Genetic Gain in Yield and Yield Related Traits of Groundnut [*Arachis hypogea* (L.)] in Central Rift Valley of Ethiopia

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Abstract: The progress made to improve groundnut varieties through breeding in Ethiopia has not been yet assessed. Therefore, in this study genetic gain in grain yield and yield related traits of 14 groundnut varieties developed by the Ethiopian Lowland Oil Crops Research Program (now Ethiopian Lowland Oil Crops Research Project) from 1976 to 2009 was assessed. The varieties were evaluated in RCBD design with three replications in the 2010 main cropping season at Melka Werer Agricultural Research Center and Miesso experimental fields. The analysis of variance indicated significant differences among the varieties for all traits except days from sowing to emergence. Positive genetic gains were observed for the yield traits (grain yield and yield components), while negative genetic gains were obtained for the phenological traits (50% flowering and pod filling periods). Grain yield was increased from 1.52 to 2.74 tons ha^{-1} during the last 33 years and the overall increase in seed yield of the latest variety *Fetene* over the oldest variety *Shulamith* was estimated to be 1.142 tons ha^{-1} or 71.4%. Based on the regression analysis, the estimated average annual rate of increase in grain yield potential was 0.03 tons ha^{-1} $year^{-1}$ with an annual relative genetic gain of 1.89%. These results demonstrated the efficiency of the adopted breeding strategies in developing varieties with higher grain yields and earlier maturity. This suggests that groundnut breeders can use similar breeding strategies to exploit the genetic potential of the crop for enhanced production.

Keywords: *Arachis hypogea*; Genetic Gain; Groundnut; Yield Plateau

1. Introduction

Groundnut (*Arachis hypogea* L.) is a member of the legume family and is native to South America, Mexico and Central America, though it also grows in other parts of the world (Sigmund and Gustav, 1991). It is high in edible oil (40-50%) and protein (25%) contents and a good source of essential vitamins and minerals (Andrew and Catherine, 2010). The average seed yield of groundnut in Ethiopia is 1.117 tons (t) hectare $(ha)^{-1}$ (CSA, 2010). The total land coverage and yield of groundnut in Ethiopia are estimated to be 41,761 ha and 46,887.2 t, respectively (MoARD, 2009).

Estimation of genetic progress is useful as it helps breeders to make decisions about what breeding strategy they should follow, whether they ought to pursue or if changes are required (Ribeiro *et al.*, 2008). Hence, plant breeders have been trying to measure breeding progress by growing varieties developed and released over a long period of time in the same environment (Tefera *et al.*, 2009).

The Lowland Oil Crop Improvement Program at Melka Werer Agricultural Research Center has conducted several research activities (from 1976 to 2009) to improve groundnut production in Ethiopia and released 14 groundnut varieties so far for commercial production. Nevertheless, the progress made in the breeding activities over the last three decades has not been assessed. Therefore, the purpose of this study was to estimate the rate of gain per year in yield and yield related traits and document the progress made in improving the genetic yield potential of groundnut.

2. Materials and Methods

2.1. Experimental Site

The experiment was conducted in 2010 cropping season at two locations, namely Melka Werer Agricultural Research Center (WARC) and Miesso under irrigated and rain fed conditions, respectively. Melka Werer and Miesso are located at the distances of 255 and 300 km to the east of Addis Ababa, respectively. Melka Werer is located at 40^0 9'E Longitude, 9^0 16' N latitude and an altitude of 750 meter above sea level (masl). Miesso is located at 45^0 12' E Longitude, 10^0 18' N latitude and an altitude of 1600 masl. These locations were purposely selected as they are among the potential areas for groundnut production in Ethiopia.

2.2 Experimental Materials

Fourteen improved groundnut varieties which were released by Melka Werer Agricultural Research Center (1976 to 2009) were used in this study (Table 1).

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Table 1. Varieties used for the study.

No	Name of variety	Year of release	Pedigree/origin
1	*Shulamith*	1976	Introduced
2	NC-4X	1986	Introduced
3	NC-343	1986	Introduced
4	*Sedi*	1993	Developed through selection
5	*Bulki*	2002	Developed through hybridization
6	*Lote*	2002	Developed through hybridization
7	*Wer-961*	2004	Developed through hybridization
8	*Wer-962*	2004	Developed through hybridization
9	*Wer-963*	2004	Developed through hybridization
10	*Wer-964*	2004	Developed through hybridization
11	*Tole-1*	2008	Developed through selection
12	*Tole-2*	2008	Developed through selection
13	*Fayo*	2008	Developed through selection
14	*Fetene*	2009	Developed through hybridization

2.3. Treatments and Experimental Design

The treatments consisted of 14 groundnut varieties planted in a randomized complete block design (RCBD) with three replications. Each plot consisted of four rows of 3 m long and 60 cm apart. The distance between plants and spacing between plots were 10 cm and 1.2 m, respectively. The net plot size was 3.6 m^2.

Experimental Procedures: After preparing the experimental fields, groundnut seeds were sown in May 2010 and the treatments were cared for recommended agronomic practices like weeding, earthling-up and fertilizer application. After physiological maturity, harvesting was done by hand between end of September and mid of October.

2.4. Data Collection and Measurement

Data on different traits were collected on plot and plant basis as indicated below.

2.4.1. Phenological Traits

Date of emergence: It was recorded when 50% of plants in the plots emerged, and was used to calculate days to flowering and days to maturity.

Days to 50 % flowering: This was recorded as the number of days from emergence to the time when 50% of the plants in the plots started flowering.

Pod filling period: It was calculated as the number of days from flowering to physiological maturity.

2.4.2. Yield Attributes

Primary branches: It was taken as the average number of primary branches from five sampled plants.

Secondary branches: It was taken as the average number of secondary branches from five sampled plants.

Number of seeds per pod: It was determined by dividing the total number of seeds from five sampled plants by the total number of pods.

Number of mature pods per plant: It was determined as the average number of well-filled pods of five randomly taken plants.

Seed yield per plant (g): It was determined as the average weight of seeds obtained from five sampled plants after one week sun drying

2.4.3 Data Collected on Plot Basis

100-seed weight (g): Hundred seeds per plot were randomly taken using an electronic seed counter, after sun drying for one week, and weighed using electronic sensitive balance.

Pod yield/plot (g): It was recorded by weighing total number of pods obtained from the net plot area after sun drying for one week. The data were converted to kg ha^{-1}.

Seed yield/plot (g): This was recorded by weighing seeds obtained from the net plot area after sun drying for one week. The data were used to calculate seed yield ha^{-1}.

Oil content: It was determined by Nuclear Magnetic Resonance (NMR) Spectroscopy at Holeta Agricultural Research Center (HARC).

2.5. Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using PROC ANOVA of SAS software to assess differences among varieties as per the procedures suggested by Gomez and Gomez (1984). Homogeneity of error mean square between the two sites was tested by the F-test on variance ratio. Combined analysis of variance was performed for those parameters when error mean squares were homogenous using PROC

GLM procedure of SAS version 9.0, taking both genotypes and locations are fixed. Before analyzing data, seeds per plant and grain yield per plant were transformed by using log transformation according to Gomez and Gomez (1984) and mean separation was done using Duncan's Multiple Range Test (DMRT).

The annual rate of gain in grain yield potential and changes produced on yield related traits were estimated by regressing the mean value of each character for each variety against the year of release for that variety. The relative gains obtained over the year of release period for traits under consideration were determined as the ratio of genetic gains to the corresponding mean value of the oldest variety and expressed as percentages. Correlation coefficients for the traits under consideration were computed using means of varieties.

3. Results and Discussion

3.1. Grain Yield Potential

The analyses of variances indicated that there were significant differences among the varieties for all characters (Table 2), demonstrating the varieties are highly variable. The mean grain yield of all groundnut varieties, averaged over locations, was 2.124 t ha^{-1} (Table 3). The most recently released variety, *Fetene,* had significantly ($P \leq 0.01$) higher grain yield than all varieties represented in the trial, and exceeded the old variety, *Shulamith*, by 1.142 t ha^{-1} (Table 4). The average grain yield of the varieties released in 1976, 1986, 1993, 2002, 2004, 2008 and 2009 were 1.598, 1.622, 1.919, 2.041, 2.286, 2.336 and 2.740 t ha^{-1}, respectively. These values indicate increases of 1.5%, 20.1%, 27.7%, 43%, 46.2% and 71.4% t ha^{-1}, respectively, over the old variety (*Shulamith*) (Table 4). The overall increase in grain yield over the old variety, *Shulamith* was estimated to be 0.526 (32.9%) t ha^{-1} considering all varieties in the trial. Hence, grain yield increased substantially with the release of new improved groundnut varieties. The results obtained in this study are in agreement with those of Naeem *et al.* (2009) who reported that improved groundnut varieties produced 10.96% higher pod yield and 23.83% higher seed yield over the check variety. Tefera *et al.* (2009) also reported that the average grain yield of soybean ranged from 1.117 to 1.710 t ha^{-1} for the period of 1980 to 1996. Demissew (2010) also reported an achievement of highest grain yield of new soybean varieties over that of the first old variety. This gives an insight for possible future opportunities to exploit the genetic potential of the crop for enhanced production.

Table 2. Mean square of characters from combined analysis of yield and yield attributing traits of groundnut varieties.

	Sources of variation						
Character	Location (l)	Variety (13)	L x V (13)	Error (12)	Mean	CV%	R^2
GY	16160587.210**	676247.140**	81456.290**	40492.780	2.124	9.470	0.920
PY	143113385.200**	4083075.400**	202027.300**	27682.200	4.492	3.700	0.990
BY	63847720.300**	8052162.500**	1866580.300**	108484.700	7.793	4.230	0.970
HI	0.061**	0.003**	0.002*	0.001	0.270	9.970	0.750
TPP	56156.540**	523.230 **	355.620**	18.830	44.930	9.660	0.990
MPP	34676.490**	45.500**	428.440**	11.530	33.490	10.140	0.990
Spod	0.030**	1.139**	0.287**	0.092	2.250	13.490	0.790
100sw	3572.439 **	1159.111 **	76.962*	21.250	59.030	7.810	0.940
100pw	20246.153**	11979.783**	349.910	412.527	188.24	10.790	0.890
Splant	7.232**	0.113**	0.003	0.004	1.75	3.420	0.980
PB	0.093	7.088**	0.941*	0.273	5.6000	9.290	0.880
SB	273.602**	30.584**	15.038**	0.153	3.100	12.610	0.990
MP%	832.805**	529.837**	70.186**	24.058	71.680	6.840	0.870
50%F	1008.107**	12.092**	6.158**	0.574	32.220	2.350	0.960
PFP	1029.000**	372.396**	0.076	0.852	97.550	0.950	0.990
Oilcont	54.241**	36.026**	20.939**	0.562	47.580	1.580	0.960
GYP	9.811**	0.112**	0.002	0.003	1.500	3.720	0.990

*** = Significant at $P \leq 0.05$; ** = Significant at $P \leq 0.01$; GY = Grain yield (kg/ha); BY = Biomass yield (kg/ha); PY = Pod yield (kg/ha); HI = Harvest index; TPP = Total pod/plant; MPP = Mature pod/plant, Spod = Seed/pod, 100sw = 100 seed weight(g); 100pw = 100 pod weight (g); Splant = Seed/plant; PB = Primary branches; SB= Secondary branches; MP% = Maturation percentage; 50%F = 50% flowering; PFP = Pod filling period; oil cont= oil content; GYP = Grain yield per plant (g).*

Table 3. Mean value of characters obtained from combined analysis of yield and yield components of groundnut varieties.

	Grain yield and yield components									
Variety.	GY	PY	BY	HI	TPP	MP	Spod	Splant	MP%	GYP
Shulamith	1.598^{f}	3.045^{g}	5.912^{h}	0.270^{bc}	34.8^{e}	20.9^{g}	2.0^{c}	1.52368^{h}	58.2^{g}	1.26468^{J}
NC-4X	1.628^{f}	3.358^{f}	6.441^{g}	0.256^{c}	34.9^{e}	22.2^{g}	1.9^{c}	1.52688^{h}	65.9^{ef}	1.34413^{I}
NC-343	1.617^{f}	3.380^{f}	6.308^{g}	0.256^{c}	36.4^{e}	23.9^{g}	2.1^{c}	1.64648^{g}	63.7^{efg}	1.39775^{hi}
Sedi	1.920^{e}	3.707^{e}	6.406^{g}	0.297^{ab}	37.8^{de}	22.3^{g}	3.0^{a}	1.70774^{fg}	65.1^{ef}	1.34272^{i}
Bulki	2.075^{cde}	4.837^{d}	7.379^{f}	0.277^{bc}	43.5^{bc}	30.8^{ef}	2.0^{c}	1.72200^{fg}	67.4^{de}	1.43775^{gh}
Lote	2.007.^{de}	4.277^{d}	7.512^{f}	0.264^{bc}	46.8^{bc}	27.7^{f}	2.0^{c}	1.74006^{ef}	60.1^{fg}	1.49727^{fg}
Werer-961	2.300^{bc}	4.857^{c}	8.776^{bc}	0.260^{c}	46.6^{bc}	29.6^{ef}	2.4^{b}	1.79926^{de}	65.7^{ef}	1.42755^{h}
Werer-962	2.266^{bc}	4.878^{c}	8.128^{de}	0.275^{bc}	46.1^{bc}	34.3^{cd}	2.0^{c}	1.74690^{ef}	74.6^{c}	1.54162^{ef}
Werer-963	2.243^{bcd}	4.847^{c}	7.990^{e}	0.277^{bc}	46.2^{bc}	36.7^{c}	3.1^{a}	1.89305^{bc}	75.2^{c}	1.56772^{de}
Werer-964	2.334^{bc}	4.837^{c}	8.235^{de}	0.279^{bc}	46.7^{bc}	35.0^{c}	2.9^{a}	1.91532^{b}	72.6^{cd}	1.58839^{cde}
Tole-1	2.355^{b}	5.198^{b}	9.055^{ab}	0.258^{c}	42.8^{cd}	37.1^{c}	2.1^{bc}	1.68336^{fg}	83.8^{ab}	1.62075^{cde}
Tole-2	2.295^{bc}	5.146^{b}	9.362^{a}	0.243^{c}	44.7^{bc}	37.7^{bc}	2.1^{c}	1.71715^{fg}	81.9^{b}	1.63859^{abc}
Fayo	2.359^{b}	5.348^{b}	9.191^{a}	0.256^{c}	49.1^{b}	41.6^{b}	2.0^{c}	1.83081^{cd}	81.5^{b}	1.67020^{ab}
Fetene	2.740^{a}	5.659^{a}	8.409^{cd}	0.327^{a}	72.7^{a}	65.5^{a}	1.9^{c}	2.01155^{a}	88.0^{a}	1.70359^{a}
Mean	2.124	4.492	7.793	0.27	44.93	33.49	2.25	1.75	71.68	1.50
CV%	9.47	3.70	4.23	9.97	9.66	10.14	13.49	3.42	6.8	3.72

Means followed by the same letter within a column were not significantly different at P ≤ 0.05, according to Duncan's Multiple Range Test; GY = Grain yield (t/ha); BY= Biomass yield (t/ha); PY = Pod yield (t/ha); HI = Harvest index; TPP = Total pods/plant; Spod = Seeds/pod, Splant = Seeds/plant; MP% = Maturation percentage; GYP= Grain yield per plant (g).

Table 4. Average grain yield, pod yield and biomass yield (t ha^{-1}) of groundnut varieties and increment over the first released variety, *Shulamith*.

Variety	Year of release	Mean grain yield (t ha^{-1})	Increment over *Shulamith*		Mean pod yield (t ha^{-1})	Increment over *Shulamith*		Mean biomass yield (t ha^{-1})	Increment over *Shulamith*	
			t ha^{-1}	%		t ha^{-1}	%		t ha^{-1}	%
Shulamith	1976	1.598	-	-	3.045	-	-	5.912	-	-
NC-4X										
NC-343	1986	1.622	0.024	1.5	3.369	0.324	10.7	6.375	0.462	7.8
Sedi	1993	1.919	0.321	20.1	3.707	0.662	21.7	6.406	0.493	8.3
Bulki										
Lote	2002	2.041	0.442	27.7	4.557	1.512	49.7	7.446	1.533	25.9
Wer-961										
Wer-962										
Wer-963										
Wer-964	2004	2.286	0.687	43.0	4.855	1.810	59.4	8.282	2.370	40.1
Tole-1										
Tole-2										
Fayo	2008	2.336	0.738	46.2	5.231	2.186	71.8	9.203	3.290	55.7
Fetene	2009	2.740	1.142	71.4	5.659	2.614	85.8	8.409	2.497	42.2

The yield levels varied significantly from 1.598 to 2.740 t ha^{-1} among the 14 varieties (Table 3). A linear regression equation showed that the relationship between yield and year of release was highly significant (P ≤ 0.01) as indicated in figures 1. Across 33 years of groundnut breeding, 32.9% improvement of yield or 1.89% increase per year was achieved (Table 7). Ntare and Waliyar (1994) reported similar result for the large-seeded Virginia type groundnut, with a relative genetic gain of 1.3-3.2% per year, which is in agreement with the findings of this study. Similarly, in other related crops, Kebere *et al.* (2006) reported a 3.24% genetic gain per year in common bean and Lange and Federizzi (2009) reported a 1.2% yield increase in soybean due to genetic improvement made in the United States. Hailu *et al.* (2009; 2010) also reported 2.20% and 1.99% year^{-1} improvements, respectively, in early and medium maturing soybean at ITTA, Nigeria.

There was no indications of yield potential plateau in groundnut 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 groundnut varieties.

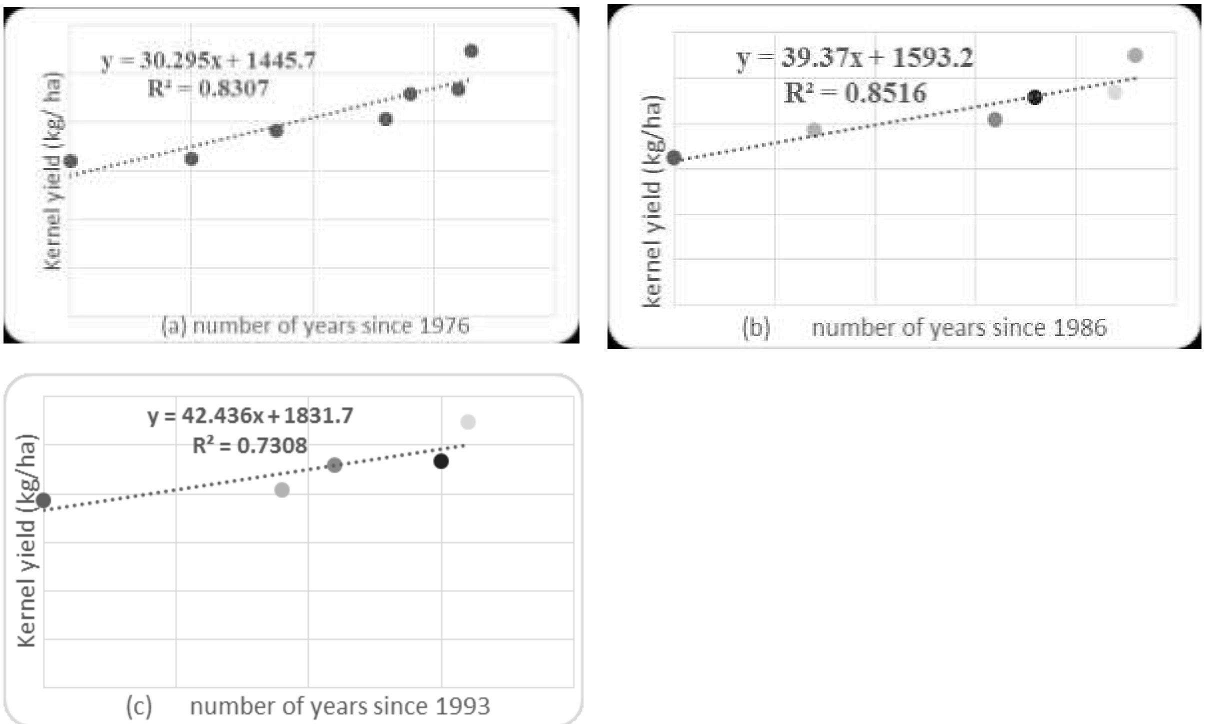

Figure 1. Relationship between mean grain yield (kg) of 14 groundnut variety and the year of release expressed as the number of years since 1976.

3.2. Harvest Index

Harvest index (the ratio of seed yield to the above ground biomass) obtained in this study ranged from 0.243 to 0.327 with a mean of 0.270 (Table 3). It can be seen from the table that there was no significant trend of increasing in harvest index. The findings of the present study is in agreement with the findings of Kebere *et al.* (2006) who reported unchanged harvest index for common bean for the period of genetic improvement. Tefera *et al.* (2009) also reported that soybean varieties did not show significant differences for harvest index over the period of the genetic improvement. Contrary to this result, Jin *et al.* (2010) found that the harvest index (HI) increased significantly with year of release, averaging 0.40% per year, rising from 0.31 to 0.38 for soybean cultivars released from 1950 to 2006 in Northeast China.

3.3. Pod Yield and Biomass Yield

Pod yield and biomass yield also showed a trend similar to that of seed yield during the 33 year period, and recently released varieties had more pod and biomass yields than old ones. In additions, significant ($P < 0.05$) difference in different yield related characters was observed among the varieties released in the same period (Table 6). The most interesting finding in the present study is that the top yielding variety both for seed (2.740 t ha^{-1}) and pod (5. 659 t ha^{-1}) yields was *Fetene* but the top yielder for biomass yield (9.362 t ha^{-1}) was Tole-2 (Table 3). This demonstrates that both grain and pod yields have been increasing during the research period.

In this study, total number of pods per plant was highly significantly and positively correlated with biomass yield (r = 0.61), pod yield (r = 0.89) and harvest index(r = 0.64) (Table 10). On the other hand, biomass yield was significantly and positively associated with pod yield (r = 0.83) and total number pod of per plant (r = 0.61) but it was not significantly correlated with harvest index (Table 10). Similarly, Vaithiyalingan *et al.* (2010) reported that pod yield had highly significant and positive associations with pods per plant, dry matter production, seed weight and harvest index. This ensures the contribution of these traits in increasing the yield potential of groundnut during the genetic progress made in the last 33 years with.

There were genotype x location interactions for pod yield, biomass yield, and harvest index (Table 2) indicating that the performance of groundnut varieties was significantly affected by the interaction effect of genotype x environment, particularly by the amount and distribution of rainfall. The results obtained in this study are in agreement with findings of Sayed *et al.* (2003) who reported that the performance of Bambara groundnut landraces tested over different seasons. The overall increases in pod and biomass yields over the old variety for Melka Werer, Miesso, and combined over locations were 1.806 (45.3%), 1.087 (51.8%) and 1.447 t ha^{-1} (47.5%), respectively. s.

Table 5. Mean values, coefficient of determination (R^2), and regression coefficients (b) of various yield attributing traits against the year of release for the varieties.

	1976-2009			1986-2009			1993-2009		
Character	Mean	R^2	b	Mean	R^2	b	Mean	R^2	b
PY	4.346	0.92	0.077**	4562.85	0.96	95.43**	4801.58	0.97	113.84**
BY	7.433.	0.84	0.093**	7686.69	0.85	116.94*	7949.11	0.87	155.41*
HI	0.28	0.09	0.0006	0.28	0.09	0.0006	0.28	0.001	-0.0002
TPP	44.93	0.520	0.76	47.2	0.53	1.07	49.51	0.48	1.46
MPP	33.49	0.53	0.89	35.91	0.54	1.26	38.45	0.54	1.84
Spod	2.25	8E-05	0.00	2.26	0.06	-0.012	2.31	0.67	-0.06
100sw	59.02	0.02	0.14	56.68	0.04	0.28	55.64	0.30	1.25
100pw	188.24	0.010	0.33	176.65	0.006	0.39	176.31	0.02	1.17
Splant	1.71	0.95	0.008*	1.74	0.90	0.008	1.77	0.80	0.006
50%F	32.23	0.23	-0.06	32.03	0.23	-0.09	31.57	0.02	0.03
PB	5.60	0.70	0.14*	5.02	0.60	0.17	4.40	0.36	0.16
SB	3.10	0.59	0.05*	3.27	0.58	0.07	3.15	0.66	0.11
MP%	73.14	0.67	0.72*	72.57	0.59	0.87	74.13	0.67	1.37
GYP	1.47	0.85	0.012*	1.51	0.81	0.014*	1.54	0.94	0.021*
Oil cont	47.58	0.42	0.13	48.41	0.02	0.02	48.69	0.15	-0.093
PFP	97.55	0.23	-0.39	94.40	0.04	-0.21	92.54	0.09	0.46
DET	7.99	0.12	-0.009	7.89	0.03	-0.006	7.88	0.04	-0.01

*** = Significant at P ≤ 0.05; ** = Significant at P ≤ 0.01; PY = Pod yield (kg/ha); BY= Biomass yield (kg/ha); HI = Harvest index; TPP = Total pod/plant; MPP = Mature pod/plant, Spod = Seed/pod, 100sw = 100 seed weight(g); 100pw = 100 pod weight (g); Splant = Seed/plant; 50%F = 50% flowering PB = Primary branches; SB = Secondary branches; MP% = Maturation percentage; GYP= Grain yield per plant(g); Oil cont = Oil content; PFP = Pod filling period; DET = Date to 50% emergency.*

Table 6. Mean value of yield related attributes obtained from combined analysis of variance for groundnut varieties grown at Melka Werer and Miesso.

Variety*	Yield related components							
	100sw	100pw	PB	SB	DTE	50%F	PFP	Oil content (%)
Shulamith	55.883^{e}	169.82^{def}	7.2000^{a}	4.9667^{b}	8.1667^{abc}	33.1667^{bc}	107.5000^{a}	43.2500^{g}
NC-4X	66.200^{bc}	191.83^{cd}	6.5500^{bc}	6.9167^{a}	7.6667^{abc}	34.6667^{a}	104.1667^{b}	45.8667^{e}
NC-343	57.500^{de}	164.78^{ef}	6.2333^{bcd}	4.7167^{bc}	8.1667^{abc}	34.0000^{ab}	103.1667^{bc}	48.1833^{dc}
Sedi	43.433^{g}	162.12^{ef}	4.3000^{g}	1.4833^{f}	8.0000^{abc}	30.5000^{e}	82.1667^{j}	50.1000^{a}
Bulki	52.750^{ef}	153.72^{fg}	5.5333^{ef}	4.4667^{c}	8.0000^{abc}	33.8333^{ab}	102.1667^{cd}	50.1167^{a}
Lote	57.600^{de}	172.67^{def}	6.1333^{cde}	3.9000^{d}	7.5000^{bc}	33.1667^{bc}	103.1667^{bc}	48.8667^{bc}
Werer-961	46.567^{g}	134.00^{gh}	4.1667^{g}	0.3000^{g}	8.0000^{abc}	29.8333^{e}	88.1667^{i}	44.6333^{f}
Werer-962	62.633^{cd}	180.93^{de}	5.9000^{cde}	4.8000^{bc}	8.0000^{abc}	31.6667^{d}	94.5000^{h}	49.9167^{a}
Werer-963	46.300^{g}	212.12^{bc}	4.1000^{g}	0.2333^{g}	7.6667^{abc}	32.0000^{d}	101.1667^{de}	43.6667^{g}
Werer-964	46.317^{g}	221.08^{b}	4.0000^{g}	0.1500^{g}	8.3333^{ab}	31.5000^{d}	97.5000^{g}	45.9833^{e}
Tole-1	87.250^{a}	265.12^{a}	6.4833^{bcd}	3.2333^{e}	8.1667^{abc}	32.3333^{dc}	100.8333^{e}	49.2667^{ab}
Tole-2	84.817^{a}	267.33^{a}	6.8333^{ab}	3.0000^{e}	8.5000^{a}	31.8333^{d}	99.1667^{f}	49.8000^{ab}
Fayo	69.800^{b}	222.17^{b}	5.8667^{de}	5.1000^{b}	8.3333^{ab}	32.1667^{d}	99.1667^{f}	47.6167^{d}
Fetene	49.350^{fg}	117.70^{h}	5.1667^{f}	0.1333^{g}	7.3333^{c}	30.5000^{e}	82.8333^{j}	48.9167^{bc}
Mean	59.03	188.24	5.60	3.100	7.99	32.23	97.55	47.58
CV%	7.81	10.79	9.287297	12.61	8.88	2.35	0.95	1.58

Means followed by the same letter within a column weren't significantly different at P ≤ 0.05, according to Duncan's multiple range test; 100sw = 100 seed weight (g); 100pw = 100 pod weight (g); PB =Primary branches (no.); SB = Secondary branches (no.); DET = Date to 50% emergency (no.); 50%F = 50% flowering (no.); PFP = Pod filling period (no).

The average rate of increase in total number of pods per year of release, estimated from the slope of the graph was 0.76 (Table 5). The relative annual gains of this trait was 2.17% over the 33 years (Table 7), indicating that genetic improvement for this trait was important for seed yield enhancement in groundnut varieties during the period of study. Similarly, Hossein (2008) found that yield increment in groundnut resulted from the increase of number of pods per plant. Awal and Ikeda (2003) also reported that the number of flowers, pegs, and pods are the most important yield components that affect the yield potential of groundnut. Consistent with this result, Royo *et al.* (2007) found out that seed yield improvement in groundnut has been associated with increases in the number of seeds per plant.

Varieties developed through hybridization and selection yielded an average yield of 0. 666 t ha^{-1} (41.3%) and 0. 618 t ha^{-1} (38.3%), respectively, higher than varieties derived from introduction (Table 8) This indicates the importance of hybridization and selection for improving the genetic potential of groundnut varieties to increase yield over the past 33 years. Moreover, averaged over the two locations, the mean pod yield of varieties developed through hybridization and selection was higher than the mean pod yield of varieties developed through introduction by 1.623 t ha^{-1} (49.8%) and 1.589 t ha^{-1} (48.7%), respectively (Table 8).

Table 7. Annual relative genetic gain and correlation coefficients for grain yield and different attributes of groundnut varieties.

Character	Relative genetic gain (% $year^{-1}$)	Correlation coefficient (r)
Grain yield	1.89	
Pod yield	2.53	0.979**
Biomass yield	1.57	0.843**
Harvest index	0.22	0.537**
Total pod	2.17	0.863**
Mature pod	4.27	0.892**
Seed per pod	0.00	0.025
Seed per plant	0.52	0.854**
Hundred seed weight	0.26	0.408**
Hundred pod weight	0.19	0.364*
Maturation percentage	1.23	0.653**
Primary branch	1.99	0.092
Secondary branch	1.03	0.543**
50% flowering	-0.19	-0.836**
Pod filling period	-0.36	-0.568**
Oil content	0.29	0.392*
Grain yield per plant	0.95	0.904**

Table 8. Average grain, pod and biomass yield increment of varieties derived from selection and hybridization over varieties derived from introduction.

Breeding strategy of variety	Mean grain yield (t ha^{-1})	Increment over introduction derived		Mean pod yield (t ha^{-1})	Increment over introduction derived		Mean biomass yield (t ha^{-1})	Increment over introduction derived	
		t ha^{-1}	%		t ha^{-1}	%		t ha^{-1}	%
Derived from introduction	1.614	-	-	3.261	-	-	6.221	-	-
Derived from selection	2.232	0.618	38.3	4.850	1.589	48.7	8.504	2.283	36.7
Derived from hybridization	2.281	0. 666	41.3	4.885	1.623	49.8	8.061	1.841	29.6

3.4. Seed Yield and Some Yield Component Traits

There were significant differences ($P \leq 0.05$) among the varieties in yield and most of the measured yield components (Table 2). From the present result, the modern variety *Fetene* produced the highest seed yield per plant (64.59 g). The estimated annual gain of grain yield per plant over the past 33 years was 1.04 g and it was significantly ($P \leq 0.05$) different from zero (Table 4). The relative genetic gains for hundred seed weight and grain yield per plant were 0.26 and 0.95% per year, respectively (Table 7).

Seed yield per plant was positively and significantly associated with pod yield (r = 0.93), biomass yield (r=0.71), seed per plant (r = 0.91), mature pod per plant (r=0.93), maturation percentage (r = 0.53), hundred seed weight (r = 0.48) and hundred pod weight (r = 0.40) (Table 10). Similar results were reported by Savitha (2008) that the number of seeds, number of pods, number of branches and 100 seed weight were positively correlated with yield per plant of avare (*Lablab Purpureus* (L.) Sweet).

The average annual rate of gain of seed over the 33 years was 0.008 seeds plant^{-1} year^{-1} (Table 5). This gain was significantly different from zero, showing that this yield component trait was increased parallel with the release of new varieties, and relative genetic gain was estimated to be 0.52% per year (Table 7). Likewise, Kebere *et al.* (2006) found a significant increase in seed number per plant of common bean over the period of genetic improvement.

However, unlike to other attributes, a non-significant relative gain per year was obtained for the number of seeds per pod during the whole period of yield improvement program (Table 7). This indicates that the challenges to increase the number of seeds per pod during the given period of time. Similarly, Kebere *et al.* (2006) found a non-significant trend of seeds per pod for common bean. On the other hand, Jin *et al.* (2010) reported that there was a smaller relationship between the year of release and seed number per pod and some of the yield gain of soybean across time comes from the increase in number of seed per pod.

Although there were variations among the varieties in oil concentration, insignificant change was observed during the past 33 years (Table 7). This may be due to that groundnut breeders may have focused more on the selection of high-yielding varieties, rather than genetic improvement in this quality trait. Similarly, Jin *et al.* (2010) also found that the absence of significant improvement in oil content among the soybean varieties over the 56 years of improvement work.

Although most recently released varieties possessed high number of primary and secondary branches, regression of mean primary and secondary branches of varieties over the year of variety release showed a non-significant trend (Table 5). The average relative annual gain of primary and secondary branches were 1.99 and 1.03% per year, respectively (Table 7), indicating that primary and secondary branches were slightly changed over the past 33 years. However, the correlation coefficient for secondary branches with yield was high and significant, which indicated the importance of this character for influencing seed yield indirectly. In this study, it was observed that secondary branch was significantly ($P \leq 0.01$) and positively correlated with number of pods per plant, number of seeds per plant, and grain yield per plant. This result is in agreement with the findings of Savitha (2008) who reported that the genetic associations between the number of branches and the number of pods and seeds per plant were high and positive.

3.5. Days to Emergence, 50% Flowering and Pod Filling Period

Mean days to emergence of all varieties represented in the trial was 7.99 days (Table 5). The combined analysis, averaged over the two locations, indicated non-significant differences among all genotypes for days to emergence but significant genotype x location interactions for this trait (Table 2). Separate location analysis indicated significant ($P \leq 0.05$) differences among genotypes at Melka Werer but non-significant difference at Miesso. The annual genetic gain for the number of days from sowing to emergence was negative (-0.009 days year^{-1}) (Table 5). This regression coefficient value was not significantly ($P \leq 0.05$) different from zero indicating that the recently released varieties emerged early compared with the old varieties. In contrast, Ribeiro *et al.* (2008) indicated that the genetic gain for days to emergence of common bean was positive (0.06 days year^{-1}), which is undesirable. Therefore, the reduction in days to emergence observed in the latest variety was an advantage obtained during the variety improvement period.

The number of days to 50% flowering for all varieties represented in this study ranged from 29.8 to 34.6 days with the mean value of 32.2 days (Table 6).The genetic gain for number of days to 50% flowering was negative (-0.06) and insignificant. This is mainly due to the early flowering character of some recently released varieties such as *Fetene*. (Table 6). But in general, there was no significant relationship between days to flowering and period of the variety released. The results obtained in this study are in agreement with the report of Kebere *et al.* (2006) who found similar results with common bean varieties. Ribeiro *et al.* (2008) also found a negative genetic gain for the number of days to 50% flowering in common bean.

Like days to 50% flowering, pod filling period also showed a decreasing trend from the oldest to the newest variety with annual genetic gain of -0.39 days/year, but insignificant (Table 5). The pod filling period of the old variety, Shulamith was 24.7 (29.8%) which is 8.3 (8.4%) days greater than the new varieties *Fetene* and *Fayo,* respectively (Table 5). Even though, increasing the length of seed filling period in soybean had been suggested as a means of increasing yield, (Kumari and Singh, 2008), Egli *et al.* (1978) reported no difference in the duration of growth of individual seed across five varieties of varying seed size and yield potential of soybean. This suggest that short pod filling period may have an advantage over the longer pod filling period of old varieties for escaping late drought due to erratic and unreliable rainfall.

3.6. Basis of Yield Gain-Morphological Characters Associated With Yield Potential Improvement

Grain yield was highly and significantly ($P \leq 0.01$) correlated with pod yield (kg/ha) (r = 0.98) and number of mature pods per plant (r = 0.89), whereas it was not significantly (r = 0.025) correlated with seed number per pod (r = 0.03). Faisal *et al.* (2006) observed that grain yield was positively and significantly correlated with number of pods per plant in their study with soybean. On the other hand, Savitha (2008) indicated that the correlations between the number of seeds per pod and the number of pods per plant with grain yield were highly significant, which indicates that these characters can attribute to yield increment. On the contrary, Sawant (1994) reported that number of seeds per pod was significantly correlated with grain yield of cowpea. Likewise Venkatesan *et al.* (2003) stated that the number of branches per plant, number of pods per plant and pod yield was positively correlated with seed yield. Generally, in this study, it was observed that number of pods per plant, biomass yield, pod yield, 100 seed weight and mature pod percentage had positive significant association with yield. Jason *et al.* (2009) also observed that new cultivars produced higher yields than old varieties as a result of higher biomass accumulation. Hence, these characters can be considered during variety selection for improving yield.

All phenological traits were significantly ($P \leq 0.01$) and negatively associated with grain yield (Table 10). Similar results were obtained by Ramteke *et al.* (2010) who showed that yield was negatively associated with days to 50% flowering and days to maturity. 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 groundnut yield loss for late maturing groundnut varieties and yield gain for early maturing varieties. However, harvest index, seed number per plant, number of branches per plant, biomass yield, grain yield per plant and 100-seed weight had positive association with grain yield of groundnut varieties. Maximum associations were observed for biomass yield and grain yield per plant. This was also in agreement with Sawant (1994) who found that seed yield was significantly and positively correlated with branches per plant, pods per plant, seeds per pod, 100 seed weight and harvest index on cowpea varieties.

Despite a significant increase of regression coefficient ($P \leq 0.05$, $b = 0.14$) of primary branch per plant over the 33 years (Table 4), a non-significant ($P > 0.05$) and positive correlation was observed between primary branch per plant and grain yield (Table 10). Contrary to the present result, Savitha (2008) indicated that the genetic association of branches with yield was high and significant. Oil content of groundnut varieties have shown a significant ($P \leq 0.05$) and positive association with grain yield (Table 10), but the regression coefficient ($b = 0.13$) indicated that there was insignificant trend for this trait from the older to the newest variety. In contrary to the findings of this study, Faisal *et al.* (2006) reported that there was a negative association of oil content with grain yield of soybean. According to the author, genetic gain for grain yield was positive (59.8 kg ha^{-1} year^{-1}) due to the higher number of seeds per plant, higher grain yield per plant, higher pod yield and greater plant biomass yield. Similar result was also obtained by Ribeiro *et al.* (2008) in common bean. Hence, based on the findings of the present study, it could be concluded that genetic yield potential improvement program of groundnut varieties over the last 33 years has been mostly correlated with a corresponding increase of pod yield, grain yield per plant, seed number per plant and biomass yield. These principal yield components were significantly correlated with each other as well (Table 10).

Table 9. Step wise regression analysis of groundnut mean grain yield (dependent variable) on selected yield components (independent variable).

Independent variable	Constant	Regression coefficient	R^2 (%)
Pod yield	387.3	0.666**	97.4

*** = Significantly at $P \leq 0.01$*

A stepwise regression analysis equation to explore the relationships between grain yield and the agronomic characters showed that PY (pod yield) was the most important character, which greatly contributed to 97.4% of the variation in grain yield among the varieties and neither of the other characters were in the best fit. In other previous studies on soybean, Demissew (2010) reported that biomass yield, harvest index and number of branches per plant were the traits that contribute most to the variation in grain yield among varieties. Similarly, Wondimu (2010) reported that harvest index, biomass yield and biomass production rate were the traits which contributed to gain in grain yield. Similarly, Yifru and Hailu (2005) and Kebere *et al.* (2006) found that biomass yield was the single most important trait that contributed most to the variation in grain yield among *teff* and haricot bean released varieties.

Table 10. Correlation coefficients of mean values of yield and yield related traits of groundnut varieties represented in the study.

Character	GY	BY	PY	HI	TPP	MPP	Spod	100sw	100pw	SPL	PB	SB	Mp%	50%F	Oil C
GY	-														
BY	0.84**	-													
PY	0.98**	0.83**	-												
HI	0.54**	0.03 ns	0.53**	-											
TPP	0.86**	0.61**	0.89**	0.64**	-										
MPP	0.89**	0.68**	0.90**	0.57**	0.97**	-									
Spod	0.03 ns	0.06 ns	0.03 ns	-0.06 ns	-0.05 ns	-0.05									
100sw	0.41**	0.39*	0.41**	0.25 ns	0.31*	0.34**	-0.38**	-							
100pw	0.36*	0.44**	0.39**	0.06 ns	0.22*	0.25*	0.04 ns	0.69**	-						
SPL	0.85**	0.64**	0.88**	0.58 ns	0.93**	0.92**	0.18 ns	0.13	0.19 ns	-					
PB	0.09 ns	0.23*	0.05 ns	-0.16 ns	-0.12 ns	-0.03 ns	-0.18 ns	0.41**	0.53**	-0.12	-				
SB	0.54**	0.34*	0.62**	0.53**	0.68**	0.59**	-0.278*	0.57**	0.38*	0.54**	0.03 ns	-			
MP%	0.65**	0.61**	0.57**	0.27*	0.41**	0.58**	-0.02 ns	0.43**	0.38**	0.44**	0.35*	0.17 ns	-		
50% F	-0.84**	-0.59**	-0.87**	-0.64**	-0.88**	-0.84**	-0.11 ns	-0.28*	-0.24*	-0.84**	0.18 ns	-0.64**	-0.377*	-	
Oil C	0.39*	0.35*	0.36*	0.14 ns	0.28*	0.34**	-0.16 ns	0.37**	0.16 ns	0.20 ns	-0.04 ns	0.21 ns	0.305*	-0.29*	-
GYP	0.90**	0.71**	0.93**	0.58**	0.92**	0.93**	0.01 ns	0.48**	0.40**	0.91**	-0.00 ns	0.69**	0.528**	-0.86**	0.38*

*** = Significant at P ≤ 0.05; ** = Significant at P ≤ 0.01; GY = Grain yield (kg/ha); BY= Biomass yield (kg/ha); PY= Pod yield (kg/ha); HI = Harvest index; TPP = Total pod/plant; MPP = Mature pod/plant, Spod = Seed/pod, 100sw = 100 seed weight(g); 100pw = 100 pod weight (g);* SPL *= Seed/plant; PB = Primary branches; SB= Secondary branches; MP% = Maturation percentage; 50%F = 50% flowering; Oil C = oil content; GYP= Grain yield per plant (g).*

4. Conclusions

The successively released new groundnut varieties in Ethiopia, between 1976 and 2009, by the Lowland Oil Crop Research Program clearly indicate the achievement gained to improve the yield of the crop through different breeding strategies. The results of this study show that there was significant increase in the grain yield potential of groundnut through consecutive release of varieties over the last 33 years. This clearly highlights the payoff from the research program. The study also shows that varieties developed through hybridization had higher progress than the introduced old varieties and the varieties developed through selection. Therefore, it is more likely that the productivity of groundnut in the future can also be increased by developing varieties using similar approaches.

5. References

Andrew, E., Catherine, P. 2010. Procurement for development forum: Groundnuts case study Chatham House. 10 St James's square. (Londonwww.chathamhouse.org.uk) (Accessed on October, 2011).

Awal, M.A. and Iked, T. 2003. Controlling canopy formation, flowering, and yield in field-grown stands of peanut (*Arachis hypogaea* L.) with ambient and regulated soil temperature. *Field Crops Research* 81: 121-132.

CSA (Central Statistical Agency). 2011. Agricultural sample survey report on area and production of crops. Addis Ababa, Ethiopia.

Demissew, T. 2010. Genetic gain in grain yield and associated traits of early and medium maturing varieties of soybean. MSc. Thesis, School of Plant Sciences, Haramaya University.

Egli, D.B., Pendleton, J.W. and Wood, J.W. 1978. Influence of seed size and position on the rate of duration of filling. *Journal of Agronomy* 70: 127–130.

Faisal, M., Malik A., Qureshi, A.S., Ashraf, M. and Ghafoor, A. 2006. Genetic variability of the main yield related characters in Soybean. *International Journal of Agriculture and Biology* 8(6): 815–819.

Gomeze, K.A. and Gomeze, A.A. 1984. *Statistical Procedures for Agricultural Research, 2nd Edition*. John Willy and Sons, New York.

Hailu, T., Kamara, A., Asafo-Adjei, B. and Dashiell, K. 2009. Improvement in grain and fodder yields of early-maturing promiscuous soybean genotypes in the guinea savanna of Nigeria. *Crop Science* 49: 2037-2042.

Hailu, T., Kamara, A., Asafo-Adjei, B. and Dashiell, K. 2010. Breeding progress for grain yield and associated traits in medium and late maturing promiscuous soybeans in Nigeria. *Euphytica* 141: 247-254.

Hossein, Z. 2008. Effect of drought stress and methanol on yield and yield components of *Glycine Max* (L.). *American Journal of Biochemistry and Biotechnology* 5 (4): 162-169

Jason, L. Bruin, De and Pedersen, P. 2009. Growth, yield, and yield component changes among old and new soybean cultivars. *Journal of Agronomy* 101: 123-130.

Jin, J., Liu. X., Wanga, G., Mi, L., Shen, Z., Chen, X. and Herbert, S.J. 2010. Agronomic and physiological contributions to the yield improvement of soybean cultivars released from 1950 to 2006 in Northeast China. *Field Crops Research* 115: 116–123.

Kebere, B., Ketema, B. and Sripichitt, P. 2006. Genetic gain in grain yield potential and associated agronomic traits in haricot bean (*Phaseolus vulgaris* L.). *Kasetsart Journal of Natural Science* 40: 835–847.

Kumari, T.S. and Singh, B.G. 2008. Analysis of dry matter production and yield potential in groundnut genotypes. *Patancheru* 15: 310-313.

Lange, C.E. and Federizzi, C.L. 2009. Estimation of soybean genetic progress in the south of Brazil using multienvironmental yield trials. *Scientia. Agricola*. (*Piracicaba, Braz.*) 66: 309-316.

Ministry of Agriculture and Rural Development (MoARD). 2009. Animal and Plant Health Regulatory Directorate Crop Variety Register Issue No. 12 Addis Ababa, Ethiopia.

Naeem, U.D., Mahmood, A.G., Khattak, S., Saeed, I. and Hassan, M.F. 2009. High yielding groundnut (*Arachis Hypogea* L.) variety "Golden" *Pakistan Journal of Bot*any 41: 2217-2222

Ntare, B.R., and Waliyar, F. 1994. The role of genetic enhancement in sustainable groundnut production in western Africa. Andhra *Pradesh, India: lCRISAT*: 502- 324

Ramteke, R., Kumar, V., Murlidharan, P. and Agarwal, D.K. 2010. Study on genetic variability and traits interrelationship among released soybean varieties of India [*Glycine max* (L.) *Merrill*]. *Electronic Journal of Plant Breeding* 1(6): 1483-1487

Ribeiro, N.D., Filho, A.C., Poersch, N.L., Jost, E. and Rosa, S.S. 2008. Genetic progress in traits of yield, phenology and morphology of common bean. *Crop Breeding and Applied Biotech* 8: 232-238

Royo, C., Alvaro, F., Martos, V., Ramdani, A., Isidro J., Villegas, D. and Garcia, D.M., L.F. 2007. Genetic changes in durum wheat yield components and associated traits in Italy and Spain during the 20th century. *Euphytica* 155: 259–270.

Sawant, D.S. 1994, Association and path analysis in cowpea. *Annals of Agricultural Research* 15: 134-139.

Sayed, A.A., Elenimo, K. Wenzel, G., Klaus, F. and Abu, S., 2003. Increasing the Productivity of Bambara Groundnut [Vigna Subterranea (L.) Verdc.] for Sustainable Food Production in Semi-Arid Africa Final Report of the EU, BAMFOOD project.

Savitha, B.N. 2008. Characterization of Avare [*Lablab purpureus* (L.) *Sweet*] Local Collections for

GeneticVariability. MSc. Thesis presented to the University of Agricultural Sciences, Dharwad.

Sigmund, R. and Gustav, E. 1991. The cultivated plants of tropics and sub-tropics: Cultivation, Economics value, and utilization. Velag Josef margrave, Germany.

Tefera, H., Kamara, A.Y., Asafo-Adjei, B. and Dashiell K.E. 2009. Improvement in grain and fodder yields of early-maturing promiscuous soybean varieties in the Guinea Savanna of Nigeria. *Crop Science* 49: 2037–2042.

Vaithiyalingan, M., Manoharan, V. and Ramamoorthi, N. 2010. Association analysis among the yield and yield attributes of early season drought tolerant groundnut (Arachis hypogeal L.) *Electronic Journal of Plant Breeding* 1: 1347-1350.

Venkatesan, M., Prakash, M., and Ganesan, J. 2003 Correlation and path analysis in cowpea (*Vigna unguiculata* L.). *Legume Research* 26: 105-108.

Wondimu, F. 2010 Assessment of genetic improvement in grain yield potential, malting quality and associated traits of barley (*Hordeum vulgare* L.) in Ethiopia. MSc. Thesis presented to the School of Graduate Studies, Haramaya University.

Yifru, T. and Hailu, T. 2005. Genetic improvement in grain yield potential and associated agronomic traits of *teff* (*Eragrostis tef*). *Euphytica* 114: 247-254.