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Correlation and Path Coefficient Analysis of Yield and Yield Related Traits in Groundnut (Arachis hypogaea L.) Genotypes at Assosa and Kamashi, Western Ethiopia

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Abstract
The lowland areas of Ethiopia have considerable potential for increased oil crop production including groundnut. In Benishangul Gumuz Region, groundnut is cultivated in various zones and woredas under rainfed condition. However, due to insufficient improved groundnut varieties found in the region the productivity was low. Therefore, this experiment was conducted to evaluate 25 groundnuts genotypes in 5 x 5 triple lattice design to generate information on the association of yield and yield related traits, and to determine the direct and indirect effects of yield related traits on grain yield at Assosa and Kamashi zones, Western Ethiopia. Data were recorded for 16 traits and subjected to ANOVA using SAS software. Further genetic analyses were conducted as per the formula suggested by biometricians. The correlation and path coefficient analysis indicated that dry pod yield hectare^{-1}showed positive and strong correlation with grain yield also exercised the highest positive phenotypic and genotypic direct effect at both locations and combined of the two locations. The trait will be useful for direct selection to increase grain yield. These indicated that there is a good opportunity to improve grain yield using the tested genotypes in groundnut breeding programs. Therefore, emphasis should be given for dry pod yield hectare^{-1}, primary branches plant^{-1}, pods plant^{-1} and 100-seed weight to enhance grain yield production.
Keywords: correlation, direct and indirect effect, variation

1. INTRODUCTION

The lowland areas of Ethiopia have considerable potential for increased oil crop production including groundnut. The estimated annual groundnut production in Ethiopia was about 103, 062.38 tons from 64,649.34 hectares of production area. The average national yield was about 1.6 tons per hectare (CSA, 2015). It is mainly produced by smallholder farmers in the lowland area of Ethiopia. Currently, the production is concentrated in some areas of Oromia, Benishangul-Gumuz, Amhara, SNNP, Harari and Gambela regions. Eastern Hararghe zone of Oromia region hold primary position in producing and supplying groundnut both to domestic and export markets as compared to other parts of the country (Wijnands *et al*., 2009).

In Benishangul Gumuz Region, groundnut is cultivated in various zones, woredas and pocket areas of the region under rainfed condition. It occupies about 14,759.25 hectare of lands with an estimated production of 258,187.68 tons in 2014/15 main cropping season. The regional average yield was 1.7 tons per hectare in the above production year. Of the total area covered by groundnut in the region, Metekel zone takes the lion-share (13,788.99 hectares) followed by Assosa and Kamashi zone with the total area coverage of 714.86 hectare and 139.24 hectare respectively. The annual production of groundnut in Metekel, Assosa and Kamahi zones of the region were 24,467.045, 1,019.184 and 199.728 tons with productivity of 1.7, 1.4 and 1.4 tons per hectare respectively in the previous cropping season (CSA, 2015). This low productivity of the crop was attached to insufficient improved varieties released in the region.

Breeders are interested in the relationship that may exist between or among traits. Information on the extent and nature of interrelationship among character help in formulating efficient scheme of multiple trait selection. Correlation studies provide an opportunity to study the magnitude and direction of association of yield with its components and also among various components. Hence, resorting to selection through correlated response entailing several contributing factors which influence seed production both directly and indirectly shall be most appropriate. Association of traits determined by correlation analysis may not provide an exact picture of the relative importance of direct and indirect influence of each of yield components on yield. The path coefficient analysis is one of the effective technique to sought out inter relationship among different yield characters and their direct and indirect effect on yield through correlation values. Path coefficient is essential to accumulate optimum combination of yield contributing characters and to know the implication of the interrelationships of various characters in a single genotype. To achieve the aim of developing a better variety in groundnut breeding programs, a breeder must exploit variability of quantitative characters existing within a collection of genotypes. Therefore, in groundnut breeding programs, information on relationship between various characters and their contribution to yield is paramount to increase groundnut production in the region as well in a country. However, no work has been conducted at Benishangul-Gumuz Regional State describing trait associations. Owing to this, an experiment was conducted with the following objectives.

Objectives of this study were to:-

1) Assess the extent of association among yield, yield components and oil content in groundnut genotypes and,
2) Estimate direct and indirect effect of yield related traits and oil content on the grain yield of groundnut genotypes

2. MATERIALS AND METHODS

2.1 Description of the Experimental Sites

The experiment was conducted at Assosa on station and Kamashi sub center of Assosa Agricultural Research Center (AsARC) experimental field, in Benishangul-Gumuz regional state (BGRS), Western Ethiopia during 2016 main cropping season. Assosa Agricultural Research Center is located in the east of Assosa town and west of Addis Ababa about 4 km and 660 km distance in Assosa *woreda*, respectively. The center is found at an altitude of 1554 meter above sea level (m.a.s.l.) at 10^0 02.505" N latitude and 34^0 34.319" E longitude. Assosa *woreda* is one of the 20 *woredas* found in Benishangul-Gumuz Regional State which is known by the production of groundnut in the region (Figure 1). It has uni modal rainfall pattern, which starts at the end of April and extends to mid-November. Maximum rainfall is received during June to October. Annual rain fall of 1056 mm and temperature range from 12.4 to 25.0^0c were received during 2016 cropping season at Assosa (AsARC, 2016). The major soil type found in Assosa area is Dystric Nitosols; the experimental site, in particular, is characterized by Nitosols. The second experimental site was Kamashi Sub-center which is found in Kamashi *woreda*. Kamashi *woreda* is one of the five *woredas* found in Kamashi Zone (Figure 1). It is located at 560 km to the west of Addis Ababa and 246 km to the south east of Assosa. The Sub-center has an altitude of 1215 m.a.s.l. with annual rainfall of 1486 mm (Table 1). The temperature ranges from 17.51^oC to 29.12^oC for the seasons mentioned above. Nitosol is the major soil type found followed by some type of Orthic Acrisols in the *woreda* (AsARC, 2011).

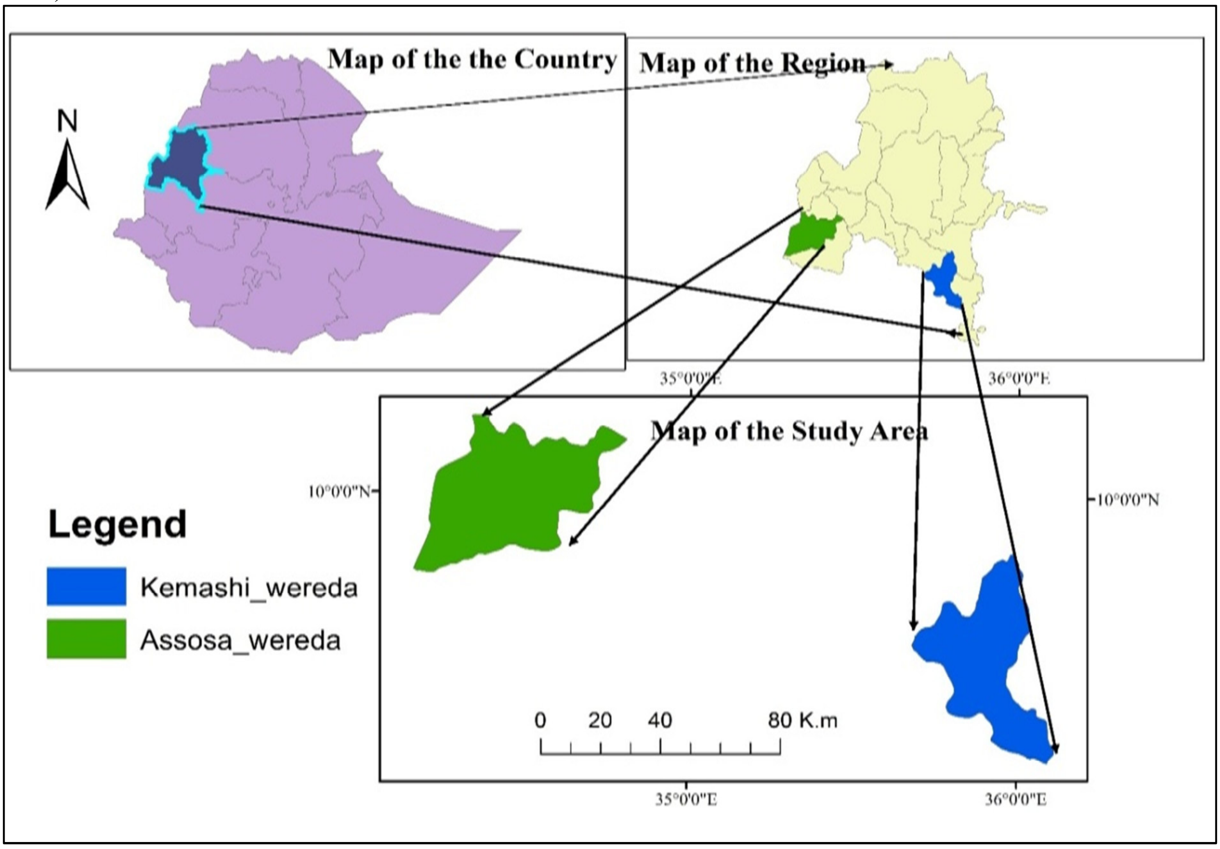

Figure 3 Geographical Map of the study area

2.2 Experimental Materials

The experimental materials comprise of 23 advanced groundnut genotypes along with two released groundnut varieties, namely, Maniputer and Roba (Table 1). The genotypes were obtained from Werer Agricultural

Research Center (WARC).

Table 1 Description of Groundnut Genotypes used in the Study

No	Genotypes	Pedigree
1.	ICGV-95492	VRR 245 X ICGs 11
2.	ICGV-01005	Ah 7223 X 55-437
3.	ICGV-01014	ICGV 88145 X ICGV 87110
4.	ICGV-01015	ICGV 88145 X ICGV 87110
5.	ICGV-01043	[(ICGV 88145 X ICGV 87110) F1 X ICGV 88312]
6.	ICGV-01080	ICGV 91284 X ICGV 91283
7.	ICGV-01105	ICGV 91284 X ICGV 87846
8.	ICGV-01124	J 11 X ICGV 87350
9.	ICGV-93280	Faizpur 1-5 XJL24
10.	ICGV-95440	VRR 245 X Var 27
11.	ICGV-95460	55-437 X ICGS 11
12.	ICGV-95469	55-437 X ICGS 11
13.	ICGV-97281	J 11 X 55-437
14.	ICGV-97328	ICGV 88145 X Ah 7223
15.	J11	J 11
16.	ICGV-98371	ICGV 92088 XTAG 24
17.	ICGV-97150	(JH 60 X PI 259747) Sel X NC AC17133] Sel XJ11) X NC Ac343] XICGV 86003]
18.	ICGV-97153	ICGV 89412 X PI 270806)
19.	ICGV-97156	91/57-2 X PI 405132
20.	ICGV-97157	91/57-2 X PI 405132
21.	ICGV-97163	ICGV 88268 XTAG 24
22.	ICGV-98369	ICGV 92088 XTAG 24
23.	ICGV-98370	ICGV 92088 XTAG 24
24.	Roba	ICG-7794
25.	Maniputer	VRR 245 X ICGs 11

Source: WARC (Werer Agricultural Research Center)

2.3 Experimental Design

The experiment was laid out in a 5 x 5 triple lattice design. Each genotype was planted in a plot size of 15 m^2 (3 m plot width x 5 m row length) and accommodated five rows at 0.6 m interval. There was 0.1 m distance between plants within a row. The spacing between plots and blocks were 0.6 m and 1 m, respectively. Fertilizer was not applied, but weeding and all other recommended agronomic practice was followed for both locations.

2.4 Data Collection

Data were collected on plot basis and plant basis from the central three rows for all parameters. For data recorded on plant basis five plants were randomly taken and tagged from the net harvestable plots and the mean value of these five plants were calculated using Micro soft Excel. The yield and yield component data that were collected on plant basis and plot basis for both locations were described as follows.

Data Collected on Plant Basis

1. **Plant height:** The length of the central axis of the stem was measured from the soil surface up to the tip of the stem. Five plants from each plot were randomly taken and measured with a ruler. The average for each plot was calculated and expressed in centimeter.
2. **Number of primary branches:** the average number of primary branches per plant from five sampled plants.
3. **Number of secondary branches:** the average number of secondary branches per plant from five sampled plants.
4. **Pod length:** Using a Vanier caliper, the length of five pods was measured and recorded in centimeter from each five sampled plants.
5. **Number of pods per plant:** was determined as the mean value of five randomly sampled plans obtained by counting total number of pods per plant.
6. **Number of mature pods per plant:** was determined as the mean value of five sampled plans obtained by counting of the number of well-filled pods.
7. **Number of seeds per pod:** The mean number of seeds per pod obtained by counting the number of seeds collected from five mature pods from each five sampled plants.

Data Collected on Plot Basis

1. **Days to flowering**: It was recorded as the number of days from sowing to 50% of the plants in the plot started flowering
2. **Days to maturity:** It was recorded as number of days from sowing to the stage when 90% of pods matured.
3. **Dry pod yield (kg/ha):** This was measured after harvesting the whole pods from the net plot and converted to kilograms per hectare after sun drying.
4. **Grain yield (kg/ha):** It was determined as shelling percentage multiplied by dry pod yield and adjusted to moisture content of 10%.
5. **Shelling percentage (SH%):** This was recorded by taking samples of about 200 g mature pods per net plot and was determined as:

$$\textbf{Shelling percentage(SH\%)} = \frac{\textbf{weight of shelled seed x100}}{\textbf{Total pod weight}}$$

6. **100-seed weight:** It was recorded by counting hundred seeds from a bulk of shelled seeds and weighed using a sensitive balance.
7. **Oil content:** was determined by Nuclear Magnetic Resonance (NMR) Spectroscopy at Holeta Agricultural Research Center (HARC).

2.5 Disease Reaction

The reaction of each genotype to leaf spot both early and late leaf spot disease was assessed by observing their symptoms on the leaves, stems and pods. The data were collected by simple scaling method by visual observation on each plot and values were given using 1 – 9 scales according to Subrahmanyam *et al.* (1995), where a score of 1 was rated as highly resistant (HR), 2 to 4 as resistant (R), 5 and 6 as moderately resistant (MR), 7 and 8 as susceptible, and 9 as highly susceptible (HS).

2.6 Data Analysis

2.6.1 Analysis of Variance

All recorded data were subjected to analysis of variance (ANOVA) using proc lattice and proc GLM of SAS software version 9.0 and treatment means were tested as significant at the 5% probability level and as highly significant at the 1% probability level. Homogeneity of error mean square between the two locations was tested by F-test and combined analyses were performed for those parameters whose error mean squares were homogenous. Mean comparison among genotype were carried out using Duncan Multiple Range Test (DMRT). Genetic parameter such as phenotypic and genotypic variance, heritability, phenotypic and genotypic coefficient of variations, genetic advance and genetic advance as percentage of mean were calculated by adopting the following Equations suggested by biometricians.

The Statistical model and ANOVA's formats of a lattice design for individual locations and combined over the two locations were presented below.

The statistical model of a lattice design for individual location is given by:

$$Y_{ijkl} = \mu + R_i + B(R)_{j(i)} + T_k + e_{ijkl}$$

Where: - Y_{ijkl} = the observed value, μ = overall mean yield, R_i = effect of the i^{th} replication, $B(R)_{j(i)}$ = effect of the j^{th} block within the i^{th} replication, T_k = effect of the K^{th} treatment and e_{ijkl} = random error

The statistical model of a lattice design for multiple locations is given by:

$$Y_{ijklm} = \mu + L_i + R(L)_{j(i)} + B_k + T_k + e_{ijklm}$$

Where: - Y_{ijklm} = the observed value, μ = overall mean yield, L_i = effect of the i^{th} location, $R(L)_{j(i)}$ = effect of the j^{th} replication within the i^{th} location, T_l = effect of the l^{th} treatment, B_k = effect of the k^{th} block and e_{ijklm} = random error

2.6.2 Association of Characters

2.6.2.1 Phenotypic and genotypic correlation

Both phenotypic and genotypic correlation coefficients, which is the inherent association between two variables were estimated using the standard procedure suggested by Weber and Moorthy (1952) using the corresponding variance and covariance components as shown in Equations below.

$$r_p(xy) = \frac{\text{Pcov}(x, y)}{\sqrt{\sigma^2 px.\sigma^2 py}}$$

Where r_p = phenotype correlation coefficient, pcov (x.y) = phenotype co-variance between variable x and y, σ^2px = phenotype variance for variable x, σ^2py = phenotype variance for variable y.

$$r_g(xy) = \frac{\text{Gcov}(x, y)}{\sqrt{\sigma^2 gx.\sigma^2 gy}}$$

Where r_g = genotype correlation coefficient, Gcov (x.y) = genotype co-variance between Variable x and y, σ^2gx

= genotype variance for variable x, σ^2gy = genotype variance for variable y.

2.6.2.2 Path coefficient analysis

Path coefficient analysis was estimated by the equation suggested by Dewey and Lu (1959) using the phenotypic and genotypic correlation coefficients to determine direct and indirect effect of different variables on seed yield.
$\mathrm{rij} = \mathrm{pij} + \Sigma \mathrm{rikPkj}$
Where rij = mutual association between independent variable (i) and dependent variable (j) as measured by phenotypic and genotypic correlation coefficient. pij = component of direct effect of independent variable (i) as measured by the phenotypic and genotypic path coefficient. ΣrikPkj = summation of components of indirect effect of a given independent variable (i) on a given dependent variable (j) via all other independent characters (K).
The residual effect (h) was calculated using the formula from Dewey and Lu (1959) as shown in Equation

$$H = \sqrt{1 - R^2}$$

3. RESULTS AND DISCUSSION

3.1 Association of Traits

3.1.1 Estimates of Correlation Coefficients at Genotypic and Phenotypic Levels

In practical breeding programs, improvement of a targeted trait can be achieved by indirect selection via other traits that are more heritable and ease to select. This selection strategy requires understanding the interrelationship of the characters among themselves and with the target character. Many interesting associations observed from this experiment among yield and yield related traits are discussed as follows. In this experiment estimate of genotypic (r_g) and phenotypic (r_{ph}) correlation coefficients between each pair of the studied traits are presented in Tables 2, 3 and 4, for Assosa, Kamashi and combined of the two locations, respectively. Genotypic correlation coefficients were found to be relatively higher in magnitude than their corresponding phenotypic correlation coefficients, except in a few cases, which clearly indicated the presence of inherent association among considered traits, while, in some cases the phenotypic correlation values were found to be higher than the genotypic correlation values suggesting the importance of environmental effects on the expression of the characters. This is in accordance with Vasanthi *et al.* (2015) and Ashish *et al.* (2015) investigation that, genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficient among groundnut genotypes they considered.

3.1.1.1 Correlation of grain yield with yield related traits

At Assosa, grain yield per hectare showed positive and highly significant ($p \leq 0.01$) genotypic and phenotypic associations with days to 50% flowering, days to maturity, primary branches per plant, total pods per plant, mature pods per plant, pod length, 100-seed weight, dry pod yield per hectare and oil content. Secondary branches per plant exhibited positive and significant phenotypic association with grain yield at this location (Table 2). At Kamashi, it showed positive and highly significant ($p \leq 0.01$) genotypic and phenotypic associations with days to 50% flowering, days to maturity, primary branches per plant, total pods per plant, 100-seed weight, shelling percentage, dry pod yield per hectare and oil content. Pod length exhibited positive and significant ($p \leq 0.05$) phenotypic association with grain yield per hectare while, plant height showed negative and significant genotypic and phenotypic associations with the trait at the location (Table 3).

After pooled analysis number of primary branches per plant, total pods per plant, mature pods per plant, pod length, 100-seed weight, dry pod yield per hectare and oil content showed positive and highly significant correlation with grain yield both at genotypic and phenotypic level. Days to 50% flowering and days to maturity showed positive at genotypic and negative at phenotypic correlation with grain yield. Secondary branches per plant exhibited positive genotypic association, while plant height and shelling percentage showed positive and highly significant phenotypic correlation with grain yield after combined analysis in this experiment (Table 4).

Generally, in those characters in which grain yield showed positive and significant to highly significant association with other trait, there were component interactions in which a gene conditioning an increase in one character will also influence another character provided when other conditions are kept constant. Positive and highly significant association of days to maturity, pods per plant and pod length with grain yield per hectare obtained in the study indicated, genotype with long maturity date, high number of pods per plants, and elongated pod produce high grain yield per hectare. These results clearly indicated that indirect selection for grain yield in groundnut can be based on these traits. In groundnut breeding programs aimed at improvement of grain yield per hectare, the characters, pods per plant, number of primary branches per plant, pod length, dry pod yield and 100-seed weight should be given more weight in the selection process. These is in agreement with Fikre *et al.* (2012) finding who reported positive and significant association of grain yield with dry pod yield per hectare, total pods per plant, mature pods per plant, 100-seed weigh, number of primary branches per plant, number of secondary branches and oil content. Such positive and significant interrelationship had been also reported earlier in groundnut by Babariya and Dobariya (2012) for days to maturity, plant height, number of pods per plant, kernel yield per plant, mature pods per plant and 100-kernel weight with pod yield per plant, at both genotypic and phenotypic levels and by Kadam *et al*. (2016) for mature pods per plant. Ashish *et al*. (2015) also reported positive and highly significant correlation of kernel yield per hectare with days to 50% flowering, days to maturity, shelling percentage, 100-kernel weight and dry pod yield per hectare and negative significant association with late leaf spot.

Early and late leaf spot correlated strongly and negatively with grain yield per hectare both at genotypic and phenotypic level for individual location and as well for combined of the two locations. These indicated biotic stresses like early and late leaf spot reduce grain yield and selection of genotypes with lower severity is effective. Similar kind of finding was reported by Kahate *et al*. (2014) for late leaf spot disease severity.

3.1.1.2 Correlation among yield related trait

At Assosa, days to 50% flowering showed positive and highly significant genotypic and phenotypic correlation with days to maturity, primary branches per plant, secondary branches per plant, total pods per plant, mature pods per plant, pod length and 100-seed weight (Table 2). Except, number of mature pods per plant, the above trait also showed positive and highly significant genotypic and phenotypic correlation with days to 50% flowering at Kamashi (Table 3). The correlation coefficient analysis also revealed that, days to maturity exhibited positive and highly significant phenotypic and genotypic association with primary and secondary branches per plant, total pods per plant, Pod length and 100-seed weight at both locations. Mature pods per plant showed positive and highly significant phenotypic and genotypic association with days to maturity at Assosa.

In this study data of plant height recorded on plant bases revealed negative and significant to highly significant genotypic and phenotypic association with days to 50% flowering, days to maturity, primary branches per plant, total pods per plant, mature pods per plant and oil content at Assosa (Table 2). At Kamashi, it showed negative and significant to highly significant genotypic and phenotypic association with days to 50% flowering, days to maturity and total pods per plant (Table 3). The analysis of correlation study also revealed that, primary branches per plant showed positive and significant to highly significant genotypic and phenotypic association with secondary branches per plant, total pods per plant, mature pods per plant, pod length and 100-seed weight at Assosa. At Kamashi, it was correlated positively and significant to highly significantly with total pods per plant, pod length and 100-seed weight both at genotypic and phenotypic association. Number of secondary branches per plant exhibited positive and significant to highly significant genotypic and phenotypic association with total pods per plant, mature pods per plant, pod length and 100-seed weight at Assosa. It was correlated positively and significantly with 100-seed weight both at genotypic and phenotypic association at Kamashi.

Number of total pods per plant showed positive and highly significant genotypic and phenotypic correlation with mature pods per plant and 100-seed weight at Assosa. It correlated positively and highly significantly at phenotypic level with pod length at Assosa. At Kamashi total pods per plant showed positive and significant to highly significant genotypic and phenotypic correlation with pod length and 100-seed weight, while mature pods per plant exhibited positive and highly significant phenotypic association. Dry pod yield per hectare exhibited positive and highly significant genotypic and phenotypic correlation with days to 50% flowering, days to maturity, primary branches per plant, number of total pods per plant, pod length and 100-seed weight at both locations. Secondary branches per plant and mature pods per plant showed positive and highly significant phenotypic and genotypic association with dry pod yield per hectare at Assosa, while shelling percentage exhibited positive and highly significant phenotypic association with dry pod yield per hectare at Kamashi.

From this experiment oil content (%) showed positive and significant to highly significant genotypic and phenotypic association with primary branches per plant, total pods and mature pods per plant, 100-seed weight, dry pod yield and grain yield per hectare at Assosa. It showed positive and highly significant phenotypic correlation with days to 50% flowering and days to maturity. Negative and significant to highly significant genotypic and phenotypic association with plant height, early and late leaf spot were also observed for this trait at this location (Table 2). At Kamashi it showed positive and significant to highly significant genotypic and phenotypic association with days to maturity, total pods per plant, shelling percentage, dry pod yield and grain yield per hectare. It also exhibited positive and significant phenotypic association with mature pods per plant. It also had negative and significant to highly significant genotypic and phenotypic association with early and late leaf spot and negative phenotypic association with plant height at this location (Table 3).

Table 2 Genotypic (r_g) (above the diagonal) and phenotypic (r_p) (below the diagonal) correlation coefficient of the 15 traits in 25 groundnut genotypes tested at Assosa.

Trait	DF	DM	PH	PB	SB	TPPP	MPPP	PL	100SW	SH	PYLD	GYLD	ELS	LLS	OC
DF	**1.00**	0.71^{**}	-0.34^{ns}	0.41^{*}	0.54^{**}	0.49^{*}	0.49^{**}	0.51^{**}	0.61^{**}	-0.26	0.49^{*}	0.45^{*}	-0.44^{*}	-0.42^{*}	0.39^{ns}
DM	0.60^{**}	**1.00**	-0.42^{*}	0.58^{**}	0.53^{**}	0.63^{**}	0.65^{**}	0.50^{*}	0.71^{**}	-0.11^{ns}	0.65^{**}	0.62^{**}	-0.60^{**}	-0.56^{**}	0.71^{**}
PH	-0.23^{*}	-0.31^{**}	**1.00**	-0.35^{ns}	-0.07^{ns}	-0.57^{**}	-0.62^{**}	0.18^{ns}	-0.19^{ns}	0.21^{ns}	-0.30^{ns}	-0.28^{ns}	0.13^{ns}	0.22^{ns}	-0.67^{**}
PB	0.35^{**}	0.40^{**}	-0.27^{*}	**1.00**	0.46^{*}	0.83^{**}	0.82^{**}	0.52^{**}	0.82^{**}	-0.06^{ns}	0.90^{**}	0.90^{**}	-0.71^{**}	-0.60^{**}	0.59^{**}
SB	0.37^{**}	0.35^{**}	0.00^{ns}	0.31^{**}	**1.00**	0.42^{*}	0.42^{*}	0.57^{**}	0.60^{**}	-0.15^{ns}	0.42^{*}	0.38^{ns}	-0.47^{*}	-0.29^{ns}	0.36^{ns}
TPPP	0.36^{**}	0.47^{**}	-0.35^{**}	0.60^{**}	0.30^{**}	**1.00**	0.98^{**}	0.39^{ns}	0.74^{**}	-0.26^{ns}	0.88^{**}	0.86^{**}	-0.63^{**}	-0.55^{**}	0.74^{**}
MPPP	0.35^{**}	0.47^{**}	-0.39^{**}	0.59^{**}	0.33^{**}	0.97^{**}	**1.00**	0.36^{ns}	0.72^{**}	-0.31^{ns}	0.85^{**}	0.82^{**}	-0.61^{**}	-0.52^{**}	0.75^{**}
PL	0.36^{**}	0.47^{**}	0.19^{ns}	0.30^{**}	0.45^{**}	0.39^{**}	0.40^{**}	**1.00**	0.64^{**}	-0.37^{ns}	0.60^{ns}	0.55^{ns}	-0.74^{ns}	-0.41^{ns}	0.18^{ns}
SW	0.52^{**}	0.58^{**}	-0.15^{ns}	0.73^{**}	0.49^{**}	0.56^{**}	0.56^{**}	0.51^{**}	**1.00**	-0.07^{ns}	0.86^{**}	0.84^{**}	-0.74^{**}	-0.58^{*}	0.63^{ns}
SH	-0.16^{ns}	-0.04^{ns}	0.14^{ns}	-0.02^{ns}	-0.07^{ns}	-0.17^{ns}	-0.22^{ns}	-0.29^{*}	-0.06^{ns}	**1.00**	-0.10^{ns}	0.00^{ns}	0.21^{ns}	-0.16^{ns}	0.05^{ns}
PYLD	0.43^{**}	0.58^{**}	-0.22^{ns}	0.75^{**}	0.32^{**}	0.67^{**}	0.66^{**}	0.47^{**}	0.73^{**}	-0.03^{ns}	**1.00**	0.99^{**}	-0.77^{**}	-0.61^{**}	0.61^{**}
GYLD	0.40^{**}	0.56^{**}	-0.21^{ns}	0.75^{**}	0.29^{*}	0.66^{**}	0.64^{**}	0.44^{**}	0.71^{**}	0.07^{ns}	0.99^{**}	**1.00**	-0.74^{**}	-0.62^{**}	0.61^{**}
ELS	-0.29^{*}	-0.33^{**}	0.06^{ns}	-0.49^{**}	-0.39^{**}	-0.41^{**}	-0.45^{**}	-0.53^{**}	-0.57^{**}	0.19^{ns}	-0.52^{**}	-0.50^{**}	**1.00**	0.49^{*}	-0.47^{*}
LLS	-0.28^{*}	-0.44^{**}	0.19^{ns}	-0.44^{**}	-0.11^{ns}	-0.39^{**}	-0.36^{**}	-0.30^{**}	-0.39^{**}	-0.11^{ns}	-0.46^{**}	-0.46^{**}	0.26^{*}	**1.00**	-0.58^{**}
OC	0.35^{**}	0.61^{**}	-0.54^{**}	0.49^{**}	0.29^{*}	0.61^{**}	0.62^{**}	0.19^{ns}	0.59^{**}	0.05^{ns}	0.55^{**}	0.54^{**}	-0.34^{**}	-0.40^{**}	**1.00**

Where: - **, *, and ns = highly significant, significant and non-significant at 1%, 5% and at P> 0.05 respectively. DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, PB = Primary branches per plant, SB = Secondary branches per plant, TPPP =Total Pods per plant, MPPP = Mature pods per plant, PL = Pod length, 100SW = Hundred seed Weight, SH% = Shelling percentage, PYLD = Dry pod yield (kg/ha),GYLD = grain yield (kg/ha), OC = Oil content (%), ELS = Early leaf spot and LLS =Late leaf spot.

Table 3 Genotypic (r_g) (above the diagonal) and phenotypic (r_p) (below the diagonal) correlation coefficient of the 15 traits in 25 groundnut genotypes grown at Kamashi.

Trait	DF	DM	PH	PB	SB	TPPP	MPPP	PL	SW	SH	PYLD	GYLD	ELS	LLS	OC
DF	**1.00**	0.67^{**}	-0.40^{*}	0.72^{**}	0.51^{**}	0.63^{**}	0.02^{ns}	0.49^{*}	0.62^{**}	-0.09^{ns}	0.64^{**}	0.59^{**}	-0.60^{**}	-0.35^{ns}	0.24^{ns}
DM	0.55^{**}	**1.00**	-0.33^{ns}	0.65^{**}	0.48^{*}	0.77^{**}	0.10^{ns}	0.58^{**}	0.84^{**}	0.04^{ns}	0.82^{**}	0.77^{**}	-0.78^{**}	-0.69^{**}	0.46^{*}
PH	-0.30^{**}	-0.26^{*}	**1.00**	-0.21^{ns}	-0.04^{ns}	-0.45^{*}	-0.30^{ns}	0.18^{ns}	-0.19^{ns}	-0.35^{ns}	-0.38^{ns}	-0.43^{*}	0.35^{ns}	0.22^{ns}	-0.52^{**}
PB	0.53^{**}	0.56^{**}	-0.21^{ns}	**1.00**	0.26^{ns}	0.41^{*}	-0.04^{ns}	0.46^{*}	0.60^{**}	-0.07^{ns}	0.62^{**}	0.56^{**}	-0.52^{**}	-0.62^{**}	0.21^{ns}
SB	0.30^{**}	0.32^{**}	-0.0004	0.22^{ns}	**1.00**	0.31^{ns}	-0.19^{ns}	0.25^{ns}	0.44^{*}	-0.03^{ns}	0.33^{ns}	0.29^{ns}	-0.44^{*}	-0.25^{ns}	0.02^{ns}
TPPP	0.44^{**}	0.65^{**}	-0.33^{**}	0.38^{**}	0.15^{ns}	**1.00**	0.37^{ns}	0.40^{*}	0.66^{**}	0.23^{ns}	0.86^{**}	0.86^{**}	-0.75^{**}	-0.60^{**}	0.60^{**}
MPPP	-0.03^{ns}	0.12^{ns}	-0.20^{**}	-0.04^{ns}	-0.14^{ns}	0.39^{**}	**1.00**	-0.13^{ns}	-0.14^{ns}	0.46^{ns}	0.19^{ns}	0.29^{ns}	0.03^{ns}	-0.30^{ns}	0.35^{ns}
PL	0.31^{**}	0.46^{**}	0.08^{ns}	0.41^{**}	0.13^{ns}	0.32^{**}	-0.02^{ns}	**1.00**	0.74^{**}	-0.37^{ns}	0.41^{*}	0.31^{ns}	-0.47^{*}	-0.20^{ns}	-0.08^{ns}
SW	0.47^{**}	0.76^{**}	-0.16^{ns}	0.53^{**}	0.29^{*}	0.55^{**}	-0.14^{ns}	0.63^{**}	**1.00**	-0.09^{ns}	0.76^{**}	0.70^{**}	-0.81^{**}	-0.50^{*}	0.28^{ns}
SH	-0.09^{ns}	0.07^{ns}	-0.23^{ns}	-0.04^{ns}	-0.02^{ns}	0.14^{ns}	0.25^{*}	-0.27^{*}	-0.04^{ns}	**1.00**	0.25^{ns}	0.43^{*}	-0.20^{ns}	-0.33^{ns}	0.61^{**}
PYLD	0.49^{**}	0.73^{**}	-0.27^{*}	0.50^{**}	0.18^{ns}	0.75^{**}	0.15^{ns}	0.32^{**}	0.70^{**}	0.20^{ns}	**1.00**	0.98^{**}	-0.76^{**}	-0.67^{**}	0.53^{**}
GYLD	0.44^{**}	0.70^{**}	-0.31^{**}	0.45^{**}	0.16^{ns}	0.74^{**}	0.21^{ns}	0.25^{*}	0.65^{**}	0.42^{**}	0.97^{**}	**1.00**	-0.76^{**}	-0.68^{**}	0.62^{**}
ELS	-0.48^{**}	-0.60^{**}	0.28^{*}	-0.36^{**}	-0.20^{ns}	-0.53^{**}	0.00^{ns}	-0.39^{**}	-0.55^{**}	-0.12^{ns}	-0.51^{**}	-0.51^{**}	**1.00**	0.57^{**}	-0.53^{**}
LLS	-0.29^{*}	-0.54^{**}	0.08^{ns}	-0.43^{**}	-0.13^{ns}	-0.43^{**}	-0.16^{ns}	-0.06^{ns}	-0.34^{**}	-0.20^{ns}	-0.46^{**}	-0.47^{**}	0.25^{*}	**1.00**	-0.55^{**}
OC	0.13^{ns}	0.38^{**}	-0.36^{**}	0.09^{ns}	0.00^{ns}	0.42^{**}	0.24^{*}	-0.07^{ns}	0.14^{ns}	0.42^{**}	0.39^{**}	0.46^{**}	-0.36^{**}	-0.35^{**}	**1.00**

Where: - **, *, and ns = highly significant, significant and non-significant at 1%, 5% and at P> 0.05 respectively. DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, PB = Primary branches per plant, SB = Secondary branches per plant, TPPP =Total Pods per plant, MPPP = Mature pods per plant, PL = Pod length, 100SW = Hundred seed Weight, SH% = Shelling percentage, PYLD = Dry pod yield (kg/ha),GYLD = grain yield (kg/ha), OC = Oil content (%), ELS = Early leaf spot and LLS =Late leaf spot.

After pooled analysis grain yield had positive and significant to highly significant phenotypic and genotypic correlation with primary branches per plant, total pods per plant, mature pods per plant, pod length, 100-seed weight, dry pod yield and oil content. Days to 50% flowering and days to maturity showed positive at genotypic, negative at phenotypic and highly significant correlation with grain yield. Secondary branches per plant exhibited positive and significant phenotypic association with grain yield per hectare. Whereas, plant height and shelling percentage showed positive and highly significant genotypic association with grain yield per hectare after combined analysis. Positive association of pod yield with number of primary branches per plant, number of mature pods per plant and 100-seed weight was reported earlier by Vasanthi *et al*. (2015). Ashish *et al*. (2015) also reported highly significant and positive correlation of kernel yield per hectare with days to 50% flowering, days to maturity, shelling percentage, 100-kernel weight and dry pod yield per hectare and negative phenotypic and genotypic correlation with early and late leaf spot (Table 4).

Generally, in those characters in which grain yield showed positive and significant to highly significant correlation with other traits, there were component interactions in which a gene conditioning an increase in one character will also influence another character provided when other conditions are kept constant. These results clearly indicated that indirect selection for grain yield in groundnut can be based on primary branches per plant, pods per plant, pod length, 100-seed weight and dry pod yield per hectare. Therefore, in groundnut breeding programs aimed at improvement of grain yield per hectare, weight should be given for number of primary branches per plant, pods per plant, pod length, 100-seed weight and dry pod yield per hectare. This is in agreement with Kamdi *et al*. (2015) investigation that, days to 50% flowering and days to maturity correlated positively with plant height and primary branches per plant. Sanjeevakumar *et al*. (2015) also reported positive and highly significant association of days to flowering with primary branches per plant, secondary branches per plant and negative and significant association with plant height and shelling percentage. The authors also reported positive and highly significant association of days to maturity with 100-kernel weight and negative and significant association with mature pods per plant.

Table 4 Genotypic (r_g) (above the diagonal) and phenotypic (r_p) (below the diagonal) correlation coefficient of the 15 traits in 25 groundnut genotypes combined of the two locations, Assosa and Kamashi.

Trait	DF	DM	PH	PB	SB	TPPP	MPPP	PL	SW	SH	PYLD	GYLD	ELS	LLS	OC
DF	**1.00**	0.73^{**}	-0.40^{*}	0.69^{**}	0.64^{**}	0.60^{**}	0.39^{*}	0.52^{**}	0.65^{**}	-0.17^{ns}	0.60^{**}	0.55^{**}	-0.51^{**}	-0.41^{**}	0.29
DM	0.84^{ns}	**1.00**	-0.44^{*}	0.77^{**}	0.59^{**}	0.77^{**}	0.50^{*}	0.59^{**}	0.84^{**}	0.01^{ns}	0.81^{**}	0.78^{**}	-0.74^{**}	-0.65^{**}	0.64^{**}
PH	-0.64^{ns}	-0.61^{ns}	**1.00**	-0.35^{ns}	-0.13^{ns}	-0.56^{**}	-0.64^{**}	0.17^{ns}	-0.23^{ns}	-0.09^{ns}	-0.41^{*}	-0.43^{*}	0.26^{ns}	0.23^{ns}	-0.66^{**}
PB	0.05^{ns}	0.18^{ns}	-0.08^{ns}	**1.00**	0.46^{ns}	0.74^{**}	0.49^{*}	0.53^{**}	0.81^{**}	0.01^{ns}	0.84^{**}	0.81^{**}	-0.75^{**}	-0.75^{**}	0.50^{*}
SB	0.31^{ns}	0.35^{ns}	-0.11^{ns}	0.24^{**}	**1.00**	0.51^{**}	0.20^{ns}	0.50^{*}	0.65^{**}	-0.12^{ns}	0.50^{*}	0.45^{*}	-0.54^{**}	-0.29^{**}	0.31^{ns}
TPPP	-0.63^{ns}	-0.41^{ns}	0.39^{ns}	0.39^{**}	-0.01^{ns}	**1.00**	0.74^{**}	0.41^{*}	0.79^{**}	0.11^{ns}	0.90^{**}	0.90^{**}	-0.76^{**}	-0.64^{**}	0.74^{**}
MPPP	-0.61^{ns}	-0.43^{ns}	0.37^{ns}	0.28^{**}	-0.06^{ns}	0.86^{**}	**1.00**	-0.01	0.41^{**}	0.30^{ns}	0.59^{**}	0.63^{**}	-0.33^{ns}	-0.53^{**}	0.72^{**}
PL	-0.18^{ns}	0.01^{ns}	0.33^{ns}	0.38^{**}	0.23^{**}	0.48^{**}	0.38^{**}	**1.00**	0.72^{**}	-0.35^{*}	0.52^{**}	0.43^{*}	-0.63^{ns}	-0.33^{**}	0.04^{ns}
SW	0.05^{ns}	0.26^{ns}	0.02^{ns}	0.65^{**}	0.37^{**}	0.47^{**}	0.28^{**}	0.59^{**}	**1.00**	-0.04^{ns}	0.89^{**}	0.84^{**}	-0.84^{ns}	-0.60^{ns}	0.48^{**}
SH	-0.37^{ns}	-0.27^{ns}	0.18^{ns}	0.02^{ns}	-0.10^{ns}	0.30^{**}	0.31^{**}	-0.11^{ns}	0.03^{ns}	**1.00**	0.16^{ns}	0.31^{ns}	0.01^{ns}	-0.27^{ns}	0.42^{*}
PYLD	-0.53^{**}	-0.28^{**}	0.36^{**}	0.51^{**}	0.04^{ns}	0.89^{**}	0.73^{**}	0.51^{**}	0.61^{**}	0.33^{**}	**1.00**	0.99^{**}	-0.81^{**}	-0.70^{**}	0.61^{**}
GYLD	-0.56^{**}	-0.32^{ns}	0.36^{**}	0.48^{**}	0.01^{ns}	0.89^{**}	0.74^{**}	0.47^{**}	0.57^{**}	0.44^{**}	0.99^{**}	**1.00**	-0.78^{**}	-0.71^{**}	0.67^{**}
ELS	-0.08^{ns}	-0.22^{**}	0.10^{ns}	-0.43^{**}	-0.28^{**}	-0.33^{**}	-0.18^{**}	-0.45^{**}	-0.56^{**}	-0.01^{ns}	-0.40^{**}	-0.38^{**}	**1.00**	0.54^{ns}	-0.53^{**}
LLS	-0.03^{ns}	-0.23^{ns}	0.03^{ns}	-0.44^{**}	-0.10^{ns}	-0.32^{**}	-0.23^{**}	-0.20^{*}	-0.38^{**}	-0.18^{*}	-0.38^{**}	-0.38^{**}	0.26^{**}	**1.00**	-0.60^{**}
OC	-0.60^{ns}	-0.36^{ns}	0.30^{ns}	0.31^{**}	-0.02^{ns}	0.82^{**}	0.77^{**}	0.32^{**}	0.40^{**}	0.42^{**}	0.78^{**}	0.79^{**}	-0.28^{**}	-0.31^{**}	**1.00**

Where: - **, *, and ns = highly significant, significant and non-significant at 1%, 5% and at P> 0.05 respectively. DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, PB = Primary branches per plant, SB = Secondary branches per plant, TPPP =Total Pods per plant, MPPP = Mature pods per plant, PL = Pod length, 100SW = Hundred seed Weight, SH% = Shelling percentage, PYLD = Dry pod yield (kg/ha),GYLD = grain yield (kg/ha), OC = Oil content (%), ELS = Early leaf spot and LLS =Late leaf spot.

3.1.2 Path Coefficient Analysis

Association of traits determined by correlation coefficient analysis may not provide an exact picture of the relative importance of direct and indirect influence of each of yield components on grain yield. To determine the interrelationship between grain yield and other yield attributes, direct and indirect effects were further analyzed by path coefficient analysis. The information obtained by this technique helps in indirect selection for genetic improvement of yield and measures the relative importance of each trait. In this experiment, ten traits were selected as casual (independent) variable and both genotypic and phenotypic correlations were partitioned into direct and indirect effects using grain yield as a dependent variable. The phenotypic and genotypic direct and indirect effects of considered traits on grain yield are presented in Tables 5 to 10 for Assosa, Kamashi and combined of the two locations below.

3.1.2.1 Phenotypic direct and indirect effects of various traits on grain yield

Phenotypic path coefficient analysis revealed that, dry pod yield per hectare that had positive and strong correlation coefficient (r_{ph}= 0.99) with grain yield per hectare also exerted the highest direct effect (1.019) on grain yield at Assosa (Table 5). Primary branches per plant (0.004), hundred seed weight (0.003), early leaf spot (0.011) and oil content (0.004) had positive direct effect on grain yield per hectare. Except early leaf spot (r_{ph} = -0.52) the other three traits namely, primary branches per plant (r_{ph}= 0.75), hundred seed weight (r_{ph} = 0.71) and oil content (r_{ph} = 0.55) had positive and highly significant phenotypic correlation with grain yield at Assosa. The indirect effects via dry pod yield per hectare were high and positive for primary branches per plant, 100-seed weight and oil content. Negative direct effect were exhibited by pod length (-0.033), days to 50% flowering (-0.029), late leaf spot (-0.022), total pods per plant (-0.015) and days to maturity (-0.00004). Except late leaf spot (r_{ph} = -0.45) the rest four traits showed positive and highly significant correlation with grain yield. The indirect effects via dry pod yield were positive and high for pods per plant, pod length, days to 50% flowering and days to maturity. Late leaf spot had negative indirect effect through dry pod yield per hectare. The positive direct effect that primary branches per plant and 100-seed weight exerted on grain yield were negligible and these traits contributed to grain yield indirectly through dry pod yield per hectare. The negative direct effects that pods per plant and days to maturity exerted on grain yield were insufficient. The phenotypic correlation they had with grain yield was positive and highly significant and contributed to grain yield indirectly through dry pod yield per hectare. Hence, these characters namely dry pod yield per hectare, primary branches, pods per plant and 100-seed weight could be considered in the improvement of grain yield (Table 5).

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Table 5 Estimates of direct (bold face) and indirect effect (off diagonal) at phenotypic level of 10 traits on seed yield in 25 groundnut genotypes tested at Assosa.

Trait	DF	DM	PB	TPPP	PL	SW	PYLD	ELS	LLS	OC	r_{ph}
DF	**-0.029**	-0.00002	0.002	-0.006	-0.012	0.002	0.438	-0.003	0.006	0.001	**0.39****
DM	-0.017	**-0.00004**	0.002	-0.007	-0.015	0.002	0.589	-0.004	0.010	0.002	**0.56****
PB	-0.010	-0.00002	**0.004**	-0.009	-0.010	0.002	0.765	-0.005	0.010	0.002	**0.75****
TPPP	-0.011	-0.00002	0.003	**-0.015**	-0.013	0.002	0.687	-0.004	0.009	0.002	**0.66****
PL	-0.011	-0.00002	0.001	-0.006	**-0.033**	0.002	0.482	-0.006	0.007	0.001	**0.44****
SW	-0.015	-0.00002	0.003	-0.009	-0.017	**0.003**	0.740	-0.006	0.009	0.002	**0.71****
PYLD	-0.013	-0.00002	0.003	-0.010	-0.016	0.002	**1.019**	-0.006	0.010	0.002	**0.99****
ELS	0.009	0.00001	-0.002	0.006	0.017	-0.002	-0.533	**0.011**	-0.006	-0.001	**-0.50****
LLS	0.008	0.00002	-0.002	0.006	0.010	-0.001	-0.464	0.003	**-0.022**	-0.001	**-0.46****
OC	-0.010	-0.00002	0.002	-0.009	-0.006	0.002	0.557	-0.004	0.009	**0.004**	**0.54****

Residual = 0.013

Where: - **, *, and ns = highly significant, significant and non-significant at 1%, 5% and P>0.05 respectively. DF = Days to 50% flowering, DM = Days to maturity (days), PB = Primary branches per plant (no), TPPP = Total Pods per plant (no), PL = Pod length (cm), 100SW = Hundred seed Weight (g), PYLD = Dry pod yield (kg/ha), OC = Oil content (%), ELS = Early leaf spot (%) and LLS =Late leaf spot (%)

At Kamashi (Table 6),similar to Assosa dry pod yield per hectare (r_{ph} = 0.97)that had positive and highly significant phenotypic correlation coefficient with grain yield exerted the highest positive phenotypic direct effect (0.96) on grain yield per hectare followed by oil content (0.066), total pods per plant (0.017) and 100-seed weight (0.012). The phenotypic correlation coefficient that, the above traits had with grain yield per hectare were positive and highly significant. Pods per plant and 100-seed weight contributed to grain yield indirectly via dry pod yield per hectare. Direct negative effect on grain yield per hectare were observed for days to 50% flowering (-0.04), days to maturity (-0.03), primary branches per plant (-0.001), pod length (-0.058), early leaf spot (-0.04) and late leaf spot (-0.014).Except early and late leaf spot the above traits had positive and highly significant correlation with grain yield per hectare. The negative direct effect exerted on grain yield by those traits and positive phenotypic correlation they had were mainly due to the favorable indirect counter balance via dry pod yield per hectare. The observed negative direct effect of days to flowering, days to maturity and pod length suggested that selection on the basis of these traits might not be effective.

Table 6 Estimates of direct (bold face) and indirect effect (off diagonal) at phenotypic level of 10 traits on grain yield in 25 groundnut genotypes tested at Kamashi.

Trait	DF	DM	PB	TPPP	PL	SW	PYLD	ELS	LLS	OC	r_{ph}
DF	**-0.040**	-0.017	-0.001	0.008	-0.018	0.006	0.468	0.019	0.004	0.009	**0.44****
DM	-0.022	**-0.030**	-0.001	0.011	-0.027	0.009	0.703	0.024	0.008	0.025	**0.70****
PB	-0.021	-0.017	**-0.001**	0.007	-0.024	0.006	0.478	0.014	0.006	0.006	**0.45***
TPPP	-0.018	-0.020	0.000	**0.017**	-0.019	0.007	0.717	0.021	0.006	0.028	**0.74****
PL	-0.012	-0.014	0.000	0.006	**-0.058**	0.008	0.309	0.015	0.001	-0.005	**0.25***
SW	-0.019	-0.023	-0.001	0.010	-0.037	**0.012**	0.673	0.022	0.005	0.010	**0.65****
PYLD	-0.020	-0.022	0.000	0.013	-0.019	0.008	**0.960**	0.020	0.007	0.026	**0.97****
ELS	0.019	0.018	0.000	-0.009	0.023	-0.007	-0.487	**-0.040**	-0.004	-0.024	**-0.51****
LLS	0.012	0.016	0.000	-0.008	0.003	-0.004	-0.441	-0.010	**-0.014**	-0.023	**-0.47****
OC	-0.005	-0.011	0.000	0.007	0.004	0.002	0.373	0.014	0.005	**0.066**	**0.46****

Residual = 0.1040

Where: - **, *, and ns = highly significant, significant and non-significant at 1%, 5% and P>0.05 respectively. DF = Days to 50% flowering, DM = Days to maturity (days), PB = Primary branches per plant (no), TPPP = Total Pods per plant (no), PL = Pod length (cm), 100SW = Hundred seed Weight (g), PYLD = Dry pod yield (kg/ha), OC = Oil content (%), ELS = Early leaf spot (%) and LLS =Late leaf spot (%)

After combined over the two locations Assosa and Kamashi, dry pod yield per hectare (r_{ph} = 0.99) which had positive and highly significant phenotypic correlation coefficient with grain yield per hectare exerted the highest positive direct effect (0.968) (Table 7). The magnitude of the direct effect was equivalent to that of the phenotypic correlation coefficient. This justifies that the correlation explains the true relationship and direct selection through this trait will be effective. Oil content (0.028) and pods per plant (0.007) exhibited positive direct effect. On the other hand negative direct effect were exhibited on grain yield by days to 50% flowering (-0.029), days to maturity (-0.007), primary branches per plant (-0.023), pod length (-0.04), hundred seed weight (-0.007), early leaf spot (-0.02) and late leaf spot (-0.017), but negligible. Positive indirect effects via dry pod yield per hectare were high for pods per plant, 100-seed weight and oil content. Early and late leaf spot showed negative indirectly effect through dry pod yield per hectare on grain yield.

The result is in agreement with earlier report of Sanjeevakumar *et al.* (2015) in which 100-kernal weight, oil content and numbers of primary branches per plant were found to have positive direct effect on pod yield. Vasanthi *et al.* (2015) also reported positive significant direct effect on pod yield by 100-seed weight and primary branches per plant. Similar result also reported by Rathod *et al.* (2015) for late leaf spot severity

Table 7 Estimates of direct (bold face) and indirect effect (off diagonal) at phenotypic level of 10 traits on grain yield in 25 groundnut genotypes of combined of Assosa and Kamashi

Trait	DF	DM	PB	TPPP	PL	SW	PYLD	ELS	LLS	OC	r_{ph}
DF	**-0.029**	-0.006	-0.001	-0.004	0.007	0.000	-0.513	0.002	0.001	-0.017	**-0.56****
DM	-0.025	**-0.007**	-0.004	-0.003	-0.001	-0.002	-0.276	0.004	0.004	-0.010	**-0.32****
PB	-0.001	-0.001	**-0.023**	0.003	-0.015	-0.005	0.497	0.008	0.008	0.009	**0.48****
TPPP	0.018	0.003	-0.009	**0.007**	-0.020	-0.003	0.858	0.007	0.005	0.023	**0.89****
PL	0.005	0.000	-0.009	0.003	**-0.040**	-0.004	0.497	0.009	0.003	0.009	**0.47****
SW	-0.001	-0.002	-0.015	0.003	-0.024	**-0.007**	0.590	0.011	0.006	0.011	**0.57****
PYLD	0.016	0.002	-0.012	0.006	-0.021	-0.004	**0.968**	0.008	0.006	0.022	**0.99****
ELS	0.002	0.002	0.010	-0.002	0.018	0.004	-0.384	**-0.020**	-0.004	-0.008	**-0.38****
LLS	0.001	0.002	0.010	-0.002	0.008	0.003	-0.366	-0.005	**-0.017**	-0.009	**-0.38****
OC	0.018	0.003	-0.007	0.005	-0.013	-0.003	0.753	0.006	0.005	**0.028**	**0.79****

Residual = 0.0155

Where: - **, *, and ns = highly significant, significant and non-significant at 1%, 5% and P>0.05 respectively. DF = Days to 50% flowering, DM = Days to maturity (days), PB = Primary branches per plant (no), TPPP = Total Pods per plant (no), PL = Pod length (cm), 100SW = Hundred seed Weight (g), PYLD = Dry pod yield (kg/ha), OIL = Oil content (%), ELS = Early leaf spot (%) and LLS =Late leaf spot (%)

3.2.1.2Genotypic direct and indirect effects of various traits on seed yield

At Assosa (Table 8), Genotypic path coefficient analysis showed that, dry pod yield per hectare exerted the highest positive genotypic direct effect (1.145) on grain yield per hectare. The genotypic correlation coefficient (r_g = 0.99) it had was positive and strong. Early leaf spot (0.017), primary branches per plant (0.015) and days to maturity (0.008) showed positive direct effect but negligible. Primary branches per plant and days to maturity had positive and highly significant genotypic correlation, while early leaf spot showed negative and highly significant genotypic correlation with grain yield per hectare. Days to 50% flowering, total pods per plant, pod length, hundred seed weight, late leaf spot and oil content showed negative direct effect on seed yield per hectare. The indirect positive effect via dry pod yield on grain yield per hectare were observed for days to maturity, primary branches per plant, total pods per plant, pod length, days to flowering and oil content. Early and late leaf spot showed negative indirect effect on seed yield via dry pod yield per hectare.

Table 8 Estimates of direct (bold face) and indirect effect (off diagonal) at genotypic level of 10 traits on grain yield in 25 groundnut genotypes tested at Assosa.

Trait	DF	DM	PB	TPPP	PL	SW	PYLD	ELS	LLS	OC	r_g
DF	**-0.018**	0.005	0.006	-0.061	-0.045	-0.002	0.562	-0.008	0.014	0.000	**0.45***
DM	-0.013	**0.008**	0.009	-0.079	-0.045	-0.002	0.739	-0.010	0.019	-0.001	**0.62****
PB	-0.007	0.004	**0.015**	-0.104	-0.047	-0.003	1.029	-0.012	0.020	-0.001	**0.90****
TPPP	-0.009	0.005	0.012	**-0.126**	-0.035	-0.002	1.011	-0.011	0.019	-0.001	**0.86****
PL	-0.009	0.004	0.008	-0.049	**-0.089**	-0.002	0.684	-0.012	0.014	0.000	**0.55****
SW	-0.011	0.005	0.012	-0.093	-0.058	**-0.003**	0.983	-0.012	0.019	-0.001	**0.84****
PYLD	-0.009	0.005	0.014	-0.111	-0.053	-0.003	**1.145**	-0.013	0.020	-0.001	**0.99****
ELS	0.008	-0.005	-0.011	0.079	0.066	0.002	-0.881	**0.017**	-0.017	0.001	**-0.74****
LLS	0.007	-0.004	-0.009	0.070	0.037	0.002	-0.695	0.008	**-0.034**	0.001	**-0.62****
OC	-0.007	0.005	0.009	-0.092	-0.016	-0.002	0.700	-0.008	0.020	**-0.001**	**0.61****

Residual = 0.0052

Where: - **, *, and ns = highly significant, significant and non-significant at 1%, 5% and P>0.05 respectively. DF = Days to 50% flowering, DM = Days to maturity (days), PB = Primary branches per plant (no), TPPP = Total Pods per plant (no), PL = Pod length (cm), 100SW = Hundred seed Weight (g), PYLD = Dry pod yield (kg/ha), OIL = Oil content (%), ELS = Early leaf spot (%) and LLS =Late leaf spot (%)

At Kamashi (Table 9),similar to Assosa, dry pod yield per hectare (1.006) exhibited the highest positive direct effect on seed yield per hectare followed by oil content (0.107) and days to 50% flowering (0.021). Negative direct effect were observed for days to maturity, primary branches per plant, total pods per plant, early and late leaf spot on seed yield per hectare. The highest positive indirect effects through dry pod yield per hectare were exhibited for total pods per plant and days to maturity followed by 100-seed weight, days to 50% flowering, primary branches per plant, pod length and oil content.

Table 9 Estimates of direct (bold face) and indirect effect (off diagonal) at genotypic level of 10 traits on grain yield in 25 groundnut genotypes tested at Kamashi.

Trait	DF	DM	PB	TPPP	PL	SW	PYLD	ELS	LLS	OC	r_g
DF	**0.021**	-0.054	-0.054	-0.019	-0.004	-0.036	0.647	0.038	0.021	0.026	**0.59****
DM	0.014	**-0.080**	-0.049	-0.023	-0.004	-0.049	0.825	0.050	0.041	0.049	**0.77****
PB	0.015	-0.052	**-0.076**	-0.012	-0.003	-0.035	0.628	0.033	0.036	0.023	**0.56****
TPPP	0.013	-0.061	-0.031	**-0.029**	-0.003	-0.039	0.863	0.048	0.035	0.064	**0.86****
PL	0.011	-0.046	-0.035	-0.012	**-0.007**	-0.043	0.411	0.030	0.012	-0.008	**0.31****
SW	0.013	-0.067	-0.046	-0.020	-0.005	**-0.058**	0.768	0.052	0.029	0.029	**0.70****
PYLD	0.014	-0.065	-0.047	-0.025	-0.003	-0.044	**1.006**	0.049	0.039	0.056	**0.98****
ELS	-0.013	0.062	0.040	0.022	0.003	0.047	-0.767	**-0.064**	-0.033	-0.057	**-0.76****
LLS	-0.007	0.055	0.047	0.018	0.001	0.029	-0.673	-0.036	**-0.058**	-0.059	**-0.68****
OC	0.005	-0.037	-0.016	-0.018	0.001	-0.016	0.532	0.034	0.032	**0.107**	**0.62****

Residual = 0.020

Where: - **, *, and ns = highly significant, significant and non-significant at 1%, 5% and P>0.05 respectively. DF = Days to 50% flowering, DM = Days to maturity (days), PB = Primary branches per plant (no), TPPP = Total Pods per plant (no), PL = Pod length (cm), 100SW = Hundred seed Weight (g), PYLD = Dry pod yield (kg/ha), OIL = Oil content (%), ELS = Early leaf spot (%) and LLS =Late leaf spot (%).

After pooled analysis dry pod yield per hectare exerted the highest direct effect on seed yield per hectare (Table 10). It had positive and strong correlation with seed yield. Oil content, days to 50% flowering and early leaf spot exerted positive direct effect on seed yield per hectare. The indirect effect via dry pod yield were positive and high for pods per plant, 100-seed weight, primary branches per plant, day to maturity, days to 50% flowering and pod length. The contribution of residual effects that influenced grain yield was very low at both genotypic and phenotypic levels for individual location and combined of the two locations, indicating that the characters included in the present investigation were sufficient enough to account for the variability in the dependant character i.e. grain yield per plant.

Negative direct effects were observed on seed yield per hectare by days to maturity, pods per plant, pod length, 100-seed weight and late leaf spot. Early and late leaf spot showed high negative indirect effect on seed yield via dry pod yield

Table 10 Estimates of direct (bold face) and indirect effect (off diagonal) at genotypic level of 10 traits on grain yield in 25 groundnut genotypes of combined over the two locations

Trait	DF	DM	PB	TPPP	PL	SW	PYLD	ELS	LLS	OC	r_g
DF	**0.032**	-0.074	-0.026	-0.067	-0.014	-0.018	0.675	-0.0002	0.004	0.043	**0.55****
DM	0.023	**-0.101**	-0.030	-0.086	-0.016	-0.023	0.909	-0.0003	0.007	0.095	**0.78****
PB	0.022	-0.078	**-0.038**	-0.083	-0.014	-0.022	0.943	-0.0003	0.008	0.074	**0.81****
TPPP	0.019	-0.077	-0.028	**-0.112**	-0.011	-0.022	1.013	-0.0003	0.007	0.110	**0.90****
PL	0.017	-0.060	-0.020	-0.047	**-0.027**	-0.020	0.580	-0.0003	0.003	0.006	**0.43****
SW	0.021	-0.085	-0.031	-0.089	-0.019	**-0.027**	0.998	-0.0004	0.006	0.071	**0.84****
PYLD	0.019	-0.082	-0.032	-0.101	-0.014	-0.024	**1.124**	-0.0003	0.007	0.090	**0.99****
ELS	-0.016	0.074	0.029	0.086	0.017	0.023	-0.910	**0.0004**	-0.005	-0.078	**-0.78****
LLS	-0.013	0.065	0.029	0.072	0.009	0.016	-0.785	0.0002	**-0.010**	-0.089	**-0.71****
OC	0.009	-0.065	-0.019	-0.083	-0.001	-0.013	0.685	-0.0002	0.006	**0.148**	**0.67****

Residual = 0.01306

Where: - **, *, and ns = highly significant, significant and non-significant at 1%, 5% and P>0.05 respectively. DF = Days to 50% flowering, DM = Days to maturity (days), PB = Primary branches per plant (no), TPPP = Total Pods per plant (no), PL = Pod length (cm), 100SW = Hundred seed Weight (g), PYLD = Dry pod yield (kg/ha), OC = Oil content (%), ELS = Early leaf spot (%) and LLS =Late leaf spot (%)

3.3 The Reaction of Groundnut Genotype against early and late leaf Spot

In the present study, early and late leaf spot disease symptoms were observed on leaves of plants from resistant to moderately resistant response. The disease level was dependent on genotype used and suitability of climatic condition during the growing season. The data regarding the reaction of various groundnut genotypes against early and late leaf spot disease were given in Appendix Table 1, 2 and 3 for Assosa, Kamashi and combined over the two locations, respectively.

The results revealed that genotypes showed significant variation for early and late leaf spot disease at individual location and combined of the two locations. Based on leaf spot disease severity scale, genotypes ICGV-95440 (26.3%), ICGV-01105 (25%), ICGV-01005 (24.5%), J11 (24.3%), ICGV-01014 (21%), ICGV-95492 (21%), ICGV-01080 (20.2%) and ICGV-93280 (19.2%) scored high early leaf spot disease severity value after combined analysis of the two locations, which implied moderate resistant of the genotypes. ICGV-01043 (17%) and ICGV-95469 (17.3%) genotypes showed the highest late leaf spot disease severity value which indicated moderate resistant of these genotypes in this study. The low early leaf spot disease severity value was scored by genotype ICGV-98371, ICGV-97150, ICGV-97153, ICGV-97156, ICGV-97157, ICGV-97163, ICGV-98370, and Maniputer, indicating resistance of these genotypes to early leaf spot.

In the present investigations, the genotypes showing resistance against early and late leaf spot disease can be utilized as a source of resistance for breeding disease resistant genotypes of groundnut. This study also revealed variation of considered genotypes against early and late leaf spot disease severity and negative association of both diseases with grain yield and most of yield related traits. These indicated biotic stresses like early and late leaf spot reduce grain yield and selection of genotypes with lower severity is effective.

4. SUMMARY AND CONCLUSIONS

Knowledge on the extent and pattern of genetic variability present in a population and interrelationship among characters are essential to design breeding strategies in crop improvement. To generate such information 25 groundnut genotypes including two released varieties (Maniputer and Roba) were tested in 5x5 triple lattice designs under rain fed condition at Assosa and Kamashi research field of Assosa Agricultural Research Center in Benishangul-Gumuz regional state, Western Ethiopia. Data were collected for 16 traits on plot base as well as plant bases and subjected to analysis of variance using SAS software proc lattice and GLM procedure for individual location and combined of the two locations. Pooled analysis was also carried out for characters whose error mean square was homogenous. Further genetic analyses were conducted as per the formula suggested by different biometricians. The correlation and path coefficient analysis indicated that, dry pod yield per hectare that showed positive and strong correlation with seed yield exercised the highest positive phenotypic and genotypic direct effect at both locations and combined over the two locations. The trait will be useful for direct selection to increase grain yield. Characters like dry pod yield per hectare, primary branches, total pods per plant and 100-seed weight correlated positively and significantly and exerted positive in direct effect via dry pod yield per hectare.

Therefore, the current study revealed the presence of considerable variability for most of all traits studied and differences in the performance of the genotypes as there were statistically significant differences among genotypes. These conditions indicated that there is good opportunity to improve these characters using the tested genotypes in groundnut breeding programs. Priority should be given for dry pod yield per hectare, primary branches per plant, total pods per plant and 100-seed weight in the improvement of grain yield in groundnut breeding programs.

5. REFERENCES

Ashish, J., Nadaf, H.L. and Gangadhara, K. 2015. Genetic variability and correlation for yield attributing traits of advanced generation recombinant inbred lines of groundnut (*Arachis hypogaea L.*). *International Journal of Genetic Engineering and Biotechnology,* 5 (2) 109 - 114

Assosa Agricultural Research Center (AsARC). 2011. Farming system survey document. *Assosa, Benishangul-Gumuze Regional State*, Ethiopia, unpublished.

Babariya, C. A. and Dobariya, K. L. 2012. Correlation coefficient and path coefficient analysis for yield components in groundnut (*Arachis hypogaea* L.) *Electronic Journal of Plant Breeding,* 3(3): 932-938.

CSA (Central Statistical Agency). 2015. The Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey, *Volume I Report on area and production of major Crops (Private Peasant Holdings, Meher Season)*, Addis Ababa, Ethiopia.

Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components of crested wheat-grass seed production. *Agronomy Journal*, 51:515-518.

Fikre Hagos, Habtamu Zeleke and Bulcha Woyossa. 2012. Genetic gain in yield and yield related traits of groundnut (*Arachis hypogea* L.) in Central Rift Valley of Ethiopia. *East African Journal of Sciences* 6 (2) 125-136

Kadam, V.K., Chavan B.H., Rajput H.J and Wakale M.B. 2016. Genetic Diversity in Summer Groundnut (*Arachis hypogea* Linn.). *International Research Journal of Multidisciplinary Studies Volume-II, Issue-I.* pp. 1-11.

Kahate, N.S., Toprope, V.N. and Gadakh, S.S. 2014. Correlation and path analysis for yield, morphology and biochemical traits in groundnut (*Arachis hypogea* L.) *Bioinfolet*, 11 (3B), 868–870.

Kamdi, S.R., Shubhangi Bhasme, P., Kadu, P.R., Karhale, S.S., Bhagat, G.J. and Neharkar, P.S. 2015. Study of genetic variability and correlations in local collections of valencia botenical types of groundnut, 33 (2): 1437-1440.

Sanjeevakumar, P., Shivanna, S., Irappa, B.M. and Shweta. 2015. Genetic Variability and Character Association Studies for Yield and Yield attributing Components. In: Groundnut (*Arachis hypogeae* L.). *International*

Journal of Recent Scientific Research.6 (6): 4568-4570.

Subrahmanyam, P.D., McDonald, F. Waliyar, L.J. Reddy, S.N. Nigam, R.W. Gibbons, V.R. Roa, A.K. Singh, S. Pande, P.M. Reddy and P.V. Rao, 1995. Screening methods and source of resistance to rust and late leaf spot of groundnut. *Information Bulletine no.47*. Patancheru 502 324, Andhra Pradesh, India: International Crop Research Institute for the Semi- Arid Tropics, pp. 24.

Vasanthi, R.P. Suneetha, N. and Sudhakar, P. 2015. Genetic variability and correlation studies for morphological, yield and yield attributes in groundnut (*Arachis hypogaea L.*) *Agricultural Research Communication Center*.38 (1): 9-15

Weber, C.R. and Moorthy, B.R. 1952. Heritable and non-heritable relationship and variability of oil content and agronomic characters in the F generations of soybean crosses. *Agronomy Journal*, 44: 202-209.

Wijnands, J.H.M., Biersteker, J. and Van Loo, E.N. 2009. Oilseed business opportunity in Ethiopia, *Oil Seed Research Report*, Addis Ababa, Ethiopia.

APPENDICES

Appendix Table 1 Mean performances of seed yield and yield related traits of 25 groundnut genotypes tested at Assosa

No	Genotype	DF	DM	PH	PBPP	SBPP	TPPP	MPPP	PL	SPP
1.	ICGV-95492	44.67^{d}	141.3^{egdfh}	32.3^{gdfce}	4.87^{feg}	1.93^{fhg}	10.267^{fheg}	7.33^{fgih}	1.983^{ih}	1.893
2.	ICGV-01005	46.33^{d}	139.3^{egfih}	39.2^{ba}	5.07^{fegd}	3.267^{bedc}	8.533^{fhg}	5.2^{i}	2.613^{bdac}	1.987
3.	ICGV-01014	48^{dc}	142.7^{egdfch}	36.13^{bc}	5.07^{fegd}	1.8^{hg}	7.33^{h}	5.733^{ih}	2.203^{gfeh}	1.987
4.	ICGV-01015	46.33^{d}	135^{ih}	40.73^{a}	5^{fegd}	2.2^{fheg}	9.533^{fheg}	6.6^{gih}	2.617^{bdac}	1.933
5.	ICGV-01043	45.33^{d}	135^{ih}	35.3^{bc}	5.33^{fcegd}	2.067^{fheg}	9.4f^{heg}	8^{fgeih}	2.413^{gfdec}	2.013
6.	ICGV-01080	46^{d}	137.67^{gfih}	33^{dfce}	4.8^{fg}	3.2^{fbedc}	13.8^{fbdecg}	10.8^{fgdech}	2.1567^{gfih}	1.933
7.	ICGV-01105	51.67^{ba}	139.3^{egfih}	29.3^{gifhe}	5.13^{fcegd}	2.73^{fbedcg}	9.933^{fheg}	8.267^{fgeih}	2.39^{gfdec}	1.973
8.	ICGV-01124	53.67^{ba}	155^{a}	30.267^{gdfhe}	5.27^{fcegd}	1.9333^{fhg}	14.667^{fbdec}	12.867^{bdec}	2.503^{dec}	1.947
9.	ICGV-93280	52.67^{ba}	142.7^{egdfch}	25.067^{ij}	6.67^{cebd}	1.6667^{hg}	13.4^{fhdecg}	$10.47^{fgdeich}$	1.9433^{ih}	1.9867
10.	ICGV-95440	44.67^{d}	136^{gih}	30.13^{gdfhe}	4.4667^{g}	1.8667^{hg}	9.667^{fheg}	8.083^{fgeih}	1.8633^{i}	1.9467
11.	ICGV-95460	45.33^{d}	139.3^{egfih}	33.2^{dce}	5^{fegd}	2.2^{fheg}	9.667^{fheg}	7.867^{fgeih}	2.2^{gfeh}	1.933
12.	ICGV-95469	50.67^{bc}	144.3^{edfc}	22.067^{j}	5.33^{fcegd}	2.33^{fhedg}	14^{fbdecg}	12.533^{fbdec}	2.17^{gfh}	1.8933
13.	ICGV-97281	45.33^{d}	135^{ih}	32.2^{gdfce}	4.53^{g}	1.3333^{h}	11.133^{fhdeg}	8.8^{fgdeih}	2.1033^{gih}	1.8666
14.	ICGV-97328	45^{d}	132.67^{i}	36.2^{bc}	6.4^{fcebd}	1.6667^{hg}	7.4h	5.933^{ih}	2.353^{gfde}	1.93
15.	J11	44.33^{d}	135.67^{ih}	28.53^{gih}	5.13^{fcegd}	1.73^{hg}	11.13^{fhdeg}	7.933^{fgeih}	2.147^{gfih}	1.93
16.	ICGV-98371	47^{dc}	147.67^{bdac}	27.93^{gih}	7.4^{b}	1.6^{hg}	17^{bdac}	13.867^{bdac}	2.41^{gfdec}	1.92
17.	ICGV-97150	52.67^{ba}	149.67^{bac}	26.6^{ih}	9.9333^{a}	3.73^{bac}	21.4^{a}	17.933^{a}	2.8733^{a}	2
18.	ICGV-97153	53.33^{ba}	147.3^{ebdac}	34.13^{dc}	5^{fegd}	2.47^{fhedcg}	10.067^{fheg}	7.2^{gih}	2.8467^{ba}	2
19.	ICGV-97156	47^{dc}	152.67^{ba}	27.3^{ih}	6.8^{cbd}	3.53^{bdc}	11.267^{fhdeg}	$9.867^{fgdeich}$	2.43^{fdec}	1.973
20.	ICGV-97157	53.67^{ba}	155.3^{a}	28.467^{gih}	6.67^{cebd}	3.6^{bdc}	15^{bdec}	11.4^{fgdec}	2.55^{bdc}	1.947
21.	ICGV-97163	54.67^{a}	149.7^{bac}	29.467^{gifhe}	6.93^{cb}	4.8667^{a}	15.1^{bdec}	13.6^{bdac}	2.6867^{bac}	1.893
22.	ICGV-98369	45.67^{d}	146.67^{ebdc}	26.3^{ih}	7.33^{b}	2.067^{fheg}	16.6^{bdac}	14.933^{bac}	2.423^{fdec}	2
23.	ICGV-98370	48^{dc}	144.3^{edfc}	28.6^{gifh}	8.13^{b}	2.067^{fheg}	18.467^{bac}	15^{bac}	2.593^{bdac}	1.9067
24.	Roba	46.33^{d}	144^{egdfc}	35^{bc}	5.13^{fcegd}	1.8^{hg}	8.333^{hg}	6.733^{gih}	2.403^{gfdec}	2.05333
25.	Maniputer	52.33^{ba}	154.3^{ba}	34.067^{dc}	9.8^{a}	3.9333^{ba}	19.667^{ba}	16.733^{ba}	2.63^{bdac}	1.987
	$(\overline{X})$	**48.43**	**143.3**	**31.3**	**6.05**	**2.46**	**12.51**	**10.15**	**2.38**	**1.95**
	R-Square (%)	**87**	**87**	**90**	**85**	**80**	**79**	**81**	**87**	**57**
	CV (%)	**4.18**	**2.95**	**7.38**	**15.3**	**27.56**	**24.8**	**26.4**	**6.81**	**3.33**

CONTNUED...

No	Genotype	100SW	SH %	PYLD	SYLD	ELS	LLS	OC
1.	ICGV-95492	33.367^{gih}	73.5^{bdac}	1055.6^{gef}	802.7^{ef}	21.667^{ba}	8^{ebdc}	43.4433^{gf}
2.	ICGV-01005	36.633^{gf}	70.3^{ebdc}	811.5^{gf}	588^{ef}	23.333^{ba}	9.67^{ebdc}	42.1667^{gih}
3.	ICGV-01014	40.567^{def}	77.833^{a}	931.9^{gef}	729.3^{ef}	20.33^{bac}	13^{ba}	42.9^{gfh}
4.	ICGV-01015	37.567^{gef}	68^{ed}	973^{gef}	682.8^{ef}	13.67^{ebdcf}	11.67^{bdac}	41.9767^{ih}
5.	ICGV-01043	33.8^{gih}	68.83^{edc}	1229.6^{dgef}	871.2^{efd}	13.67^{ebdcf}	17.667^{a}	42.3667^{gih}
6.	ICGV-01080	29.087^{i}	71.83^{ebdac}	900^{gef}	668.5^{ef}	21^{ba}	9^{ebdc}	43.8567^{fe}
7.	ICGV-01105	33.62^{gih}	70.67^{ebdc}	931.1^{gef}	678.2^{ef}	26.333^{a}	10^{ebdac}	43.3333^{gfh}
8.	ICGV-01124	45.333^{dc}	66.5^{e}	1355.9^{de}	927.8^{ecd}	20.33^{bac}	3.667^{ed}	47.31^{b}
9.	ICGV-93280	35.4^{gihf}	75.833^{ba}	1135.2^{gef}	885^{efd}	21.667^{ba}	4.667^{edc}	45.6667^{c}
10.	ICGV-95440	31.913^{gih}	73.17^{bdac}	800.7^{g}	606.8^{ef}	27^{a}	10.7^{ebdac}	45.13^{dce}
11.	ICGV-95460	32.8^{gih}	74.83^{bac}	814.1^{gf}	625.5^{ef}	19.67^{bdac}	10^{ebdac}	44.8^{dce}
12.	ICGV-95469	32.233^{gih}	60.667^{f}	840.4^{gf}	529^{f}	18^{ebdacf}	17.667^{a}	43.4433^{gf}
13.	ICGV-97281	34.85^{gihf}	73.7^{bdac}	988.5^{gef}	747.4^{ef}	19.3^{ebdac}	8.333^{ebdc}	44.1667^{dfe}
14.	ICGV-97328	33.133^{gih}	71.83^{ebdac}	833.3^{gf}	616.1^{ef}	18.3^{ebdacf}	4^{ed}	41.5^{i}
15.	J11	29.56^{ih}	72^{ebdac}	896.7^{gef}	665^{ef}	23.667^{ba}	11^{ebdac}	44.9^{dce}
16.	ICGV-98371	43.233^{de}	68.5^{ed}	1675.9^{dc}	1182^{bcd}	7.333^{edf}	3.333^{e}	47.4^{b}
17.	ICGV-97150	59.867^{a}	67.833^{ed}	2494.4^{a}	1743.5^{a}	6.667^{f}	3.3^{e}	47.61^{b}
18.	ICGV-97153	36.2^{ghf}	69.167^{edc}	1315.9^{def}	926.9^{ecd}	8^{edcf}	3.3^{e}	42.11^{gih}
19.	ICGV-97156	43.983^{dc}	73.17^{bdac}	1065.2^{gef}	767.3^{ef}	13.3^{ebdcf}	5.67^{ebdc}	47.8433^{ba}
20.	ICGV-97157	49.5^{bc}	75.667^{ba}	1688.5^{dc}	1259^{bc}	7^{ef}	4.67^{edc}	48.8867^{a}
21.	ICGV-97163	51.7^{b}	67.667^{ed}	1395.9^{de}	932.9^{ecd}	6^{f}	3.667^{ed}	47.51^{b}
22.	ICGV-98369	34.6^{gihf}	71.3^{ebdc}	1696.3^{dc}	1249^{bc}	13.3^{ebdcf}	3.333^{e}	47.0667^{b}
23.	ICGV-98370	54^{ba}	71.83^{ebdac}	1952.2^{bc}	1439.7^{ba}	7.333^{edf}	4ed	47.5^{b}
24.	Roba	29.067^{i}	72^{ebdac}	800.4^{g}	593.2^{ef}	17^{ebdacf}	12^{bac}	43.3^{gfh}
25.	Maniputer	58.033^{a}	72.67^{ebdac}	2348.1^{ba}	1733.5^{a}	7^{ef}	3.667^{ed}	45.28^{dc}
	($\overline{X}$)	**39.20**	**71.17**	**1237.2**	**898.02**	**16.04**	**7.84**	**44.85**
	R-Square (%)	**94**	**74**	**88.289**	**87.5**	**72.4**	**75.5**	**95.2**
	CV (%)	**8.7**	**4.39**	**20.8**	**21.16**	**39.8**	**51.29**	**1.621973**

Appendix Table 2 Mean performances of seed yield and yield related traits of 25 groundnut genotypes tested at Kamashi

No	Genotype	DF	DM	PH	PBPP	SBPP	TPPP	MPPP	PL	SPPo
1.	ICGV-95492	37^{ehgf}	126cbd	39.4^{feg}	5.3333^{ji}	1.33^{f}	28.6^{efgd}	23.667^{ebdc}	2.2767^{fgh}	1.893
2.	ICGV-01005	37^{ehgf}	128^{cb}	52.533^{a}	5.3333^{ji}	2.2^{fecd}	25.4^{hefgi}	18.933^{edf}	2.9133^{bdac}	1.987
3.	ICGV-01014	37.3^{ehdgf}	126.3^{cbd}	49.867^{ba}	5.6^{hji}	2.467^{bcd}	22.533^{hgi}	17.867^{ef}	2.6467^{fdec}	1.987
4.	ICGV-01015	38^{ebdgcf}	127.7^{cbd}	48.667^{bac}	5.4^{ji}	1.53^{fed}	28.067^{hefgd}	21.267^{ebdfc}	3.03^{ba}	1.933
5.	ICGV-01043	36.67^{hgf}	127^{cbd}	48.13^{bdac}	5.0667^{ji}	1.93^{fecd}	23.133^{hgi}	17.733^{ef}	2.88^{bdc}	2.013
6.	ICGV-01080	37^{ehgf}	125.7^{cbd}	41.07^{feg}	5.4667^{ji}	1.73^{fecd}	25.8^{hefgi}	19.67^{edfc}	2.17^{h}	1.933
7.	ICGV-01105	39^{bdac}	127.3^{cbd}	36^{hg}	6.3^{fhegi}	2.2^{fecd}	25.867^{hefgi}	21.267^{ebdfc}	2.6267^{fdec}	1.973
8.	ICGV-01124	38.67^{ebdac}	134.3^{a}	36^{hg}	8.5333^{b}	2.13^{fecd}	27.8^{hefg}	27.333^{bac}	2.7^{bdec}	1.947
9.	ICGV-93280	38.7^{ebdac}	124.67^{d}	42.2^{fdeg}	8.2^{cb}	1.73^{fecd}	30.13^{efcd}	28.8^{ba}	2.6067^{fdec}	1.98
10.	ICGV-95440	36.67^{hgf}	125.7^{cbd}	38.07^{fheg}	4.73^{j}	1.4667^{fe}	19.533i	26.13^{bdac}	2.2767^{fgh}	1.947
11.	ICGV-95460	37.3^{ehdgf}	126.3^{cbd}	43.6^{fdec}	5.6667^{hji}	2^{fecd}	26.533^{hefg}	20.93^{ebdfc}	2.367^{fgeh}	1.933
12.	ICGV-95469	39b^{dac}	124.67^{d}	28.8^{i}	6.3^{fhegi}	2.2667^{ecd}	23.6^{hgi}	17.867^{ef}	2.327^{fgeh}	1.893
13.	ICGV-97281	36.33^{hg}	125^{cd}	44.13^{bdec}	5.4^{ji}	2.33^{becd}	23.733^{hfgi}	19.867^{edfc}	2.19^{gh}	1.8667
14.	ICGV-97328	37.33^{ehdgf}	127.3^{cbd}	52.267^{a}	7.33^{cebd}	2.067^{fecd}	21.867^{hi}	22.467^{ebdfc}	2.583^{fdec}	1.933
15.	J11	37^{ehgf}	127^{cbd}	43.87^{fdec}	5.4667^{ji}	2.33^{becd}	25.467^{hefgi}	25.13^{ebdac}	2.2767^{fgh}	1.933
16.	ICGV-98371	37.67^{ehdgcf}	133.67^{a}	37.73^{fhg}	7.27^{fcebd}	2.067^{fecd}	30.867^{ecd}	18.4^{edf}	2.5433^{fgde}	1.92
17.	ICGV-97150	39.33^{bac}	135.33^{a}	32.867^{hi}	6^{fhjgi}	3.2^{ba}	41.4^{a}	27.067^{bac}	2.7967^{bdc}	2
18.	ICGV-97153	39.67^{ba}	136^{a}	42.07^{fdeg}	10.4^{a}	2.47^{bcd}	30.667^{ecd}	15.133^{f}	3.2467^{a}	2
19.	ICGV-97156	39.667^{ba}	134.67^{a}	36.4^{hg}	8^{cbd}	2^{fecd}	34.2^{bcd}	20.13^{edfc}	2.9333^{bac}	1.97
20.	ICGV-97157	39^{bdac}	136^{a}	36.33^{hg}	6.8^{fhegd}	2.267^{ecd}	39.267^{ba}	32.133^{a}	2.8767^{bdc}	1.947
21.	ICGV-97163	39.667^{ba}	134.67^{a}	42.07^{fdeg}	7.33^{cebd}	3.6667^{a}	30.533^{ecd}	18.267^{edf}	2.653^{fbdec}	1.893
22.	ICGV-98369	36^{h}	128.33^{b}	36.6^{hg}	5.93^{hjgi}	1.87^{fecd}	24.867^{hefgi}	23.53^{ebdc}	2.62^{fdec}	2
23.	ICGV-98370	38.3^{ebdacf}	133.3^{a}	36^{hg}	7.07^{fcegd}	1.73^{fecd}	35.067^{bc}	22.267^{ebdfc}	2.62^{fdec}	1.907
24.	Roba	38^{ebdgcf}	127.3^{cbd}	44.27^{bdec}	5.6^{hji}	2.53^{bc}	24.67^{hefgi}	19.8^{edfc}	2.8567^{bdc}	2.093
25.	Maniputer	40^{a}	134^{a}	41.6^{feg}	8.5333^{b}	2.67^{bc}	30.067^{efcd}	20.4^{edfc}	2.7167^{bdc}	1.987
	($\overline{X}$)	**38.01**	**129.45**	**41.22**	**6.53**	**2.17**	**27.98**	**21.84**	**2.63**	**1.96**
	R-Square (%)	**77**	**94**	**89**	**90**	**77**	**85**	**72**	**82**	**57**
	CV (%)	**2.56**	**1.19**	**7.79**	**10.47**	**21.55**	**11.7**	**18.40**	**7.41**	**3.60**

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No	Genotype	100SW	SH %	PYLD	SYLD	ELS	LLS	OC
1.	ICGV-95492	34.583^{jk}	73.167^{fgdc}	2785.2^{edc}	2089.9^{edc}	20.333^{bac}	7.333^{edgcf}	49.967^{fbedcg}
2.	ICGV-01005	43.85^{dfe}	67.833^{h}	2256.3^{f}	1578.8^{gf}	25.667^{a}	8.667^{edgcf}	48.267^{g}
3.	ICGV-01014	43.913^{dfe}	73.167^{fgdc}	2271.5^{ef}	1724.9^{ef}	21.667^{ba}	11.667^{ac}	47.8^{g}
4.	ICGV-01015	41.497^{gfh}	65^{i}	1675.6^{g}	1127.8^{g}	16.667^{ebdac}	11.333^{dac}	$48.843f^{g}$
5.	ICGV-01043	42.7^{gfe}	71.667^{fgdh}	2229.6^{gf}	1655.2^{ef}	13.333^{ebdac}	16.333^{a}	48.243^{g}
6.	ICGV-01080	33.523^{k}	77.167^{bc}	2111.9^{gf}	1695.2^{ef}	19.333^{bac}	8^{edgcf}	51.7^{bedc}
7.	ICGV-01105	38.26^{jih}	75.833^{bdc}	2177.4^{gf}	1710.2^{ef}	23.667^{ba}	9.667^{edagcf}	49.133^{feg}
8.	ICGV-01124	39.1^{gih}	71.167^{fgdh}	2427.8^{edf}	1785.8^{edf}	20.667^{bac}	2^{gf}	49.643^{fedcg}
9.	ICGV-93280	35.713^{jik}	78.667^{b}	2788.9^{edc}	2271.4^{c}	16.667^{ebdac}	4^{edgcf}	51.233^{fbedc}
10	ICGV-95440	32.79^{k}	78.667^{b}	1987.4^{gf}	1619.6^{ef}	25.667^{a}	10.333^{edac}	50.167^{fbedcg}
11	ICGV-95460	35.1^{jk}	78.5^{b}	2100.7^{gf}	1707.6^{ef}	16.667^{ebdac}	9.333^{edagcf}	50.433^{fbedcg}
12	ICGV-95469	39.703^{gh}	68.5^{gh}	1949.6^{gf}	1388.2^{gf}	17^{ebdac}	17^{a}	49.033^{feg}
13	ICGV-97281	35.4^{jik}	77.333^{bc}	1918.5^{gf}	1536.9^{gf}	$18b^{dac}$	5.667^{edgcf}	49.433^{fedg}
14	ICGV-97328	40.51^{gfh}	70.5^{fgh}	2090.7^{gf}	1529.3^{gf}	18.333^{bdac}	3.667^{edgf}	48.91^{fg}
15	J11	32.587^{k}	77.333^{bc}	2198.9^{gf}	1762.9^{edf}	25^{ba}	10^{edacf}	51.767^{bedc}
16	ICGV-98371	45.73^{dce}	75.167^{fbdc}	2941.1^{bdc}	2290.6^{bc}	8^{edc}	1.667^{g}	52.343^{bac}
17	ICGV-97150	53.32^{b}	75.5^{bdc}	3523.7^{a}	2753.4^{ba}	4^{e}	1.667^{g}	51.443^{fbedc}
18	ICGV-97153	59.733^{a}	70.333^{fgh}	3485.9^{a}	2543^{bac}	6.333^{ed}	2.667^{egf}	49.09^{feg}
19	ICGV-97156	54.747^{b}	75.667^{bdc}	3262.6^{bac}	2554.5^{bac}	5.667^{ed}	3.667^{edgf}	54.733^{a}
20	ICGV-97157	53.477^{b}	81^{a}	3406.3^{ba}	2859.1^{a}	4^{e}	3.667^{edgf}	52.543^{ba}
21	ICGV-97163	47.367^{dc}	$73fgd^{c}$	2919.3^{bdc}	2206.4^{dc}	4.333^{e}	2.667^{egf}	51.567^{fbedc}
22	ICGV-98369	46.703^{dc}	78.667^{b}	2144.8^{gf}	1747.7^{edf}	12^{ebdc}	2^{gf}	52^{bdc}
23	ICGV-98370	48.533^{c}	78.833^{b}	3370.4^{ba}	2750.4^{ba}	5^{e}	1.667^{g}	52.313^{bac}
24	Roba	38.29^{jih}	77.66^{7bc}	1985.6^{gf}	1600.4^{ef}	13.667^{ebdac}	9.333^{edagcf}	50.033^{fbedcg}
25	Maniputer	52.543^{b}	76.167^{bdc}	3068.9bac	2423.7^{bac}	5^{e}	2^{gf}	50.2^{fbedcg}
	$(\overline{X})$	**42.79**	**74.66**	**2523.14**	**1956.52**	**14.66**	**6.64**	**50.43**
	R-Square (%)	**97**	**85**	**89**	**88**	**76**	**77**	**78**
	CV (%)	**4.89**	**3.53**	**11.49**	**12.87**	**44.8**	**60.7**	**2.79**

Appendix Table 3 Mean performances of combined of the two locations for yield and yield related traits among 25 groundnut genotypes

No	Genotype	PB	TPPP	PL	SPPo	SH%	PYLD	SYLD	ELS	LLS
1.	ICGV-95492	5.1^{ef}	19.43^{hgfji}	2.13^{h}	1.893	73.3^{bdec}	1920.4^{feg}	1446.3^{cebd}	21^{ba}	7.7^{fcebd}
2.	ICGV-01005	5.2^{ef}	16.967^{hkji}	2.763^{cb}	1.987	69.083^{fg}	1533.9^{ji}	1083.4^{gfh}	24.5^{a}	9.167^{cbd}
3.	ICGV-01014	5.33^{ef}	14.933^{k}	2.425^{gef}	1.98	75.5^{bac}	1601.7^{jhig}	1227.1^{gefd}	21^{ba}	12.3^{b}
4.	ICGV-01015	5.2^{ef}	18.8^{hgkfji}	2.823^{b}	1.933	66.5^{hg}	1324.3^{j}	905.3^{h}	15.167^{bdc}	11.5^{b}
5.	ICGV-01043	5.2^{ef}	16.267^{kj}	2.647^{cebd}	2.013	70.25^{fe}	1729.6^{fhig}	1263.2^{gefd}	13.5^{bedc}	17^{a}
6.	ICGV-01080	5.13^{ef}	19.8^{hgefji}	2.1633^{h}	1.93	74.5^{bdac}	1505.9^{ji}	1181.8^{gefh}	20.167^{ba}	8.5^{cebd}
7.	ICGV-01105	5.73^{ed}	17.9^{hgkji}	2.5083^{ed}	1.973	73.25^{bdec}	1554.3^{jhi}	1194.2^{gefh}	25^{a}	9.83^{cb}
8.	ICGV-01124	6.9^{cb}	21.23^{hgefd}	2.6^{cebd}	1.947	68.833^{fg}	1891.9^{fheg}	1356.8^{cefd}	20.5^{ba}	2.83^{f}
9.	ICGV-93280	7.43^{cb}	21.767^{gefd}	2.275^{gfh}	1.987	77.25^{ba}	1962fe	1578.2^{cb}	19.167^{ba}	4.33^{fed}
10.	ICGV-95440	4.6^{f}	14.6^{k}	2.07^{h}	1.947	75.917^{ba}	1394.1^{ji}	1113.2^{gfh}	26.3^{a}	10.5^{b}
11.	ICGV-95460	5.3^{ef}	18.1^{hgkji}	2.268^{gfh}	1.933	76.667^{ba}	1457.4^{ji}	1166.5^{gefh}	18.167^{ba}	9.667^{cb}
12.	ICGV-95469	5.83^{ed}	18.8^{hgkfji}	2.248^{gfh}	1.893	64.583^{h}	1395^{ji}	958.6^{gh}	17.5^{bac}	17.3^{a}
13.	ICGV-97281	4.9667^{ef}	17.43^{hgkji}	2.1467^{h}	1.86667	75.5^{bac}	1453.5^{ji}	1142.2^{gfh}	18.667^{ba}	7^{fcebd}
14.	ICGV-97328	6.8667^{c}	14.633^{k}	2.468^{efd}	1.93	71.167^{fde}	1462^{ji}	1072.7^{gfh}	18.333^{ba}	3.833^{fed}
15.	J11	5.3^{ef}	18.3^{hgkji}	2.2117^{gh}	1.93	74.67^{bdac}	1547.8^{jhi}	1214^{gefd}	24.333^{a}	10.5^{b}
16.	ICGV-98371	7.33^{cb}	23.93^{cebd}	2.477^{efd}	1.92	71.833^{fdec}	2308.5^{cd}	1736.3^{b}	7.667^{ed}	2.5^{f}
17.	ICGV-97150	7.9667^{b}	31.4a	2.835b	2	71.667^{fdec}	3009.1^{a}	2248.5^{a}	5.333^{e}	2.5^{f}
18.	ICGV-97153	7.7^{cb}	20.37^{hgefji}	3.0467a	2	69.75^{feg}	2400.9^{bcd}	1735^{b}	7.167^{ed}	3^{f}
19.	ICGV-97156	7.4^{cb}	22.733^{cefd}	2.68^{cbd}	1.973	74.42^{bdac}	2163.9^{ed}	1660.9^{b}	9.5^{edc}	4.67^{fced}
20.	ICGV-97157	6.73^{cd}	27.133^{b}	2.713^{cbd}	1.947	78.3^{a}	2547.4^{bc}	2059.1^{a}	5.5^{e}	4.167^{fed}
21.	ICGV-97163	7.13^{cb}	22.83^{cefd}	2.67^{cbd}	1.893	70.33^{fe}	2157.6^{ed}	1569.7^{cb}	5.167^{e}	3.167^{fe}
22.	ICGV-98369	6.63^{cd}	20.73^{hgefdi}	2.521^{ced}	2	75^{bdac}	1920.6^{feg}	1498.4^{cbd}	12.667^{bedc}	2.667^{f}
23.	ICGV-98370	7.6^{cb}	26.767^{cb}	2.607^{cebd}	1.907	75.3^{bac}	2661.3^{b}	2095.1^{a}	6.167^{e}	2.83^{f}
24.	Roba	5.3667^{ef}	16.5^{kji}	2.63^{cebd}	2.07333	74.8^{bdac}	1393ji	1096.8^{gfh}	15.3^{bdc}	10.67^{b}
25.	Maniputer	9.1667^{a}	24.867^{cbd}	2.675^{cbd}	1.987	74.41^{bdac}	2708.5^{ba}	2078.6^{a}	6^{e}	2.833^{f}
	$(\overline{X})$	**6.28**	**20.25**	**2.5**	**1.95**	**72.9**	**1880.2**	**1427.27**	**15.35**	**7.24**
	R-Square (%)	**88**	**95**	**87**	**57**	**82**	**95**	**95**	**1535**	**77**
	CV (%)	**12.9**	**15.76**	**7.2**	**3.5**	**3.96**	**14.6**	**15.6**	**42.3**	**55.6**