

VARIATION AND ASSOCIATION ANALYSIS IN GRASS PEA (*LATHYRUS SATIVUS* L.)

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ABSTRACT: The study was conducted on 50 landrace populations of grass pea at Adet Research Center, Ethiopia, using Randomised Complete Block Design in three replications to determine morphological variability and character associations. Evaluations were made on plant and yield characters from eight plants tagged randomly from each plot. The data were subjected to Analysis of Variance (ANOVA), heritability, correlation and cluster analyses. Higher mean and CV values were recorded for most of the agronomic traits for populations collected from Gondar region and the higher altitude group (>2500 m) indicating the presence of high genetic diversity in this region and altitude group. Phenotypic coefficient of variation (PCV) was slightly higher than genotypic coefficient of variation (GCV) for all the characters studied signifying that genotypic factors exerted reasonable effect in estimating the variation. The wide difference between PCV (22.4%) and GCV (13.0%) for seed yield per plant indicated the complexity of this trait and the important role of other factors such as environment in influencing yield potential in addition to the genetic factors. The strong positive association of pods per plant, 100 seed weight and primary branches per plant with seed yield indicated the possibility of selecting lines for yield improvement based on these characters at the very early stage of the grass pea breeding program.

Key words/phrases: Correlation grass pea, heritability, *Lathyrus sativus*, variation

INTRODUCTION

Grass pea (*Lathyrus sativus*) belongs to the genus *Lathyrus* in the tribe Viciae of the Leguminosae family (Purseglove, 1968; Goyder, 1986). It is a self-pollinated annual vine closely resembling field pea in growth habit but its leaflets are long and grass shaped. The origin of grass pea is unknown (Thulin, 1983). But Purseglove (1968) postulated southern Europe and western India as centres of origin. Vavilov (1951) and lately Asfaw Telaye *et al.* (1994) considered Ethiopia as a primary source of diversity for grass pea.

Grass pea is a highly popular food and feed legume in the farming system of drought affected areas due to its tolerance to drought, flooding and diseases

and its importance in ameliorating soil fertility (Campbell and Tiwari, 1997) even though heavy consumption of grass pea seed is associated with the development of lathyrism, a crippling disorder, in humans. It is dominantly cultivated in Ethiopia, India, Pakistan, Bangladesh and Nepal (Bharati, 1986; Wuletaw Tadesse *et al.*, 1997). According to Kaul *et al.* (1986), grass pea accounts for more than twenty five percent of the area as well as production of all pulses grown in Bangladesh. Furthermore Lal *et al.* (1986) indicated that grass pea is the third largest pulse crop of India in area after chickpea and pigeon pea. In Ethiopia, it is the third important pulse crop after fababean and chickpea with 142,170 hectares of production area and 1,047,440 quintals of production (CSA, 1998).

Melaku Werede (1988), Endashaw Bekele (1983) and Dawit Tadesse (1994) showed that the valuable genetic diversity of several crops is under constant danger of being irretrievably lost due to natural calamities such as drought, replacement of the landrace by genetically uniform crop varieties and change and development in land use. In the case of grass pea under Ethiopian condition, the association of grass pea with lathyrism and the cereal based extension program coupled with the absence of improved varieties for grass pea production are important factors leading to the reduction of grass pea production and genetic resources (Wuletaw Tadesse, 1999). Hence there is a great need for germplasm collection and maintenance to promote a grass pea breeding program for developing varieties with high grain yield and low toxin content.

Genetic variability studies are essential to undertake germplasm collection for *ex-situ* conservation and to identify sites with high genetic diversity for *in situ* conservation (Abebe Demissie and Bjornstand, 1996; Endashaw Bekele, 1983). Furthermore, genetic variation in crop plants for characters of agronomic importance leading to the determination of complex characters such as 'yield' should be determined since it forms the base in crop improvement. In such an improvement process, Thorpe (1976) indicated that character associations are important to indicate common elements of epigenetic control and/or similar response of characters to selection pressure. However, such studies were not carried out for grass pea in Ethiopia. Hence, this study was carried out with the following objectives.

1. To study the magnitude and variation of some morphological characters and their patterns of distribution.
2. To identify sites of high genetic variation for *in-situ* conservation and generate information for further grass pea germplasm collection.
3. To determine the associations between different agronomic characters in grass pea.

MATERIALS AND METHODS

The study was carried out from September 1998 to February 1999 at Adet Research Centre which is located at 37° 29' E and 11° 16' N and at an altitude of 2240 m above sea level in Gojam Administrative Zone, Ethiopia. The soil is Vertisol with pH level of 6.0. The rainfall (1230 mm per annum) and other weather variables of the test period were generally conducive for normal growth of grass pea.

Fifty grass pea landrace populations, which are believed to represent the national collection in the Biodiversity Research and Conservation Institute of Ethiopia, were used in this study (Table 1). These populations were selected from all grass pea growing administrative regions based on different altitude groups of legume production classified by Asfaw Telaye *et al.* (1994) as low (<1900m), mid (1901–2250 m), high (2551–2550 m) and very high (>2550 m) altitudes. Planting of the populations were carried out in the first week of September at Adet Research Center experimental field in a plot size of 4 m² (four rows of 5 m length and 0.2 m row spacing) each, using randomised complete block design (RCBD) in three replications at a seeding rate of 40 kg/ha. The spacing between plots and blocks were 1 and 1.5 m, respectively. Fertilizer and irrigation water were not applied. Eight plants from the central two rows in each plot were tagged randomly and evaluated for days to 50 % flowering, days to 90% maturity, number of pods/plant, plant height (cm), 100 seed weight (g), seed yield per plant (g) and harvest index per plant (%).

Statistical analyses

Analyses of variances were determined for all morphological characters using MSTAT C soft ware. Clustering of the populations was carried out using mean values of morphological characters with the help of SPSS software. Correlation analysis was also carried out using the same software. Genetic and phenotypic correlations, variance components, coefficient of variation, heritability and genetic advance were determined as follows following Johanson *et al.* (1955).

Genotypic correlation = $\frac{\text{cov}(x, y)}{\sqrt{(S_{gx}^2 \times S_{gy}^2)}}$ where COV xy is the genetic covariance

between two traits, S²_{gx} and S²_{gy} are the genetic covariances of the two traits.

Phenotypic correlation = $\frac{\text{cov}(x, y)}{\sqrt{(S_{px}^2 \times S_{py}^2)}}$ where COV xy is the phenotypic

covariance between two traits, S²_{px} and S²_{py} are the phenotypic covariances of the two traits. Cov xy for each pair of traits was computed from the analysis of covariance in a similar manner as the analysis of variance.

Phenotypic variance (vp) = genotype ms/r ; error variance (ve) = error ms/r , genotypic variance (vg) = $vp-ve$, where r = number of replications and ms = mean squares. Phenotypic coefficient of variation (pcv) = $100 \times \sqrt{(vp)} / m$ and genotypic coefficient of variation (gcv) = $100 \times \sqrt{(vg)} / m$ where m = the mean value. Heritability (h^2) = vg/vp and genetic advance (GS) = $(I)(h^2) \sqrt{(vp)}$ where I = selection differential (2.06 for selecting 5% of the genotypes); gs (% of the mean) = $(gs/m) \times 100$.

Table 1. Plant genetic resource Center (PGRC/E) acc no., administrative region, county and altitude of the collecting sites of the populations.

No.	cc. no.	Region	County	Altitude (m)
1	46003	Shoa	Yerer	2050
2	46008	Shoa	Muketurie	2240
3	46012	Gojam	Mota	2550
4	46016	Shoa	Sayadibir	2700
5	46020	Shoa	Ambo	2235
6	46023	Shoa	Menagesha	2500
7	46024	Shoa	Kara	2460
8	46027	Shoa	Ginchi	2420
9	46030	Gojam	Enebsie	2300
10	46033	Gondar	Este	2330
11	46034	Wollo	Wogeltena	2090
12	46035	Wollo	Wogeltena	2375
13	46042	Gojam	Debrework	2540
14	46044	Gojam	Shebelberenta	2410
15	46049	Gojam	Dejen	2490
16	46050	Gojam	Felegebrhan	2700
17	46073	Gojam	Yetnora	2420
18	46099	Wollo	Kalu	1880
19	46100	Wollo	Bistima	2000
20	46106	Wollo	Wodere	1950
21	46110	Wollega	Kelem	1600
22	46111	Wollo	Sulula	1700
23	207493	Gondar	Kemkem	2400
24	207496	Tigray	Didiba	2200
25	207497	Tigray	GentaAfeshum	2200
26	207499	Gondar	Gondar	2600
27	207566	Tigray	Hintalo	2150
28	207567	Tigray	Laymaychew	2100
29	208449	Gojam	Adet	2300
30	211511	Wollega	Nejo	1740
31	215247	Wollo	--Gobalafto	1900
32	219945	Tigray	Adiabeiti	1870
33	219946	Tigray	Laymaichew	2080
34	219949	Tigray	Adiabeiti	2150
35	219950	Tigray	Adwa	2230
36	219952	Tigray	Naendre	1700
37	220118	Ertrea	Mendefera	1980
38	226001	Wollo	Debresina	2400
39	226006	Wollo	Kelela	2500
40	226010	Wollo	Legambo	2640
41	223219	Tigray	Tserai	1930
42	226014	Gondar	Este	2645
43	226019	Gojam	Bahirdar	1685
44	228495	Gojam	Awbel	2400
45	236711	Gojam	Damot	1840
46	46107	Gondar	Maksegnit	1950
47	236686	Gojam	Mertolemariam	2555
48	436705	Gondar	Woreta	1800
49	236708	Gondar	Dabat	2730
50	236701	Gojam	TisAbay	1700

RESULTS AND DISCUSSION

Variations in quantitative characters

The mean, range and coefficient of variation in agronomic traits are widely used to determine variations within and between populations (Jaradat, 1991; Sharma *et al.*, 1995; Endashaw Bekele, 1996, Getachew Belay, 1997). Similarly, variations in grass pea were determined in the present study. As indicated in Table 2, mean yield per plant ranged from 42-132.9 g while the number of pods per plant ranged from 199-675. Days-to-flowering and maturing ranged from 39-73 and 127-165 days, respectively.

Analysis of variance showed highly significant differences between populations for days-to-maturity, pods per plant, seed yield per plant, harvest index and dry matter yield (Table 3). As indicated in Tables 4 and 5, the character that showed the highest coefficient of variation was not the same for all regions and altitude groups indicating the effect of environment on the variability of traits. Number of pods per plant showed much variation (CV= 53.7%) in the population collected from Eritrea followed by those from Gondar region (CV= 26.9%). The mean number of pods per plant, however, was highest (506 pods per plant) in the population from Gondar. Mean seed yield per plant for grass pea was highest in the population collected from Eritrea (107 g) followed by Gondar region (100.8 g/plant). The high mean and CV values observed in the population from Eritrea may be due to the low number of populations used from the region for the study.

Populations collected from Gondar showed the highest mean primary branches per plant while populations from Tigray showed least primary branches per plant. Plant height showed higher coefficient of variation (6.8%) in populations collected from Eritrea. Populations from Gondar are in general long with mean heights of 120.9 cm (Table 4). Total biomass per plant is also high in populations from this region (259.1 g). Populations from Gondar and Eritrea regions showed low harvest index while populations from Wollega showed high harvest index. The low harvest index in grass pea from Gondar region and Eritrea could be due to high biomass production. Variation in phenological traits was also observed among populations from different regions. The highest coefficient of variation was observed in the population from Gondar, 1.5% for days-to-flowering and 3.2% for days-to-maturity. Populations from Wollega took minimum days-to-flower (mean = 44) and to mature (mean = 132 days) while populations from Gondar were late both to flower and mature with means of 62 and 154 days, respectively.

Table 2. Mean values for 10 morphological characters in 50 grass pea populations of Ethiopia, 1998.

Acc.no	PRB	PLHT	DF	DM	PPP	SPP	SW	BIOM	SY	HI
46003.00	9.00	101.00	49.00	142.00	335.00	3.00	8.00	147.00	76.00	57.00
46008.00	9.00	104.00	55.00	141.00	288.00	3.00	8.00	152.00	62.00	42.00
46012.00	9.00	119.00	56.00	145.00	462.00	3.00	8.00	228.00	104.00	44.00
46016.00	10.00	104.00	50.00	140.00	327.00	3.00	8.00	145.00	67.00	42.00
46020.00	9.00	103.00	52.00	140.00	344.00	3.00	9.00	159.00	77.00	46.00
46023.00	10.00	103.00	54.00	138.00	396.00	3.00	7.00	155.00	72.00	85.00
46024.00	10.00	103.00	54.00	141.00	486.00	3.00	8.00	219.00	115.00	48.00
46027.00	9.00	104.00	55.00	142.00	361.00	3.00	8.00	158.00	77.00	44.00
46030.00	10.00	111.00	61.00	145.00	328.00	3.00	8.00	179.00	70.00	36.00
46033.00	9.00	122.00	58.00	144.00	412.00	3.00	9.00	197.00	93.00	43.00
46034.00	9.00	116.00	46.00	143.00	306.00	3.00	10.00	164.00	80.00	48.00
46035.00	9.00	106.00	49.00	145.00	307.00	3.00	9.00	149.00	73.00	48.00
46042.00	9.00	112.00	56.00	144.00	477.00	3.00	8.00	206.00	86.00	46.00
46044.00	10.00	118.00	57.00	147.00	445.00	3.00	8.00	184.00	86.00	48.00
46049.00	10.00	117.00	59.00	151.00	509.00	3.00	8.00	220.00	100.00	44.00
46050.00	9.00	119.00	62.00	144.00	386.00	3.00	7.00	159.00	95.00	42.00
46077.00	10.00	109.00	62.00	152.00	454.00	3.00	8.00	292.00	98.00	41.00
46099.00	10.00	106.00	52.00	141.00	389.00	3.00	8.00	195.00	93.00	46.00
46100.00	8.00	113.00	44.00	134.00	301.00	3.00	9.00	144.00	73.00	47.00
46106.00	9.00	118.00	50.00	142.00	333.00	3.00	9.00	172.00	82.00	48.00
46110.00	10.00	194.00	42.00	130.00	334.00	3.00	8.00	123.00	65.00	52.00
46111.00	10.00	117.00	44.00	140.00	348.00	3.00	9.00	168.00	93.00	54.00
207493.0	11.00	121.00	52.00	148.00	517.00	3.00	8.00	259.00	107.00	43.00
207496.0	9.00	94.00	40.00	127.00	200.00	3.00	9.00	86.00	45.00	51.00
207497.0	8.00	104.00	45.00	136.00	282.00	3.00	9.00	143.00	79.00	53.00
207499.0	9.00	122.00	57.00	145.00	410.00	3.00	10.00	186.00	92.00	47.00
207566.0	8.00	93.00	41.00	130.00	198.00	3.00	8.00	87.00	42.00	40.00
207567.0	9.00	110.00	52.00	143.00	354.00	3.00	9.00	159.00	82.00	50.00
208449.0	9.00	107.00	55.00	142.00	422.00	3.00	8.00	206.00	95.00	46.00
211511.0	8.00	94.00	46.00	135.00	304.00	3.00	8.00	121.00	67.00	54.00
215247.0	11.00	120.00	52.00	140.00	504.00	3.00	8.00	229.00	116.00	48.00
219945.0	8.00	95.00	44.00	135.00	243.00	3.00	8.00	115.00	55.00	48.00
219946.0	10.00	114.00	46.00	142.00	481.00	3.00	9.00	209.00	104.00	50.00
219949.0	9.00	115.00	49.00	141.00	435.00	3.00	10.00	193.00	91.00	45.00
219950.0	9.00	101.00	49.00	135.00	291.00	3.00	10.00	145.00	70.00	44.00
219952.0	9.00	122.00	48.00	142.00	395.00	3.00	9.00	205.00	95.00	45.00
220118.0	10.00	107.00	52.00	148.00	464.00	3.00	9.00	226.00	105.00	44.00
226001.0	9.00	110.00	57.00	142.00	385.00	3.00	8.00	182.00	87.00	45.00
226006.0	8.00	115.00	51.00	135.00	355.00	3.00	9.00	182.00	90.00	46.00
226010.0	9.00	122.00	52.00	140.00	345.00	3.00	12.00	177.00	89.00	64.00
223219.0	9.00	105.00	39.00	135.00	315.00	3.00	9.00	141.00	79.00	56.00
226014.0	9.00	120.00	55.00	165.00	364.00	3.00	9.00	217.00	90.00	43.00
226019.0	11.00	121.00	57.00	143.00	530.00	3.00	8.00	231.00	114.00	49.00
228495.0	9.00	103.00	61.00	145.00	334.00	3.00	8.00	166.00	76.00	46.00
236711.0	8.00	122.00	57.00	150.00	441.00	3.00	8.00	257.00	87.00	42.00
46106.00	10.00	123.00	73.00	156.00	513.00	3.00	7.00	289.00	84.00	35.00
236686.0	7.00	106.00	60.00	148.00	253.00	3.00	7.00	107.00	55.00	53.00
236705.0	12.00	125.00	68.00	161.00	670.00	3.00	8.00	374.00	114.00	30.00
236708	11.00	111.00	71.00	156.00	675.00	3.00	7.00	373.90	127.00	42.60
236701	10.00	115.00	65.00	151.00	385.00	3.00	9.00	302.60	132.90	45.10
46003.00	9.00	101.00	49.00	142.00	335.00	3.00	8.00	147.00	76.00	57.00

NPB, Number of primary branches/plant; PLH, plant height; DF, days-to-flowering; DM, days-to-maturity; NPP, number of pods/plant; SW, 100 seed weight; Bim, biomass; SYP, seed yield/plant; Hi, harvest index.

Table 3. Mean squares for 9 quantitative morphological traits of 50 grass pea populations.

Character code @	Mean sq,for rep	Mean sq. for population	Mean sq. for error	CV	SE
NPB	2.434	2.064**	0.974	10.58	0.14
PLH	128.488	238.661	171.224	11.82	1.85
DF	62.914	171.109**	27.142	9.78	0.73
DM	335.605*	162.003**	73.824	6.01	1.21
NPP	8331.588	30405.988**	11309.8	27.41	15.03
SW	1.19	2.280**	0.949	11.44	0.13
Bim	5557.791	9320.301**	2976.59	29.25	7.71
SYP	746.793	1122.440*	744.363	31.66	3.85
Hi	41.771	183.348**	55.527	15.81	1.05

@ NPB, Number of primary branches/plant; PLH, plant height; DF, days-to-flowering; DM, days-to-maturity; NPP, number of pods/plant; SW, 100 seed weight; Bim, biomass; SYP, seed yield/plant; Hi, harvest index; * and ** indicates significance at 5% and 1%, respectively.

Variations in the various morphological characters were also observed by altitude groups (Table 5). The highest altitude group (group 4), which included populations collected from above 2550 m showed higher coefficient of variation for the morphological traits studied. Similarly the mean performance of the populations in this altitude group was much higher than others. As it can be expected days-to-flowering and days-to-maturity were minimum for populations in the low and mid altitude groups. The highest mean seed yield per plant was obtained from populations in the low altitude areas due to their short maturity period indicating the effectiveness of the crop to use efficiently the available short cycle moisture especially in the low moisture stress areas. In general, regions and altitude groups with high coefficient of variation were associated with high variability for the particular trait considered. The Gondar region has the highest CV for most traits studied indicating the presence of high genetic diversity of grass pea in the region.

Cluster analysis

Hierarchical clustering of the 50 grass pea landrace populations based on quantitative morphological characters was carried out (Fig. 1). The populations were grouped in two major clusters. Forty-eight populations were grouped in cluster I (CI) while only two populations, acc.no. 436705 and 236708, were grouped in cluster II (CII). These populations were collected from Gondar region at Woreta (1800 m.a.s.l.) and Dabat (2730 m.a.s.l.) districts.

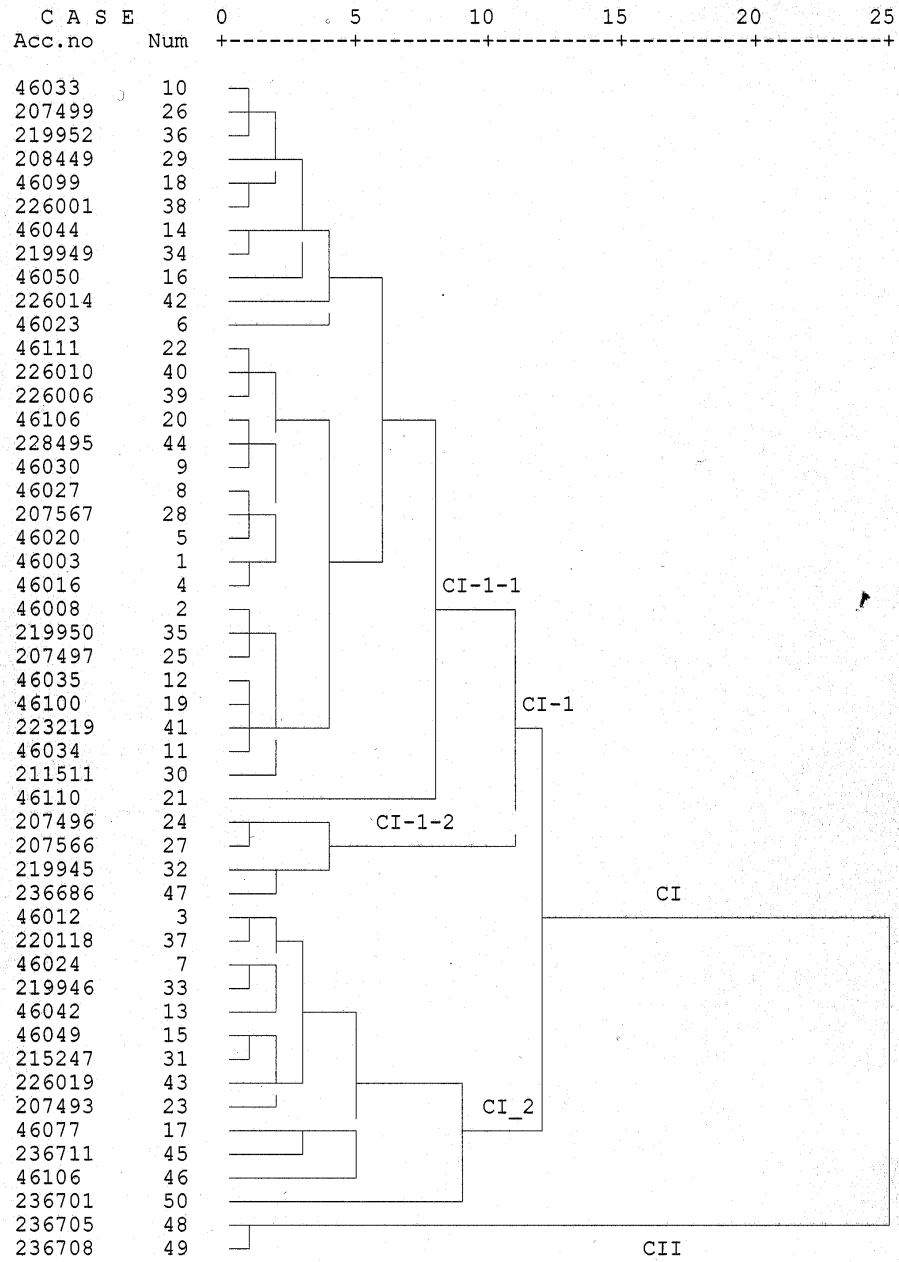


Fig. 1. Dendrogram for the 50 grass population based on morphological characters.

Table 4. Mean, and coefficient of variation by regions and over the entire data.

Regions	NPB		PLH		DF		DM		NPP		SW		Bim		SYP		HI	
	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV
Gojjam	9.4	0.1	113.9	1.9	58.6	0.5	146.5	0.7	434.6	15.8	8.1	0.8	208.8	9.2	94.6	5	45	0.6
Gondar	10	0.2	120.9	2.3	62.1	1.5	153.5	3.2	505.7	26.9	8.3	0.1	259.1	14.9	100.8	5	41	1.0
Shoa	9.3	0.2	102.9	2.3	52.8	0.6	140.7	1.3	363.6	19.8	8.1	0.1	162.4	9.0	78.0	5	52	4.5
Wollo	9.4	0.1	114.5	1.8	49.6	0.5	140.3	0.9	357.4	14.8	9.1	0.3	176.3	7.5	87.6	4	50	1.6
Tigray	8.8	0.1	105.2	2.0	45.3	0.5	136.3	1.0	317.3	15.1	9.1	0.1	148.4	7.3	73.3	4	48	0.8
Wollega	9	0.3	94.1	3.7	44.0	0.9	132.3	1.7	319.3	25.3	7.8	0.2	121.6	10.7	65.9	6	53	1.6
Eritria*	9.6	0.4	108.9	6.8	51.0	1.3	147.7	1.8	470.5	53.7	8.9	0.3	230.3	28.7	107.3	13	44	2.6
Ethiop	9.3	0.23	110.7	27.3	53.1	17.81	142.8	14.2	392.3	65.6	8.5	30.9	188.1	73.2	86.7	80	47	56

*, (independent country since 1991); NPB, Number of primary branches/plant; PLH, plant height; DF, days to flowering; DM, days to maturity; NPP, number of pods/plant; SW, 100 seed weight; Bim, biomass; SYP, seed yield/plant; HI, harvest index.

Table 5. Mean and coefficient of variation of 50 grass pea populations by altitude groups.

Altitude Group	NPB		PLH		DF		DM		NPP		SW		Bim		SYP		HI	
	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV	M	CV
<1900 m	9.6	0.1	12	1.9	52.3	0.7	143	0.8	417.3	16.8	8.4	0.1	204.6	9.7	94.7	5.1	46.4	0.7
1901-2250 m	9.1	0.1	107	1.6	48.8	0.5	139.2	0.8	330.2	12.9	8.9	0.1	159.8	6.5	74.7	3	47.2	0.9
2251-2550 m	9.4	0.1	11	1.6	56.1	0.5	144.2	0.8	415.8	14.1	8.2	0.1	198.6	7.5	89.3	3.2	47.2	1.9
>2550 m	9.4	0.2	115	2.2	57.1	1.3	147.7	3.3	429.1	22.1	8.7	0.1	195.5	10.3	92.9	6.2	47.5	2.2

NPB, Number of primary branches/plant; PLH, plant height; DF, days to flowering; DM, days to maturity; NPP, number of pods/plant; SW, 100 seed weight; Bim, biomass; SYP, seed yield/plant; HI, harvest index.

Heritability, genetic advance and estimates for components of variance

The phenotypic (PCV) and genetic (GCV) coefficient of variation, estimate of the component of variance, heritability (broad sense), and genetic advance (as percent of the mean) are given in Table 6. The phenotypic coefficient of variation (PCV) was slightly higher than genotypic coefficient of variation for all the characters studied signifying that genotypic factors had effect in estimating the variation. The wide difference between PCV (22.4%) and GCV (13.0%) for seed yield per plant indicates the complexity of this trait and the important role of other factors such as environment in influencing yield potential in addition to the genetic factors. A similar result was obtained by Getachew Belay (1997) in durum wheat.

Table 6. Summary statistics and estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) broad sense heritability (H^2) and genetic advance (GS) in 50 grass pea populations for 9 quantitative traits.

Characters	Mean	Range	Vp	Ve	Vg	PCV (%)	GCV (%)	H^2	GS (% of mean)
NPB	9.02	8-12	0.68	0.32	0.36	9.19	6.68	52.9	9.7
PLH	110.7	93-125	79.5	57	22.4	8.05	4.28	28.2	4.6
DF	53.2	39-73	57	9	47.9	14.22	13.02	84.14	24.5
DM	143	127-165	54	25	29	5.13	3.79	54.4	5.7
NPP	387.9	199-675	10135	3769.9	6365	25.9	20.5	62.8	33.5
SW	8.5	7-12	0.76	0.31	0.45	10.2	7.8	59.2	12
Bim	186.5	86-374	3106.8	992	2115	29.8	24.6	68	41.8
SYP	86.2	42-133	374	248	126	22.4	13	33.6	15.2
Hi	47.1	30-85	61	18.5	42.6	16.59	9.1	69.7	23.5

* Vp, phenotypic variance; Ve, error variance; Vg, genotypic variance.

The table shows that most of the characters had high heritability estimates indicating relatively less influence of the environment on them. Days-to-flowering showed high heritability estimate ($h^2=84.14\%$). On the other hand, heritability estimate was low ($h^2=33.0\%$) for seed yield per plant and plant height ($h^2=28\%$), clearly indicating the major influence of the environment on these characters.

Correlation analysis of quantitative characters

Thorpe (1976) indicated that character associations are important to indicate common elements of epigenetic control and/or similar response of characters to selection pressure. In the present study, in all the regions (data not indicated here) and the entire data (Table 7), seed yield per plant was highly correlated with number of primary branches per plant, number of pods per plant and plant height. Similarly, we note a highly significant correlation

between days-to-flowering and days-to-maturity. The presence of persistent correlation among most characters considered could be due to natural selection between individuals within a population which changes the genetic constitution of the population, but the mean fitness will not change if the population is already at the limit of the carrying capacity of its environment which of course is common in most cultivated plants (Endashaw Bekele, 1996). The highly significant correlations between the different characters also indicate the presence of some common elements of genetic control such as pleiotropy and high linkage between genes.

Table 7. Genotypic (G) and phenotypic (p) correlations in 9 quantitative morphological characters of 50 grass pea populations.

Characters	NPB	PLH	DF	DM	NPP	SW	Bim	SYP	Hi
NPB (G)		.069	0.625**	0.707**	0.986**	-0.301	0.884**	0.905**	-0.28
(P)		0.273	0.249	0.264	0.634**	-0.11	0.578**	0.537**	0.986**
PLH (G)			0.986**	0.819**	0.606**	0.41**	0.86**	0.676**	-0.677**
(P)			0.261	0.547**	0.606**	0.11	0.605**	0.629**	-0.105
DF (G)				1	0.891**	-0.609**	0.956**	1	-1.56
(P)				0.578**	0.407**	-0.314	0.426**	0.205	-0.83**
DM (G)					0.813**	-0.42**	1	0.91**	-0.69**
(P)					0.535**	-0.16	0.55**	0.43**	-0.23
NPP (G)						0.504**	0.991**	0.982**	-0.50**
(P)						0.198	0.85**	0.781**	-0.108
SW (G)							-0.39*	-0.134	0.184
(P)							-0.103	-0.02	0.232
Bim (G)								0.791**	-0.619**
(P)								0.709	-0.285
SYP (G)									-0.606**
(P)									-0.006
Hi									

*, ** Indicates significance at 5% and 1%, respectively.

The effect of environment on the genotypic performance of most traits was explained by many authors (Getachew Belay, 1997; Wuletaw Tadesse, 1998). Accordingly, splitting of genotypic and phenotypic correlations is important for clear understanding of character associations as indicated in Table 8. Genotypic and phenotypic correlations showed similar signs for most traits except for the association between number of primary branches per plant and harvest index for which the phenotypic correlation is strongly positive while the genetic coefficient is negative. In some cases the phenotypic and genotypic correlations were close in magnitude indicating that the impact of the environments over the traits mentioned is not significant. However, in other cases, the difference in the magnitude of the two coefficients is high indicating the effect of environmental variances and covariances as indicated in the case of the association between yield and harvest index where the genotypic

correlation coefficient and the phenotypic correlation coefficients are -0.606 and -0.006, respectively.

A strong positive genotypic correlation was observed between days-to-flowering and seed yield per plant. A very strong genetic correlation was also noted between days-to-flowering and days-to-maturity. A similar result was reported by Getachew Belay (1997) in durum wheat. Plant height showed strong positive genetic correlation with most of the traits studied except with harvest index. The strong positive association of pods per plant, 100 seed weight and primary branches per plant with seed yield indicated the possibility of selecting lines for yield improvement based on these characters at the very early stage of the breeding program.

Table 8. Correlation among 10 different characters of 50 grass pea populations in Ethiopia.

Character	Bim	DF	DM	HI	NPB	NPP	PLH	SPP	SW	SYP
Bim		0.172**	0.485**	-0.011	0.372**	0.803**	0.576**	0.308**	0.033	0.784**
DF			0.326**	-0.055	0.119**	0.155**	0.09	0.194**	-0.015	0.086
DM				0.136**	0.194**	0.518**	0.604**	0.465**	0.044	0.455**
HI					0.004	0.166**	0.111**	0.110**	-0.039	0.207**
NPB						0.397**	0.232**	0.166**	0.017	0.352**
NPP							0.589**	0.379**	0	0.787**
PLH								0.379**	0.005	0.557**
SPP									-0.007	0.298**
SW										-0.003
SYP										

NPB, Number of primary branches/plant; PLH, plant height; DF, days-to-flowering; DM, days-to-maturity; NPP, number of pods/plant; SW, 100 seed weight; Bim, biomass; SYP, seed yield/plant; Hi, harvest index.

SUMMARY AND CONCLUSION

Variation is the source of plant breeding without which crop improvement would be impeded. It is also important to improve germplasm collection and conservation. Mean, coefficient of variation (CV), heritability and correlation of characters are important tools to determine variation between populations in different regions and also in different altitude groups. The variability of 50 grass pea populations collected from different administrative regions and altitude groups in Ethiopia was investigated in this study. The results indicate the presence of high genetic diversity in Gondar region and the higher altitude class (>2550 m), which of course is important in setting priority during germplasm collection for *ex situ* conservation and selecting sites for *in situ* conservation in this region and altitude group. There was highly significant correlation between the different characters in all the entire data and the different regions indicating the presence of some common elements of genetic control such as pleiotropy and high linkage between genes. Strong positive genotypic and phenotypic correlations were observed between days-to-

flowering and seed yield per plant. A very strong genetic correlation was also achieved between days-to-flowering and days-to-maturity. Plant height showed strong positive genetic correlation with most of the traits studied except with harvest index.

The strong positive association of pods per plant, 100 seed weight and primary branches per plant with seed yield indicated the possibility of selecting lines for yield improvement based on these characters at the very early stage of the grass pea breeding program. Furthermore, the variations in the morphological characters observed in the present study are important for future breeding program by analysing their ODAP variability.

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