hailu *et al*. (2009) reported a 24.2 kg ha^{-1} average rate of increase in grain yield of early maturing soybean genotypes per year of release during two decades of soybean breeding in Nigeria. Another study by the same authors (Hailu *et al.,* 2010) showed a 23.61 kg ha^{-1} annual rate of gain for medium maturing genotypes at IITA, Nigeria. Likewise, Amsal (1994) in durum wheat, Yifru and Hailu (2005) in tef, Wondimu (2010) in barley and Demissew (2010) in soybean reported respective increase of 64, 27.16, 44.24, and 13.26 kg ha^{-1} yr^{-1} in grain yield potential of varieties over the year of released.

Table 3. Mean grain yield (kg ha^{-1}) of *Desi* type chickpea varieties at Debre Zeit and Akaki and averaged across locations

Varieties	Locations		Mean
	Debre Zeit	Akaki	
DZ-10-11	1922.2^{d}	1257.2^{d}	1589.7^{c}
Dubie	2118.6^{bcd}	1345.3^{cd}	1732.0^{c}
Mariye	2053.5^{cd}	1369.3^{cd}	1711.4^{c}
Worku	2199.3^{bcd}	1571.0b^{cd}	1885.1^{bc}
Akaki	2305.7^{abcd}	1791.1^{abc}	2048.4^{ab}
Kutaye	2733.1^{a}	1840.2^{abc}	2286.6^{a}
Mastewal	2523.3^{ab}	1851.1^{abc}	2187.2^{ab}
Fetenech	2342.2^{abcd}	2083.6^{ab}	2212.9^{ab}
Naatolii	2437.4^{abc}	2169.3^{a}	2303.3^{a}
Minjar	2415.3^{abc}	1741.0^{abcd}	2078.1^{ab}
Mean	2305.06	1701.91	2003.48
CV (%)	10.15	16.04	12.69
R^2	0.84	0.68	0.85

Means followed by the same letter with in a column are not significantly different from each other at $P \leq 0.05$ according to Duncan's Multiple Range Test

The relative annual genetic yield gain in *Desi* type chickpea varieties during the period 1974-2010 was 1.16% (Table 8). Similar to the present study, an annual increase of 1.2% has been reported by Karmakar and Bhatnagar (1996) in 43 varieties of soybean released between 1969 and 1993 in India. Likewise, Hailu *et al*. (2009), Wondimu (2010) and Demissew (2010) reported in soybean, the relative rate of gain of 2.2%, 1.34% and 1.27% respectively. These values are somewhat greater than the relative genetic gain observed in the present study. Another study by Wilcox (2001) showed that increases in seed yield per year for elite soybean lines were in the range of 0.95 to 1.14% and an average of 1.0% for different maturity groups in USA. Moreover, De Bruin and Pedersen (2009) reported a 0.7% increment in grain yield potential of soybean each year in USA.

Table 4 Trends in genetic progress in grain yield for *Desi* type chickpea varieties released in 1985, 1994, 1995, 2005, 2006; 2007 and 2010 over the average of the first two older varieties (DZ-10-11 and Dubie) released in 1970s

Varieties	Year of release	Mean grain yield kg ha^{-1}	Increment over average of the first two older varieties(1970s)	
			kg ha^{-1}	%
DZ-10-11 Dubie	1974 1978	1660.85	---	---
Mariye	1985	1711.40	50.45	3.04
Worku	1994	1885.10	224.25	13.50
Akaki	1995	2048.40	387.55	23.33
Kutaye	2005	2286.60	625.75	37.68
Mastewal Fetenech	2006 2006	2200.05	539.20	32.47
Naatolii	2007	2303.30	642.45	38.68
Minjar	2010	2078.10	417.25	25.12

The rate of relative genetic gain achieved through crop breeding in haricot bean (Kebere *et al*., 2006) in Ethiopia was more than twice the relative rate of genetic improvement achieved in the present study (1.16%). However, the relative genetic gain in this study was greater than 0.79 and 0.66% relative annual genetic gains that has been recorded in tef and faba bean varieties, respectively, in Ethiopia (Yifru and Hailu, 2005; Tamene, 2008) . This indicates that chickpea breeders have made best level of efforts over the last 36 years to improve the yield of *Desi* type chickpea in Ethiopia. Generally, the results of the present study showed that the *Desi* type chickpea improvement program that employed germplasm introduction and selection was the major breeding methods that contributed to the successful improvement in grain yield (Table 6). It can also be seen from Table 5 that consistent yield improvement was observed in different decades. This indicates that grain yield potential of *Desi* type chickpea has not attained plateau in Ethiopia; indicating that the opportunity for breeders to further improve *Desi* type chickpea yield through the existing breeding strategy. Similarly, Amsal (1994) in wheat, Yifru and Hailu (2005) in tef, Kebere *et al*. (2006) in haricot bean, Tamene (2008) in faba bean, Wondimu (2010) in barley and Demissew (2010) in soybean in Ethiopia and Hailu *et al*. (2009) in soybean in Nigeria, Edwin and Masters (2005) in cocoa in Ghana, Khodarahmi *et al*. (2010) in wheat in Iran, Wilcox (2001) in soybean in USA and Jin *et al.* (2010) in soybean in Northeast China found no indication of yield potential plateau.

Table 5. Trends in genetic progress in grain yield and biomass yield for *Desi* type chickpea varieties released in 1980s, 1990s and 2000s over the average of the first two older varieties (DZ-10-11 and Dubie) released in 1970s

Varieties	Year of release	Mean grain yield kg ha^{-1}	Increment over average of the two older varieties (1970s)		Mean biomass yield (kg ha^{-1})	Increment over average of the two older varieties (1970s)	
			kg ha^{-1}	%		kg ha^{-1}	%
DZ-10-11 Dubie	1974 1978	1660.85	---	---	2869.95	---	---
Mariye	1985	1711.40	50.45	3.04	2927.50	57.55	2.01
Worku Akaki	1994 1995	1966.75	305.9	18.42	3390.20	520.25	18.13
Kutaye Mastewal Fetenech Naatolii Minjar	2005 2006 2006 2007 2010	2213.62	552.77	33.28	3792.02	922.07	32.13

Biomass Yield, Harvest Index and Plant Height

A combined analysis of variance, across locations, revealed a non-significant location x variety interaction for biomass yield while highly significant differences were observed between locations and among varieties (Table 2). This might be due to the past breeding efforts to develop varieties that perform relatively well over wide range of environment for biomass yield in *Desi* type chickpea varieties. In line with these results, Qureshi *et al*. (2004), Fikru (2004) and Temesgen (2007) reported significant difference among genotypes. The mean biomass yield of all *Desi* type chickpea varieties, averaged across locations was 3440.80 kg ha^{-1} (Table 9). The average biomass yield of varieties released in 1970, 1980s, 1990s and 2000s were 2869.95, 2927.50, 3390.20 and 3792.02 kg ha^{-1} respectively. These indicate an increase of 57.55 (2.01%), 520.25 (18.13%), and 922.07 kg ha^{-1}(32.13%), respectively over the first two older varieties which were released in 1970s (Table 5). In other words, improvement in grain yield potential of *Desi* type chickpea was associated with parallel increase in biomass yield and this is also true for haricot bean and faba bean in Ethiopia (Kebere *et al.,* 2006; Tamene, 2008).

Table 6. Average increment in grain and biomass yield for *Desi* type chickpea varieties derived from introduction over variety derived from local collection

Variety	Average grain yield (kg ha^{-1})	Grain yield increment over local collection		Average biomass yield(kg ha^{-1})	Biomass yield increment over local collection	
		kg ha^{-1}	%		kg ha^{-1}	%
Local collection derived	1660.85	---	---	2869.95	---	---
Introduction derived	2089.13	428.28	25.79	3583.50	713.55	24.86

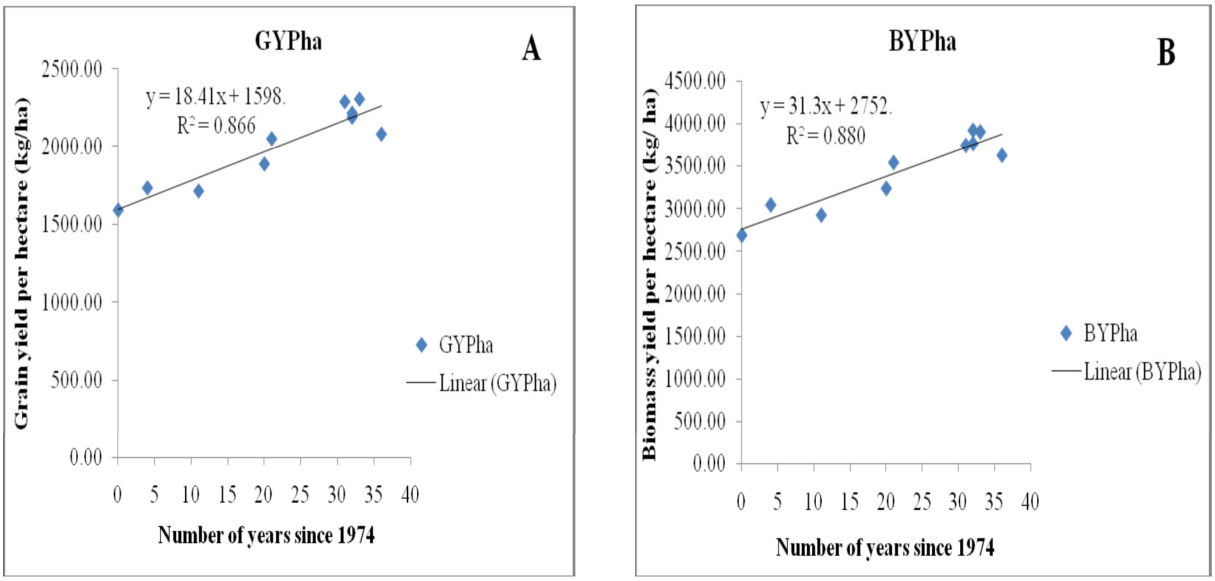

Figure 1. Plot of grain yield (A) and biomass yield (B) of *Desi* type chickpea varieties against years of release of the varieties

Mean biomass yield of varieties developed from local collection and introduced germplasm were 2869.95 and 3583.50 kg ha^{-1} respectively, which indicated 713.55 kg ha^{-1} (24.86%) increment over the varieties developed from local collection (Table 6). This indicates the importance of introduced materials as a contributing factor to the large increment in biomass yield of *Desi* type chickpea varieties over the last 36 years. This is in agreement with the findings of Kebere *et al*. (2006).

Table 7. Estimates of mean values, coefficient of determination (R^2), regression coefficient (b) and intercept for various traits from linear regression of the mean value of each trait for each *Desi* type chickpea variety against the year of variety release since 1974

Traits	Mean	R^2	b	intercept
Days to flowering	46.90	0.14	0.20	42.50
Days to maturity	120.90	0.03	-0.03	121.65
Number of primary branches per plant	2.59	0.45	0.01*	2.45
Number of secondary branches per plant	9.26	0.40	-0.07*	10.80
Plant height	29.05	0.01	-0.01	29.36
Number of pods per plant	48.27	0.04	-0.08	50.06
Number of seeds per pod	1.18	0.00	-0.00002	1.18
Number of seeds per plant	56.86	0.03	-0.10	59.01
Grain yield per plant	12.28	0.36	0.06	10.97
Grain yield per hectare	2003.48	0.87	18.42**	1598.27
Hundred seed weight	20.57	0.23	0.15	17.29
Biomass yield per hectare	3440.80	0.88	31.30**	2752.19
Grain filling period	74.00	0.23	-0.23	79.14
Harvest index	0.584	0.02	-0.00014	0.59
Biomass production rate	28.85	0.86	0.27**	22.93
Seed growth rate	27.75	0.71	0.33**	20.58
Grain yield per day	16.79	0.84	0.16**	13.30

*, ** = Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

Linear regression of biomass yield of *Desi* type chickpea variety means on year of variety release revealed a highly significant ($p \leq 0.01$) trend of increase over the period studied (Table 7). Accordingly, biomass yield increased by 31.30 kg ha^{-1} yr^{-1} (Figure 1B), indicating that *Desi* type chickpea genetic potential improvement program has significantly enhanced the biomass yielding of modern varieties. This implies that improved grain yield in the modern varieties appears to be associated more with the production of a higher biomass than with a higher partitioning efficiency to the grain sink. Likewise, Yifru and Hailu (2005) in tef, Kebere *et al*. (2006) in haricot bean, Tamene (2008) in faba bean excluding the releases for waterlogged conditions and Demissew (2010) in soybean reported an increase in biomass yield of modern varieties compared to older varieties in Ethiopia; in contrast, Morrison *et al*. (2000) reported that no consistent relation of biomass yield of soybean cultivars with year of release in Canada. In Nigeria, Hailu *et al*. (2009) found that biomass yield showed non-significant increase by 22.81 kg ha^{-1} yr^{-1}. The annual relative genetic gain for biomass yield of this chickpea type variety was estimated 1.16% for the period 1974-2010 (Table 8).

For harvest index, combined analysis of variance revealed highly significant ($p \leq 0.01$) difference between locations and among varieties. But, there was no location x variety interaction for the trait (Table 2). In agreement with the present study, Qureshi *et al*. (2004), Melese (2005) and Malik *et al*. (2010) reported that the result of analysis of variance showed highly significant differences among genotypes for harvest index in chickpea genotypes. The mean harvest index of varieties across locations was 0.58 (Table 9). In line with this, high harvest index value (0.59) has been reported in chickpea (Saxena *et al*., 1983). Kebere *et al*. (2006) also found high harvest indices value of 0.57 in haricot bean. On the contrary, mean harvest index as low as 0.31 and 0.36 has been reported in chickpea by Yucel *et al*. (2006) and Malik *et al*. (2010), respectively.

Linear regression coefficient indicated that harvest index for the period studied was nearly zero (Table 7). As the rate of biomass yield was similar to that of yield gain, harvest index was not steadily modified with the year of release of a variety. This may be indicates more production of biomass than with a higher partitioning to the grain sink. Similarly, Yifru and Hailu (2005) found no change in harvest index of tef. Lack of trend of increasing in harvest index was reported by Kebere *et al*. (2006) in haricot bean. Demissew (2010) also reported that harvest index showed a non- significant annual decrease during the 34 years of soybean improvement. On the contrary, significant increasing trend in harvest index was observed with the release of modern varieties of soybean and barley (Hailu *et al*., 2009 and Wondimu, 2010) respectively.

Table 8. Estimates of the mean annual relative genetic gain (RGG); and correlation coefficient of all traits with grain yield (R_{GYPha}), year of release of the variety (R_{YOR}) and biomass yield (R_{BYPha})

Traits	Mean of the older variety	RGG (% per year)	Correlation coefficient (R)		
			R_{GYPha}	R_{YoR}	R_{BYPha}
Days to flowering	39.33	0.51	0.40	0.37	0.42
Days to maturity	118.67	-0.03	-0.23	-0.16	-0.23
Number of primary branches per plant	2.33	0.43	0.68*	0.67*	0.69*
Number of secondary branches per plant	10.08	-0.69	-0.51	-0.63*	-0.56
Plant height	31.00	-0.03	-0.21	-0.11	-0.14
Number of pods per plant	50.88	-0.16	-0.37	-0.21	-0.43
Number of seeds per pod	1.38	0.00	-0.04	-0.00	-0.09
Number of seeds per plant	69.70	-0.14	-0.32	-0.16	-0.39
Grain yield per plant	9.75	0.62	0.52	0.60	0.45
Grain yield per hectare	1589.7	1.16	---	0.93**	0.98**
Hundred seed weight	12.60	1.19	0.51	0.48	0.50
Biomass yield per hectare	2693.2	1.16	0.98**	0.94**	---
Grain filling period	79.33	-0.29	-0.54	-0.48	-0.56
Harvest index	0.597	-0.02	-0.07	-0.12	-0.25
Biomass production rate	22.94	1.18	0.98**	0.93**	1.00**
Seed growth rate	20.30	1.63	0.92**	0.84**	0.91**
Grain yield per day	13.53	1.18	0.99**	0.92**	0.97**

*, ** = Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

The mean plant height of the tested varieties over locations was 29.05 cm (Table 9). There was highly significant ($p \leq 0.01$) and significant difference among locations and varieties in plant height, while the location x variety interaction effect was non-significant (Table 2). The highly significant differences observed among varieties was supported by different authors (Saleem *et al*., 2002, Arshad *et al*., 2004, Fikru, 2004, Melese, 2005). As indicated in Table 2, almost all the studied parameters showed a non-significant location x variety interaction effects, except days to flowering, days to maturity, grain filling period and hundred seed weight. This revealed that varieties with better performances for these traits in one set of environments may also repeat nearly the same performances under another set of environments. According to Singh (2005), when a breeder intends to develop varieties with average performance over wide range of environments, minimizing the magnitude of genotype by environment interaction in his/her breeding materials that show wide adaptation coupled with agronomic stability.

As evident from regression of variety means against year of release, the annual rate of gain was -0.01 cm $plant^{-1}$ yr^{-1} and was not significantly different from zero (Table 7) with relative genetic gain of -0.03% yr^{-1} (Table 10). This indicates that yield potential improvement program did not markedly affect this trait for the past 36 years. Likewise, a non-significant reduction in plant height was reported in haricot bean by Kebere *et al*. (2006). Yifru and Hailu (2005) reported that the relative genetic gain of plant height over the last 35 years of tef breeding program was low (0.4285 cm $plant^{-1}$ $year^{-1}$) and was not significantly different from zero. However, significant negative relations between plant height and year of variety release were reported by Wondimu (2010) in food barely. Significant reduction in plant height in linseed has been reported by Ersullo (2010), indicating that newer varieties were shorter than older ones. In the same way, Donmez *et al.* (2001) reported similar finding that modern varieties showed significantly decreased plant height and reduced lodging in winter wheat varieties. In contrast, plant height showed a highly significant increase over the 34 years and increased by 1.00 cm plant^{-1} yr^{-1} in soybean yield potential improvement program (Demissew, 2010).

Yield Attributes

Location mean squares from combined analysis of variance were non-significant for number of seeds pod^{-1} and grain yield plant^{-1} and highly significant ($p \leq 0.01$) for number of pods plant^{-1} and hundred seed weight (Table 2). There were highly significant differences among varieties for all these yield components. Except hundred seed weight which showed highly significant location by variety interaction, all other yield components were non-significant. Likewise, Abebe (1985), Saleem *et al*. (2002), Fikru (2004), Arshad *et al*. (2004), Melese (2005), Yucel *et al*. (2006), Temesgen (2007), and Malik *et al*. (2010) found significant difference in the above yield components among genotypes.

Table 9. Mean biomass yield (BYPha in kg ha^{-1}), harvest index (HI) plant height (PH in cm) and grain yield per plant (GYPP in g) of *Desi* type chickpea varieties at Debre Zeit and Akaki and over locations

Varieties	Locations								Mean			
	Debre Zeit				Akaki							
	BYPha	HI	PH	GYPP	BYPha	HI	PH	GYPP	BYPha	HI	PH	GYPP
DZ-10-11	3315.0^{d}	0.58^{a}	35.13^{a}	9.77^{a}	2071.5c	0.61^{a}	26.87^{a}	9.73^{c}	2693.2^{d}	0.597^{ab}	31.00^{ab}	9.75^{c}
Dubie	3762.8^{bcd}	0.56^{a}	31.07^{a}	10.87^{a}	2279.5^{bc}	0.58^{a}	29.13^{a}	11.17^{bc}	3046.7^{cd}	0.572^{bc}	30.10^{ab}	10.99^{bc}
Mariye	3575.4^{cd}	0.58^{a}	31.00^{a}	15.37^{a}	2330.6^{bc}	0.60^{a}	20.75^{a}	12.26^{abc}	2927.5^{d}	0.588^{abc}	25.88^{c}	13.81^{a}
Worku	3834.3^{abcd}	0.57^{a}	31.60^{a}	14.22^{a}	2643.3^{bc}	0.60^{a}	28.40^{a}	10.39^{bc}	3238.8^{bcd}	0.585^{bc}	30.00^{ab}	12.31^{ab}
Akaki	4042.2^{abc}	0.57^{a}	30.67^{a}	12.05^{a}	3041.0^{ab}	0.59^{a}	26.69^{a}	11.56^{abc}	3541.6^{abc}	0.577^{bc}	28.68^{abc}	11.80^{abc}
Kutaye	4499.6^{a}	0.60^{a}	28.93^{a}	13.77 ^{a}	2988.9^{abc}	0.63^{a}	26.20^{a}	14.07^{a}	3744.2^{ab}	0.613^{a}	27.57^{bc}	13.92^{a}
Mastewal	4395.3^{ab}	0.57^{a}	32.47^{a}	12.83^{a}	3135.0^{ab}	0.59^{a}	23.33^{a}	12.96^{ab}	3765.1^{ab}	0.580^{bc}	27.90^{abc}	12.89^{ab}
Fetenech	4201.5^{abc}	0.55^{a}	30.60^{a}	11.18^{a}	3639.5^{a}	0.57^{a}	27.79^{a}	11.96^{abc}	3920.5^{a}	0.562^{c}	29.19^{abc}	11.57^{abc}
Naatolii	4159.0^{abc}	0.59^{a}	32.40^{a}	12.73^{a}	3650.1^{a}	0.59^{a}	25.10a	12.89^{ab}	3904.6^{a}	0.588^{abc}	28.75^{abc}	12.81^{ab}
Minjar	4273.8^{abc}	0.57^{a}	35.07^{a}	13.92^{a}	2977.7^{abc}	0.59^{a}	27.83^{a}	11.93^{abc}	3625.7^{ab}	0.578^{bc}	31.45^{a}	12.93^{ab}
Mean	4005.89	0.57	31.89	12.66	2875.72	0.59	26.21	11.89	3440.80	0.584	29.05	12.28
CV (%)	9.37	3.32	7.53	17.09	17.34	3.52	11.58	11.16	12.82	3.42	9.42	14.62
R^2	0.84	0.56	0.73	0.58	0.68	0.58	0.57	0.61	0.86	0.64	0.79	0.60

Means followed by the same letter within a column are not significantly different from each other at $P \leq 0.05$ according to Duncan's Multiple Range Test,

Among yield components, number of primary branches plant^{-1}, secondary branches plant^{-1} and number of seeds plant^{-1} were treated separately because mean squares of error for these traits were heterogeneous across the two locations. Accordingly, there was no significant difference observed among varieties for both primary and secondary branches plant^{-1} at Debre Zeit, while at Akaki significant ($p \leq 0.05$) and highly significant ($p \leq 0.01$) differences recorded for primary and secondary branches plant^{-1}, respectively. The same is true for number of seeds plant^{-1}, significant and highly significant differences were observed at Debre Zeit and Akaki, respectively.

The mean primary and secondary branches of all varieties in the trial averaged over the two locations were 3 and 9 branches plant$^{-1,}$ respectively. It ranges from 2.33 (DZ-10-11) to 2.73 (Naatolii) primary branches plant^{-1} and generally older varieties had lower number of primary branches than the newer and high yielder varieties (Table 10). Similar trend was reported by Saleem *et al*. (2005) who observed primary branches ranging from 2.33 to 2.47 branches plant^{-1} in chickpea genotypes. This difference is reflected in the linear regression coefficient that showed a significant ($p \leq 0.05$) increase in primary branches plant^{-1} with annual rate of gain of 0.01 primary branches plant^{-1} yr^{-1} (Table 9) or by 0.43% yr^{-1} relative increase as compared to the older variety for the last 36 years in *Desi* type chickpea improvement program (Table 8). Similarly, Demissew (2010) found from linear regression of mean number of branches of soybean genotypes against year of release that a highly significant increment with a relative genetic gain of 0.74% yr^{-1}.

Number of secondary branches plant^{-1} showed a decreasing trend with years of variety release, which indicated that newer varieties had less number of secondary branches plant$^{- 1}$ than the older ones (Table 10). Linear regression of variety means against year of variety release showed significant ($p \leq 0.05$) reduction trend in number of secondary branches plant$^{- 1}$ (Table 7) with relative annual genetic reduction of -0.69% (Table 8).

The over location mean of number of pods plant^{-1} and number of seeds plant^{-1} were 48.27 pods plant^{-1} and 56.86 seeds plant^{-1} respectively (Table 10). Both number of pods plant^{-1} and number of seeds plant^{-1} showed a non-significant annual decrease of -0.08 and -0.10 (Table 7) during the last three decades of *Desi* type chickpea improvement with a relative annual genetic reduction of -0.16 and -0.14% (Table 10) respectively. On the contrary, Tamene (2008) reported highly significant reduction for these traits in faba bean. Jin *et al*. (2010) reported insignificant increase in pods plant^{-1} over years in Northeast China which may be associated with the decrease in plant height and slow increase in biomass yield. Similarly, Kebere *et al*. (2006) reported non-significant increase in pods plant^{-1} of haricot bean over years of improvement. The non-significant improvement for both pods plant^{-1} and number of seeds plant^{-1} may be due to the slight increment in hundred seed weight in the newer and high yielding varieties.

Linear regression of variety means against years of variety release revealed non-significant improvement in number of seeds pod^{-1}, grain yield plant^{-1} and hundred seed weight (Table 8). In similar studies Kebere *et al*. (2006) in haricot bean, Tamene (2008) in faba bean and Demissew (2010) in soybean reported non-significant increase in number of seeds pod^{-1}. In line with the present study the non-significant improvement trend for hundred seed weight was also reported by Yifru and Hailu (2005) and Kebere *et al*. (2006). The haricot bean yield potential improvement program substantially improved grain yield plant^{-1} (Kebere *et al*., 2006), which was in contrast with the present study and the report of Tamene (2008).

The slight negative progress in number of pods plant^{-1}, number of seeds pod^{-1} and number of seeds plant^{-1} may be considered as the result of a negative compensatory response to the slight increment in seed size during the period variety development (Table 7), which is similar to the findings of Tamene (2010) in faba bean. However, for simultaneous improving seed size and number of pods plant^{-1} and number of seeds plant^{-1} a compromise between selection progresses for both traits must be made, or the breeder must set a minimum standard for one trait while selecting for the other.

Phenological Traits

From a combined analysis of variance highly significant ($p \leq 0.01$) differences were observed between locations, among varieties and location x variety interaction for the three phenological traits (days to flowering, days to maturity and grain filling period) (Table 2). This showed that, the varieties responded differently to the different locations for these traits and varieties with better performances in one set of environment may not produce the same performances under another set of environment.

Mean days to flowering for *Desi* type chickpea varieties represented in the current study was 44.57 days at Debre Zeit and 49.23 days at Akaki. But the overall mean of this trait over locations was 46.90 days. However, at both locations the newer variety was relatively similar in days to flowering with the older varieties. The variety Dubie was the earliest to flowering at both locations and over locations, even though it was not significantly different from some other varieties (Table 10). Yifru and Hailu (2005) also reported non-significant different between one of the modern varieties and that of farmer variety in days to heading in tef improvement program.

Linear regression analysis showed that the number of days to flowering in modern varieties increased non-significantly (Table 7). This non-significant increase attributed to late flowering character of some of the recently released varieties (Table 10). This was in agreement with the finding of Yifru and Hailu (2005) on tef varieties released in Ethiopia from 1960 to 1995. Kebere *et al*. (2006) in haricot bean found non-significant reduction in number of days to flowering. In contrast, Demissew (2010) reported significant increases in days to flower over years of soybean improvement. Donmez *et al.* (2001) in winter wheat and Ersullo (2010) in linseed reported that modern cultivars become significantly earlier than the oldest ones for both days to flowering and maturity.

The average number of days to maturity in all *Desi* type chickpea varieties over locations was estimated to be 120.90, which ranged from 117.50 (Minjar) to 126.50 (Mariye) (Table 10). Mean of days to maturity was 113.83 days at Debre Zeit and 128.00 days at Akaki. Regression analysis of number of days to maturity on year of variety release showed negative regression coefficient of 0.03, which was not significantly different from zero (Table 7). In this case, the non-significant reduction for days to maturity occurred due to early maturing character of in some of the modern varieties (Table 10). In similar studies on haricot bean and tef, Kebere *et al.* (2006) and Yifru and Hailu (2005) reported a non-significant increase in days to maturity whereas Wondimu (2010) reported a non-significant negative regression coefficient of this trait on food barley.

In general, when days to maturity increases, the phenology of the crops inters to the dry spell, which intern leads to loss in yield. Singh and Saxena (1999) reported that unlike other crops in chickpea early maturing genotypes produce higher seed yield than the late ones in most situations. Moreover, contrary to other crops, this trait in chickpea has not been found to be under the control of major genes.

As indicated in Table 10, indicated, the decrease in grain filling period showed negative and inconsistent trend which is not significantly different from zero. This made clear that the decrement in grain filling period was not considered in the release of improved varieties, although some recently released varieties of chickpea showed shorter grain filling period. Similar results were reported by Yifru and Hailu (2005) on tef for the period between 1970 and 1995 and Wondimu (2010) on food barley. On the contrary, Ersullo (2010) reported that days to grain filling period of modern varieties increased significantly in linseed improvement program.

Productivity Traits

Combined analysis of variance for biomass production rate, seed growth rate and grain yield day^{-1} showed that both location and variety effects were highly significant ($p \leq 0.01$) whereas location by variety interaction effects were non-significant for all productivity traits (Table 4). The lowest biomass production rate, seed growth rate and grain yield day^{-1} was recorded from one of the oldest varieties (DZ-10-11). Mean biomass production rate, seed growth rate and grain yield day^{-1} from combined analysis were 28.85, 27.75 and 16.79 kg ha^{-1} day^{-1} respectively (Table 10).

Linear regression of the mean value of each of these traits showed highly significant ($p \leq 0.01$) increases in biomass production rate, seed growth rate and grain yield day^{-1} with the annual rate of increase of 0.27, 0.33 and 0.16 kg ha^{-1} day^{-1} , respectively (Table 7). The relative genetic gains of these traits respectively were 1.18, 1.63 and 1.18% yr^{-1}, indicating that these traits were effectively and significantly improved for the last 36 years of *Desi* type chickpea breeding program. Similar to the present study, Kebere *et al*. (2006) on haricot bean reported that an increased trend in biomass production rate, seed growth rate and grain yield day^{-1} with annual genetic gain of 1.179, 1.198 and 0.665 kg ha^{-1} day^{-1} respectively. Tamene (2008) and Demissew (2010) also report that significant improvement in biomass production rate and seed growth rate in faba bean and soybean respectively. Amsal (1994) and Wonidmu (2010) observed significant changes in the spike grain sink filling rate and total grain sink filling rate with year of cultivar release. In contrary, Yifru and Hailu (2005) and Wondimu (2010) observed non-significant increases in biomass production rate on tef and food barley yield. In general, most modern varieties showed a relatively higher rate of biomass production, seed growth and grain yield day^{-1}, which were highly correlated with grain yield, biomass yield and year of release. In line with this, Amsal (1994) reported that total grain sink filling rate of recent varieties were superior to the older varieties.

Association of Grain Yield with Other Traits

The correlation coefficients of grain yield and biomass yield of *Desi* type chickpea with all the traits studied is presented in Table 8. There was a highly significant positive correlation between grain yield and biomass yield, where as a non-significant association observed with harvest index and plant height. Similarly, Yifru and Hailu (2005) on tef, Kebere *et al*. (2006) on haricot bean, Tamene (2008) on faba bean and Hailu *et al*. (2009) on soybean reported positive association between grain yield and biomass yield but no association of grain yield with harvest index and plant height. Noor *et al*. (2003) on chickpea reported that grain yield was positively associated with biological yield but negatively with harvest index. This revealed that varieties with high biomass yield produced more grain yield in most situations. Same findings reported by Bicer (2005) on chickpea, correlation showed that biological yield is an important character determining the seed yield. Singh *et al*. (1990) found that selection for high biological yield and harvest index would lead to high seed yield. Sharma *et al.* (2005) and Sharma and Saini (2010) reported that plant height is negatively and non-significantly associated with grain yield similar to the present study.

However, contradicting result was reported in China by Cui and Yu (2005) on soybean, stating that harvest index is a larger contributor to the progress of soybean yield improvements than biomass. Jin *et al*. (2010) also reported the correlation coefficients between harvest index and grain yield to be significant and positive which may be due to faster increase in grain yield than biomass yield. Generally from the present study, any improvement of biomass yield would result a substantial increment on grain yield potential of Desi type chickpea. In other words improved grain yield in the modern varieties appears to be associated more with the production of a higher biomass than with a higher partitioning efficiency to the grain sink. Similarly, Noor *et al*. (2003) indicated that to improve grain yield emphasis should be given on development of chickpea cultivars with higher biological yield.

Number of primary branches showed significantly positive association with grain yield (Table 8). This indicates that improvement in primary branches had contributed to the present grain yield progress obtained in recently released *Desi* type chickpea varieties. Abebe (1985) also reported primary branches plant^{-1} had positive direct effect on grain yield. In the same manner, Ali *et al*. (2008) reported positive and highly significant correlation between grain yield and primary branches plant^{-1} but the association of grain yield with secondary branches plant^{-1} and plant height was non-significant. Similarly, Sharma and Saini (2010) also found that primary branches were the most important character that was highly correlated with grain yield.

Yield attributes such as number of secondary branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1} and number of seeds plant^{-1} showed a non-significant association with grain yield (Table 8), indicating that any improvement in these traits had as such no negative or positive contribution to grain yield as the genetic controls of these traits and that of grain yield are independent. Likewise, Tamene (2008) on faba bean indicated that number of pods plant^{-1} and number of seeds plant^{-1} were negatively associated but statistically non-significant and Kebere *et al*.(2006) pointed out that number of pods plant^{-1} and number of seeds pod^{-1} did not show association with grain yield which was in contrast with the finding of Demissew (2010) on soybean.

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Table 10 Mean values of phenological traits, yield attributes and productivity traits of *Desi* type chickpea varieties over the two locations (Debre Zeit and Akaki)

Varieties	Trait											
	DF	DM	NPBPP	NSBPP	NPoPP	NSPPo	NSPP	HSW	GFP	BPR	SGR	GYPD
DZ-10-11	39.33e	118.67ef	2.33a	10.08a	50.88abc	1.38a	69.70a	12.60f	79.33bc	22.94c	20.30e	13.53c
Dubie	38.83e	119.83cde	2.53a	10.77a	45.10bcd	1.02c	45.88a	19.87d	81.00ab	25.78c	21.80e	14.64c
Mariye	53.50b	126.50a	2.63a	10.93a	55.30a	1.10bc	60.90a	22.68b	73.00e	23.55c	24.16de	13.75c
Worku	42.00d	124.33b	2.60a	9.62a	52.07ab	1.14bc	59.02a	21.40c	82.33a	26.54bc	23.48e	15.43bc
Akaki	53.67b	119.33cdef	2.47a	7.98a	42.50cd	1.22b	51.88a	20.18d	65.67f	30.00ab	31.17abc	17.32ab
Kutaye	41.33d	119.17def	2.63a	10.32a	53.40ab	1.19b	63.45a	19.72d	77.83cd	31.99a	29.97bc	19.53a
Mastewal	56.17a	121.50c	2.73a	9.53a	42.37cd	1.21b	51.37a	23.12b	65.33f	31.34a	33.85ab	18.19a
Fetenech	48.50c	121.17cd	2.67a	9.23a	48.73abcd	1.15b	55.85a	18.33e	72.67e	32.54a	30.42abc	18.36a
Naatolii	53.83b	121.00dc	2.73a	7.47a	40.95d	1.16b	47.13a	28.60a	67.17f	32.62a	34.55a	19.23a
Minjar	41.83d	117.50f	2.53a	6.65a	51.35ab	1.23b	63.38a	19.22de	75.67d	31.26a	27.84cd	17.90ab
Mean	46.90	120.90	2.59	9.26	48.27	1.18	56.86	20.57	74.00	28.85	27.75	16.79
CV (%)	3.61	1.44	9.67	18.28	13.87	8.33	14.53	3.89	2.92	12.51	12.21	12.50
R^2	0.97	0.97	0.71	0.72	0.60	0.64	0.69	0.98	0.96	0.90	0.91	0.89

Means followed by the same letter with in a column are not significantly different from each other at $P \leq 0.05$ according to Duncan's Multiple Range Test,

However, the correlation of grain yield with hundred seed weight and grain yield plant^{-1} was not significant though it was sizeable and positive (Table 8). This indicated that the higher yielder *Desi* type chickpea varieties would have high number of primary branches plant^{-1} with large seed size. On the other hand, those varieties having more secondary branches would have high number of seeds plant^{-1} and pod^{-1} resulted in small seed size and finally gave low yield. It was also true from the correlation coefficient, the association between secondary branches plant^{-1} and number of seeds plant^{-1} were positive but hundred seed weight with this traits was negative (Table 11). Several authors in *Desi* type chickpea (Tomar *et al*., 1982; Misra, 1991; Noor *et al*., 2003; Fikru, 2004; Arshad *et al*., 2004; Yucel *et al*., 2006) noticed that grain yield exhibited a significant positive correlation with hundred seed weight. Conversely, significant negative correlation was noted between grain yield and 100 seed weight in *Kabuli* type chickpea (Toker and Cagirgan, 2004; Sharma *et al*, 2005; Sharma and Saini, 2010).

All phenological traits showed a non-significant association with grain yield (Table 8). According to Sharma and Saini (2010), days to maturity and days to flowering showed non-significant negative and positive correlation with yield respectively in chickpea. Similar result was reported by Amsal (1994) on wheat, Yifru and Hailu (2005) on tef and Kebere *et al*. (2006) on haricot bean who showed lack of correlation between grain yield and these phenological traits. In contrast, negative association was observed between days to flowering and days to maturity with grain yield of *Desi* type chickpea (Fikru, 2004). On the contrary, Singh *et al*. (1990) in chickpea, Hailu *et al*. (2009) and Demissew (2010) on soybean indicated that strong positive correlations of grain yield with days to flowering and days to maturity.

There was a highly significant ($p \leq 0.01$) positive association between grain yield with biomass production rate, seed growth rate and grain yield day^{-1} (Table 8), indicating that improvement in these traits contributed immensely to grain yield in *Desi* type chickpea improvement program for the past 36 years and also is very important for further improvement in chickpea breeding program. Similar to the present study, Kebere *et al*. (2006) on haricot bean, Tamene (2008) on faba bean and Demissew (2010) on soybean reported positive association of grain yield with these traits. Yifru and Hailu (2005) also identified productivity traits such as total grain sink filling rate, biomass production rate and panicle grain sink filling rate to be significantly and positively correlated to grain yield.

Based on stepwise regression analysis using grain yield as a dependent variable (Table 12), biomass yield and harvest index were the two most important traits which contributed most to the variation in grain yield. About 96.5% of the total variation in grain yield of *Des*i type chickpea was contributed by biomass yield and 99.8% by biomass yield and harvest index together. It can be considered that changes in these traits had probably contributed to the changes in grain yield during the past 36 years of *Desi* type chickpea breeding in Ethiopia. Similarly, Singh *et al*. (1990) revealed that the total variation in seed yield accounted for by the biological yield and harvest index was 44 .6% and by biological yield alone was 39 .4%. This exhibited that biological yield is the major direct contributor to seed yield. According to Yifru and Hailu (2005) on tef and Kebere *et al*. (2006) on haricot bean, biomass was the single most important trait that contributed most to the variation in grain yield of the varieties in the period studied. In similar study, Demissew (2010) reported that biomass yield, harvest index and number of branches plant^{-1} were traits which contributed to the variation in grain yield of soybean. Similarly, Wondimu (2010) also indicated that biomass yield, harvest index and biomass production rate were the most important traits contributing to the variation of food barley improvement program.

Table 11. Estimates of correlation coefficient among all the traits of *Desi* type chickpea variety means over the two locations (Debre Zeit and Akaki)

	YoR€	DF	DM	NPBPP	NSBPP	PH	NPoPP	NSPPo	NSPP	GYPP	GYPha	HSW	BYPha	GFP	HI	BPR	SGR
DF	0.37	---															
DM	-0.16	0.41	---														
NPBPP	0.67*	0.56	0.44	---													
NSBPP	-0.63*	-0.23	0.46	-0.06	---												
PH	-0.11	-0.65*	-0.62	-0.55	-0.41	---											
NPoPP	-0.21	-0.48	0.28	-0.22	0.40	-0.08	---										
NSPPo	-0.00	-0.09	-0.48	-0.52	-0.29	0.35	0.06	---									
NSPP	-0.16	-0.45	-0.09	-0.49	0.14	0.17	0.81**	0.63*	---								
GYPP	0.60	0.40	0.37	0.69*	-0.09	-0.66*	0.23	-0.33	-0.03	---							
GYPha	0.93**	0.40	-0.23	0.68*	-0.51	-0.21	-0.37	-0.04	-0.32	0.52	---						
HSW	0.48	0.64*	0.42	0.80**	-0.27	-0.48	-0.44	-0.52	-0.66*	0.63	0.51	---					
BYPha	0.94**	0.42	-0.23	0.69*	-0.56	-0.14	-0.43	-0.09	-0.39	0.45	0.98**	0.50	---				
GFP	-0.48	-0.92**	-0.01	-0.42	0.45	0.44	0.65*	-0.11	0.45	-0.28	-0.54	-0.52	-0.56	---			
HI	-0.12	-0.21	0.00	-0.18	0.19	-0.20	0.40	0.42	0.55	0.28	-0.07	-0.04	-0.25	0.22	---		
BPR	0.93**	0.33	-0.36	0.59	-0.60	-0.05	-0.43	-0.03	-0.35	0.41	0.98**	0.42	1.00**	-0.52	-0.22	---	
SGR	0.84**	0.70*	-0.13	0.68*	-0.54	-0.35	-0.58	0.01	-0.45	0.49	0.92**	0.62	0.91**	-0.82**	-0.13	0.89**	---
GYPD	0.92**	0.31	-0.36	0.59	-0.55	-0.12	-0.38	0.02	-0.28	0.47	0.99**	0.43	0.97**	-0.50	-0.04	0.98**	0.89**

*, **= Significant at $P \leq 0.05$ and $P \leq 0.01$ respectively

€= Abbreviations: BPR= biomass production rate (Kg ha^{-1} day^{-1}), BYPha= biomass yield per hectare (Kg ha^{-1}), DF= days to flowering, DM= days to physiological maturity, GFP= grain filling period (days), GYPD= grain yield per day (Kg ha^{-1} day^{-1}), GYPha= grain yield per hectare (Kg ha^{-1}), GYPP= grain yield per plant (g), HI= harvest index, HSW= hundred seed weight (g), NPBPP= number of primary branches per plant, NPoPP= number of pods per plant, NSBPP= number of secondary branches per plant, NSPP= number of seeds per plant, NSPPo= number of seeds per pod, PH= plant height (cm), SGR= seed growth rate (Kg ha^{-1} day^{-1}) , YoR= year of release

Table 12. Summary of selection from stepwise regression analysis of mean grain yield of *Desi* type chickpea as dependent variable on the other traits as independent variables

Independent variables	Constant	Regression coefficient (b)	R^2	VIF
Biomass yield per hectare	-2053.29	0.61	0.965	1.066
Harvest index		3346.23	0.9979	1.066

All regression coefficients are significant at $P \leq 0.01$, VIF: Variance Inflation Factor

CONCLUSIONS

Ethiopia is known for wide genetic base of chickpea which is a potential for developing improved varieties targeting high yield, disease resistance and other quality traits. However, this huge potential is not yet exploited due to lack of strong breeding program that enable collection, characterization, evaluation and identification of desirable traits for genetic improvement. Mostly national breeding programs are based on material introduction from other countries such as Syria and India. Although, this has its own contribution for variety development and improvement of local materials, establishment of strong hybridization program in the country is inevitable to create high genetic variability and hybrid variety development if possible.

Varieties developed from crossing and introduced germplasm was the most important sources of genetic material contributing to the genetic improvement of grain yield of *Desi* type chickpea varieties for the last three decades which revealed chickpea breeding effort should focus on crossing works than landrace selection. However, the existence of strong improvement and relationship between grain and biomass yield, and insignificant improvement and relationship of harvest index with that of grain yield revealed that varieties with grain yield recorded was high while partitioning of dry matter was relatively less in favor of seeds. The results, therefore, indicated that biomass yield may serve as an index for identifying chickpea varieties with higher grain yield. Hence, it is of vital importance to give due attention to biomass yield while selecting *Desi* type chickpea varieties for proper productivity and commercial purpose.

Generally, the existing conventional breeding scheme is time taking, laborious and the desirable traits are masked by environmental effect. Incorporation of modern breeding tools (biotechnology) such as molecular markers, have paramount importance to identify the target genes and make use of desirable traits of diverse genetic resource of the country for sustainable development of improved varieties. Hence, use of modern tools aid to know genetic makeup of different varieties that can be used effectively for breeding and conservation program.

Finally, it should be emphasized that data generated from an experiment conducted for one season may not be sufficient enough to measure the average improvement. Therefore, data from many years are preferred to make reliable recommendations. But data collected herein from two locations and one season may be used as the base line for yield potential experiments for several years.

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