



Research Article

Exploring the Effect of Phenotypic Variability on Genetic gain in Groundnut (*Arachis hypogaea* L.) Yield under Semi Drought Conditions

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Abstract | Peanut breeding has gained importance gradually by the awareness of the tremendous benefits of this crop from the health and nutritional point of view, arousing considerable production in Pakistan. The pod that encloses the seeds is an economically vital part of the groundnut plant and enhance the market value of groundnut. The experiment was conducted in the Department of Plant Breeding and Genetics, Pir Mehar Ali Shah, Arid Agriculture University, Rawalpindi during Kharif, 2020 with RCBD Design 15 genotypes keeping in view, 15 important yield-related parameters were selected to study under correlation and path analysis. Correlation analysis revealed a significant relation of pod yield with directly contributing yield components like, Peg⁻¹, Pods⁻¹, MPP⁻¹, APL and HSW. In contrast, LA, LLA, PB, SB, MPP⁻¹ and SP were those characters that were in a strong negative association with pod yield. The association of these characters with pod yield indicated the importance of these traits for selecting high yielding genotypes under the screening process. Path analysis revealed a positive direct effect of leaflet area, pods per plant, shelling percentage, average pod length and hundred seed weight. In contrast, leaf area, pegs per plant and mature pods per plant revealed negative direct effect. The mean values for genotypes N0334, abCG005 and BARI-2000 had maximum pod yield per plant among all the genotypes. Biplot and cluster analysis indicated the overall variability among genotypes and degree of genetic diversity. Cluster demonstration also validates the association of parameters revealed in correlation analysis. Thus results provide the information of the association of characters in correlation and split the correlation value into indirect and direct effects of characters to yield, useful for selection of traits in the breeding program.

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Keywords | Groundnut, *Arachis hypogaea* L., Correlation, Path analysis, Cluster analysis, Character association, Pod yield



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Introduction

Groundnut (*Arachis hypogaea* L.) is the important oilseed crop and ranked sixth. Higher and denser energy levels of protein, fats, and many other healthy nutrients for lesser consumption Singh, A., *et al.* (2021)., increase the importance of peanuts in terms of reducing weight and heart diseases because primary fats in peanuts are monounsaturated (Nunes *et al.*, 2023). A coenzyme Q10 in peanuts is known for protecting the heart during oxygen deficiency (Marappan, G. 2020). Moreover, certain unsaturated fats, vitamins, minerals and bioactive components in peanuts are known to have effects of cancer prevention (Gonzalez and Salvado 2006), such as phytosterols (Woyengo *et al.*, 2009) and resveratrol (Nabavi *et al.*, 2014) were studied in this regard. Awareness of these important benefits of peanut crops can reduce the consumption of undesirable supplements. There is a need to improve and increase the peanut production with best breeding strategies keeping in mind the nutrients, oil quality and crop yield (Arya *et al.*, 2016).

Groundnut is signified for different production conditions, such as intercropping and rotation with cereals. Still, due to drought, the low availability of soil nutrients to the crop caused a decrease in its production. Results have shown a reduction in yield contributing parameters like a pod and seed number, pod weight and seed weight, pod filling rate, and harvest index in water stress. However, the principal component analysis revealed a high pod filling rate, good harvest index and good seed yield in genotypes like 55-437, ICGG-4750 and ICG-12697. These parameters can be taken to select genotypes in water deficit conditions (Karim *et al.*, 2020). This in turn reduces overall production and yield of the groundnut unlike other major crops. The groundnut production is highly and variably reduced by the major limiting factors instead of other agro-climatic conditions (Jahanzaib *et al.*, 2019). Globally groundnut production increased marginally in the last decade (2000-2010). About 70% of groundnut is grown under arid and semi-arid areas, where groundnut crop frequently faces drought stresses for different durations and intensities (Nadeem *et al.*, 2024) together with high irradiance and temperature (Kambiranda *et al.*, 2011). Almost 56- 85% yield losses are observed in drought stress, intensity and duration (Ravi *et al.*, 2011), thereby causing a considerable decrease in crop performance respecting plant persistence, economic yield and quality (Hall 2001).

The number of pods per plant and hundred seed weight were indicated as chief traits under path analysis for realizing the progress in yield. Omar and Aisha (2021) noted that kernel weight had negative effect on pod yield through the indirect effect of no. of pods per plant, seeds per pod and shelling percentage. Moreover, economically important traits such as, kernel yield, no. of pods per plant, hundred kernel weights, and dry haulm yield were observed positively and significantly associated with pod yield (Rao *et al.*, 2014). The dry pod yield per hectare revealed a high direct effect towards yield, and a negative relationship was established with days taken to flowering, pod per plant, shoots length, shelling percentage, and specific leaf area Thakur *et al.* (2013). Moreover, kernel yield per hectare, mature pods per plant, number of branches and plant height were observed with high heritability and genetic coefficient of variation values (Zaman *et al.*, 2011). Kumar *et al.* (2012), Alam *et al.* (2014), Kumar *et al.* (2014) evaluated many characters for pod yield. High magnitude of genotypic correlation coefficients was observed than the corresponding phenotypic correlation coefficients. Mohapatra, and Khan (2020) investigated the relationship between yield-related traits and physiological traits by studying four F3 crosses of three groundnut genotypes. They found a positive and highly significant association of kernel yield per plant and shelling percentage with dry pod yield per plant which are important characters to consider in the selection point of view. Whereas, path analysis in this study facilitates assessing yield-related parameters e.g kernel yield per plant with a high value of positive and direct effect, which can be used to select genotypes with high yield in the next generation. Luz *et al.* (2011) identified a substantial immediate impact of the number of pegs in the lower plant third on the number of mature pods through a path analysis study. These findings showed the importance of the use of the number of pegs in the lower plant third in the selection of peanut populations for several mature pods. The relationship between yield and its related traits has been exploited by selecting and analyzing traits between yield and its related traits in groundnut genotypes. Correlation, path analysis and multivariate analysis revealed that plant height, hundred seed weight, number of pods per plant and number of secondary branches contribute directly to grain yield. Diversity among the genotypes has been shown through cluster analysis (Nelson *et al.*, 2020). Hence, an effective selection program can be designed to understand the associ-

ations among yield components (John *et al.*, 2015).

Yield loss due to water stress can be controlled by selecting and developing such varieties that are better adapted to water-limited conditions (Ravi *et al.*, 2011). Knowledge of physiological and molecular genetics makes understanding about the stress response and helps to develop stress-tolerant varieties. Amini-far *et al.* (2013) studied the physiology and features of the plant that were correlated with drought tolerance. He observed that water use efficiency (WUE) deals with soil water use efficiency for biomass production, and it was considered an important drought avoidance trait. Mahmood *et al.* (2019) proposed a genetic modification technique, such as CRISPR/Cas9, for characterization of stress-related genes and epigenomic techniques to understand the stress biology thus helping in developing drought stress tolerant high yielding crop varieties. Different plant breeding methods such as Genomic modification techniques, Molecular markers, Gene expression and Proteomic approaches for constructing high yielding groundnut crops should also be employed. The demand for food security needs genetically improved varieties and cultivars and genetically variability being used as a best option in the past for higher production (Jahanzaib *et al.*, 2020). The main objectives of peanut breeding programs include improvements in seed yield, oil production per unit area, resistance to major diseases and pests, resistance to drought, and plant architecture.

The present study was designed to determine the correlation and path analysis keeping in view the importance of the genetic association among the traits indicating the yield. In peanut breeding program pod yield is an important character under consideration (Woyann *et al.*, 2019) and the selection for desirable genotypes depends on variation present in the population (Andrade, 2019), (Vinithashri *et al.*, 2019), which can be measured employing range, standard error and variance to identify the desired traits (Dinesh *et al.*, 2018). The yield of the groundnut is contributed by polygenic components, which are influenced by environmental challenges and fluctuations (Santos *et al.*, 2014). Therefore, it is important to estimate the breeding value of genotype by separating the phenotypic variation into genetic and environmental component variance and the extent of correlation between yield supporting traits. There is a chance that

there may be no specific gene for yield and selection based on the only yield is not effective (Kamdar, *et al.*, 2020). Here correlations provide a picture to understand component characters contributing yield. However, a path analysis study has little correlation difference; it divides correlation coefficients into direct and indirect effects on final yield (Dewey and Lu, 1959; Venkataravana *et al.*, 2020).

Materials and Methods

Plant Material

The experiment was conducted in the Department of Plant Breeding and Genetics, Pir Mehar Ali Shah, Arid Agriculture University, Rawalpindi during Kharif, 2020 with RCBD Design 15 genotypes i.e. BARI 2011, Chakori, 02CG002, BARD-479, Golden, N0334, Banki, abCG005, BARI-2000, BARI-89, 11CG005, Chico, 10CG003, Majalaya super and Majalaya with four replication

Table 1: Genotypes Used in the Experiment.

Sr.No	Genotypes	Sr.No	Genotypes
1	BARI 2011	9	BARI-2000
2	Chakori	10	BARI-89
3	02CG002	11	11CG005
4	BARD-479	12	Chico
5	Golden	13	10CG003
6	N0334	14	Majalaya super
7	Banki	15	Majalaya
8	abCG005		

Experimental Conditions

Plant × plant and row × row distance was maintained at 12cm and 45cm respectively. The experiment was conducted under rainfed conditions with all suitable agronomic practices. Observations were recorded for 15 morphological characters namely leaf area, leaflet area, number of pegs per plant, number of primary branches, number of secondary branches, plant height, pod weight per plant, shelling percentage, hundred seed weight, number of pods per plant, pod length, number of mature pods per plant, percentage of pegs converted into pods, percentage of pegs converted into mature pods, percentage of mature pods.

The land was brought to fine, and a suitable seed bed was prepared with one deep plowing one month before sowing. The previous crop residues and weeds

were removed and the land was leveled.

Under study genotypes of groundnut was obtained from Barani Agriculture Research Institute Chakwal. To control seed borne diseases, the seeds were treated with fungicide Benlate and Vitavax (2 gm /kg of seed).

Data Collection

The data were recorded for the following parameters.

S.N.	Parameters	Abbreviation
1	Leaf Area	LA
2	Leaf Area of Leaflets	LLA
3	Number of Primary Branches	PB
4	Number of Secondary Branches,	SB
5	Plant Height (cm)	PH
6	Number of Pegs per Plant	Pegs -1
7	Pod Weight per Plant	PWP
8	Shelling Percentage	SP Shelling percent = Kernel weight (g) * 100 /pod weight (g)
9	Hundred Seed Weight	HSW
10	Number of Pods per Plant	Pods -1
11	Pod Length	PL
12	Number of Mature Pods per Plant	MPP-1
13	Percentage of pegs converted into pods	PPCP
14	Percentage of pegs converted into mature pods	PPCMP
15	Percentage of mature pods	PMP

Statistical Analysis

The means calculated from the recorded data for different selected parameters were analyzed statistically and compared at a 5% level of least significant difference following [Steel et al. \(1997\)](#) to determine the significance of the traits studied. Genetic parameters, correlation coefficients were calculated according to the method suggested by [Singh and Chaudhary \(1979\)](#). The significance of the genotypic correlation has tested the help of standard errors as suggested by [Kwon and Torrie \(1964\)](#) and [Reeve and Rao \(1981\)](#). Path analysis measures the direct effect of one variable upon another and enables the splitting of correlation coefficients into components of direct and indirect effects ([Dewey and Lu, 1959](#)). Cluster analysis and principal component analysis have been computed to determine relationships and variability among the accessions ([Gan et al., 2007](#), [Nelson et al., 2020](#)).

Results and Discussion

Mean Performance

The mean values and range of pod yield and other traits of 15 peanut genotypes during the period of study are given in [Table 2](#). In the present study, mean values of LA among peanut genotypes ranged from 21.52 to 47.83 (cm²), with a mean value of 31.96 (cm²). The maximum value for LA was observed in Majalaya. According to [Kiniry et al. \(2004\)](#) leaf area is an important parameter concerning proper light interception and radiation use efficiency. The no. of PB and SB of given genotypes ranged from 6 to 10 and 4 to 5 respectively, with mean values of 8 and 5 ([Table 2](#)). The mean value of genotypes BARD-479 and Majalaya had 10, whereas genotypes N0.334 and 10CG003 showed the minimum number of PB (6). The PH of 15 genotypes ranged from 11.75 to 17.00 cm, with a mean value of 14.16 cm ([Table 2](#)). The genotype 02CG002 had 17.00 cm of PH. Whereas, in Chico minimum of 11.75 cm, PH was recorded. The Pegs⁻¹ of 15 genotypes was ranged from 34.25 to 54.5, with a mean value of 44.27 ([Table 2](#)). The genotype abCG005 had a maximum no. of Pegs⁻¹ 54.5, whereas the minimum no. of pegs of 34.25 per plant was recorded in Chakori.

The Pods⁻¹ of under-study genotypes ranged from 17.75 to 42 ([Table 2](#)). Maximum no. of Pods⁻¹ was recorded in Golden (42.00) and N0334 (40.5), whereas Chico showed a minimum no. of Pods⁻¹ with 17.75. The PPCP of 15 genotypes was seen to be range from 52.83 to 83.2%, with a mean value of 74.55% ([Table 2](#)). The recorded PPCP in genotype BARI-89 was 83.20, whereas in Chico of minimum 52.83 PPCP. The MPP⁻¹ and PPCMP of under study genotypes ranged from 11.25 to 28.25 and 30.58 to 69.85, respectively with a mean value of 19.98 and 48.25% ([Table 2](#)). Maximum no. of MPP⁻¹ was recorded in Golden with 28.25 whereas 10CG003 had the minimum number of MPP⁻¹ (11.25). The number of mature pods determines the actual pod yield. According to the percentage of pegs conversion in mature pods maximum percentage was seen in BARI-89 with 69.85%, whereas, Majalaya had the minimum PPCMP of 30.58%. The PWP for 15 given genotypes ranged from 11g to 33.25g, with a mean value of 26.33 ([Table 2](#)). The genotype which showed maximum PWP was N0334 with 33.25 g. The minimum recorded PWP was 11.00g in genotype Chico.

Table 2: Analysis of variance for yield and yield related traits in 15 peanut genotypes.

Genotypes	L A (cm ²)	LLA (cm ²)	PB	SB	PH (cm)	Peg ¹	Pod ¹	PPCP	MPP-1	PPCP	PMP	PWP (g)	SP	APL (cm)	HSW (g)
BARI 2011	29.3	8.32	9	5	13.88	35.5	24.75	70.55	17	47.9	68.38	18.75	66.52	2.72	31.25
Chakori	23.55	5.75	9	4	15.5	34.25	25.75	74.93	17.5	50.05	66.95	29.25	63.75	2.96	52.05
02CG002	32	8.47	7.75	5.25	17	39.25	29	74.28	20.5	51.78	69.4	28.75	68.9	3.08	38.9
BARD-479	30.95	7.78	10	4	14	38	27.75	74.13	20	52.72	72.57	28.25	61.97	2.58	41.53
Golden	30.6	8.18	7.25	5	12.88	50	42	82.6	28.25	57.05	69.92	29.25	61.4	2.9	38.65
N0334	29.35	7.45	6.25	4.75	14.25	53.25	40.5	76.63	25.75	49.13	64.08	33.25	65.38	3	40.1
Banki	24.33	6.63	6.5	5.75	15.63	46	36.5	80.23	21.5	47.9	59.15	25.75	66.25	2.61	53.08
abCG005	21.52	5.4	6.25	7	14.5	54.5	35.75	67.3	26.25	49.32	73.4	31.75	67.75	2.7	45.83
BARI-2000	25.5	6.45	7.75	4	14.75	51.25	36	77.82	21.5	47.75	62.2	31.5	68.3	2.92	47.6
BARI-89	34.35	9.27	8	4.75	13.63	40	27.75	83.2	23.5	69.85	84.45	30	66.32	2.69	46.96
11CG005	24.47	6.65	6.5	6	13.88	49.5	40.75	76.9	23.25	43.9	57.67	28.75	67.63	2.57	36.63
Chico	45.53	13.27	7.75	6.25	11.75	39.25	17.75	52.83	12.75	37.65	74.65	11	71.1	1.92	34.03
10CG003	40.78	8.5	6.25	3.75	13	43.75	25.5	74.38	11.25	34.07	46.1	27	66.48	3.24	43.08
Majalaya S	39.33	10.45	7.75	3.75	12.5	43	27.5	79.97	16.75	54.13	67.6	17.5	65.15	3.12	32.9
Majalaya	47.83	12.58	10	4.25	15.25	46.5	35	72.57	14	30.58	43.78	24.25	62.22	3	30.73
Mean value	31.7	8.4	7.8	4.9	42.3	14.2	31.7	74.6	20.0	48.3	65.4	26.4	65.9	2.8	42.6
LSD	8.303	2.633	2.997	3.635	3.683	13.53	12.20	19.31	7.376	16.74	18.99	9.146	18.63	0.6253	8.416
Range	21.5-46.0	5.4-13.3	6-10	4-7	34-54	11.8-17.0	18-42	52.8-83.2	11.3-28.3	30.6-69.9	43.8-84.5	11-33.3	61.4-71.1	1.9-3.2	29.8-58.2
S.ov	L (cm ²)	LA (cm ²)	PB	SB	PH (cm)	Peg ¹	Pod ¹	PPCP	MPP-1	PPCP	PMP	PWP (g)	SP	APL (cm)	HSW
MS(VAR)	264.51 ^{**}	21.01 ^{**}	6.70 ^{**}	3.96 ^{**}	7.34 ^{ns}	168.37 ^{**}	201.84 ^{**}	219.05 ^{ns}	102.48 ^{**}	360.36 ^{**}	447.81 [*]	150.13 [*]	29.66 ^{**}	0.412 ^{**}	205.56 ^{**}
MS(REP)	23.18 ^{ns}	2.329 ^{ns}	2 ^{ns}	5.978 ^{**}	0.46 ^{ns}	2.311 ^{ns}	14.51 ^{ns}	32.75 ^{ns}	1.93 ^{ns}	84.02 ^{ns}	112.9 ^{ns}	184.04 ^{**}	9.97 ^{ns}	0.072 ^{ns}	125.03 ^{**}
MS(E)	15.902	2.195	1.905	1.097	3.906	4.799	9.232	155.56	1.392	137.54	177.12	40.37	11.095	0.63	22.26
F.Ratio(V)	16.63	9.57	3.52	3.61	1.88	35.08	21.86	1.41	73.61	2.62	2.53	3.72	2.673	6.57	9.235
F.Ratio(R)	1.458	1.06	1.05	5.45	1.18	.48	1.571	.21	1.385	.611	.637	4.56	.899	1.16	5.62
STEROR	1.994	.74	.69	.524	.988	1.095	1.519	6.236	.59	5.86	6.654	3.18	1.665	1.125	2.36
CD1	5.64	2.09	1.952	1.481	2.795	3.098	4.297	17.64	1.669	16.59	18.82	8.985	4.711	.354	6.67
CD2	7.501	2.79	2.596	1.97	3.717	4.121	5.715	23.46	2.219	22.06	25.03	11.95	6.265	.471	8.87
G.VAR.	62.153	4.70	1.198	.715	.859	40.894	48.152	15.87	25.272	55.71	67.67	27.441	4.642	.087	45.83
P.VAR	78.055	6.89	3.102	1.812	4.765	45.693	57.383	171.44	26.664	193.24	244.79	67.807	15.737	.15	68.08
GCOV	24.669	25.99	14.15	17.26	6.547	14.446	22.041	5.34	25.157	15.47	12.59	19.893	3.267	10.55	16.56
PCOV	27.645	31.48	22.78	27.47	15.418	15.27	24.061	17.56	25.84	28.81	23.94	31.27	6.016	13.82	20.18
COH	0.796	0.68	0.386	0.395	0.18	0.895	0.839	0.09	0.948	0.28	0.28	0.405	0.295	0.58	0.67

The SP per plant of under-study genotypes ranged from 61.38 to 71.10% with the mean value of 65.94 (Table 2). The maximum recorded SP was in genotype Chico with 71.10%, whereas genotype Golden showed a minimum percentage of 61.38%. The APL per plant ranged from 1.92 to 3.24 with a mean value of 2.8 (Table 2). The genotype which showed the maximum APL per plant was 10CG003 with 3.24 cm, whereas the minimum pod length was recorded in genotype Chico with 1.92cm. HSW per plant of studied genotypes ranged from 30.73g to 53.08g with an average value of 40.89g (Table 2). The maximum HSW was calculated in genotype Banki with 53.08g, whereas genotype Majalaya showed a minimum HSW with 30.73g. Higher HSW in genotypes like Banki (58.17g), Chakori (52.1g) and BARI-2000 (52.1g) was recorded. Analysis of variance indicated highly significant differences among all genotypes except PH and PPCP for pod yield and yield-related traits. In contrast, non-significant differences were observed for replications except PWP and HSW (Table 2). This showed that the influence of the environment was less on traits.

Trait Association and Correlation Coefficient

The results revealed by the correlation coefficient study between 15 genotypes are given in Table 3. A

highly significant difference is present between all the genotypes for under study attributes with higher genotypic correlation coefficients than phenotypic correlation coefficient, which indicate less environmental influences. Pod yield showed positive significant genotypic correlation with PH ($r=0.80^{**}$), number of Pegs⁻¹ ($r=0.53^{*}$), number of Pods⁻¹ ($r=0.73^{**}$), PPCP ($r=0.89^{**}$), MPP⁻¹ ($r=0.74^{**}$), APL ($r=0.60^{*}$), HSW (0.74^{**}). Similarly, a positive and highly significant genotypic correlation was observed between the number of Pods⁻¹ and number of Pegs⁻¹ ($r=0.83^{**}$), number of Pods⁻¹ and MPP⁻¹ ($r=0.66^{**}$). The negative significant genotypic correlation coefficient of pod yield with LA ($r=-0.73^{**}$) and LLA ($r=-0.91^{**}$) was also observed. Negatively recorded significant genotypic correlation coefficient between the SP and APL was $r=-0.64^{*}$. The phenotypic correlation coefficient results showed that number of Pods⁻¹ ($r=0.57^{*}$) and MPP⁻¹ ($r=0.56^{*}$) had a significant and positive correlation with pod yield. At the same time, the phenotypic correlation of pod yield with all other characters was non-significant.

Direct and Indirect effect of Traits on Yield

The estimates of direct and indirect effects of LA, LLA, PB, SB, PH, PPCP, MPP⁻¹, PPCMP, PMP, PWP, SP APL and HSW upon pod yield are given

Table 3: Genotypic Correlation between 15 peanut traits.

Variables	LA (cm ²)	LLA (cm ²)	PB	SB	PH (cm)	Peg ⁻¹	Pod ⁻¹	PPCP	MPP ⁻¹	PPC ⁻¹ MP	PMP	PWP (g)	SP	APL (cm)	HSW (g)
LA (G)	1														
LLA	0.97 **	1													
PB	0.37	.045	1												
SB	-0.36	-0.12	-0.70**	1											
PH (cm)	-0.66 **	-0.70 **	0.15	0.05	1										
Peg ⁻¹	-0.25	-0.29	-0.74**	0.39	-0.01	1									
Pod ⁻¹	-0.49	-0.50	-0.46	0.22	0.36	0.83**	1								
PPCP	-0.73**	-0.96 **	-0.12	-0.92**	0.75 **	0.41	0.94**	1							
MPP ⁻¹	-0.71**	-0.62 *	-0.47	0.43	0.26	0.57*	0.76**	0.86**	1						
PPCMP	-0.55 *	-0.44	-0.15	-0.04	-0.06	-0.11	0.09	0.66**	0.79**	1					
PMP	-0.32	-0.06	-0.09	0.38	-0.51	-0.32	-0.34	0.23	0.53*	0.92**	1				
PWP (g)	-0.73**	-0.91**	-0.45	-0.14	0.80 **	0.53*	0.73**	0.89**	0.74**	0.30	-0.14	1			
SP	-0.08	0.05	-0.65**	0.85 **	-0.18	0.01	-0.42	-1.16	-0.20	-0.20	0.29	-0.40	1		
APL (cm)	-0.03	-0.27	-0.06	-0.82**	0.56 *	0.17	.031	1.19	0.03	0.06	-0.56*	0.60*	-0.64*	1	
HSW (g)	-0.67**	-0.76 **	-0.34	-0.01	0.69 **	0.09	0.15	0.56 *	0.34	0.44	0.24	0.74**	0.02	0.10	1

LA (Leaf area), **LLA** (Leaflet Area), **PB** (Primary Branches), **SB** (Secondary Branches), **PH** (Plant Height), **PPCP** (Percentage of Pegs Converted into Pods), **MPP⁻¹** (Mature Pods per Plant), **PPCMP** (Percentage of Pegs Converted into Mature Pods), **PMP** (Percentage of Mature Pods), **PWP** (Pods Weight per Plant), **SP** (Shelling Percentage), **APL** (Average Pod Length), **HSW** (Hundred Seed Weight).

Table 4: Direct (Parenthesis) and Indirect effects of 14 different traits on grain yield of 15 peanut genotypes.

Variables	LA (cm ²)	LLA- (cm ²)	PB	SB	Peg P ⁻¹	PH (cm)	Pod P ⁻¹	PPCP	MPP ⁻¹	PPC- MP	PMP	SP	APL (cm)	HSW (g)	PWP (g)
LA	(0.810)	-0.549	-0.003	0.014	-3.515	-0.0152	5.496	-2.183	-2.143	1.710	-0.421	.0032	0.052	-0.029	-0.773
LLA	0.781	(-0.570)	-0.003	0.007	-3.126	-0.0151	5.376	-2.712	-1.839	1.340	-0.077	-.0156	-0.055	-0.033	-0.943
PB	0.395	-0.335	(-0.005)	0.029	-6.711	.0045	9.114	-1.653	-2.800	0.892	-0.093	.1285	0.094	-0.025	-0.966
SB	-0.966	0.358	0.013	(-0.012)	11.672	-0.0148	-7.863	-7.235	3.231	1.212	0.931	-.3651	-1.454	0.000	-0.493
Peg ⁻¹	-0.459	0.2872	0.006	-0.022	(6.203)	0.009	-8.442	1.433	1.925	-0.096	-.273	.039	-0.011	0.005	0.605
PH (cm)	-1.510	1.056	-0.003	0.021	6.676	(0.008)	-11.261	6.539	1.420	0.303	-1.851	.0536	0.274	0.056	1.781
Pod ⁻¹	-0.517	0.356	0.005	-0.011	6.080	0.011	(-8.613)	1.733	2.067	-.5087	-0.153	.0873	0.172	0.008	0.717
PPCP	-0.792	0.692	0.004	0.037	3.981	0.024	-6.684	(2.234)	2.246	-2.260	0.537	.2342	0.916	0.031	1.200
MPP ⁻¹	-0.660	0.404	0.006	-0.014	4.608	0.005	-6.871	1.936	(2.591)	-2.094	0.709	.0433	-0.041	0.018	0.629
PPCMP	-0.452	0.249	0.002	0.005	0.194	-0.001	-1.429	1.646	1.769	(-3.067)	1.312	.032	0.014	0.019	0.293
PMP	-0.239	0.031	0.000	-0.007	-1.187	-0.011	0.927	0.842	1.289	-2.824	(1.425)	-.0456	-0.347	0.010	-0.137
SP	-0.017	-0.057	0.004	-0.027	-1.552	-0.003	4.830	-3.358	-720	0.630	0.417	(-0.156)	-0.400	0.001	-0.408
APL	0.084	0.063	-0.010	0.034	-0.137	0.005	-2.959	4.088	-0.214	-0.089	-0.989	.1245	(0.501)	-0.003	0.509
HSW (g)	-.556	0.448	0.003	-0.000	0.784	0.011	-1.689	1.656	1.097	-1.382	0.338	-.0049	-0.034	(0.042)	0.714

LA (Leaf Area), LLA (Leaflet Area), PB (Primary Branches), SB (Secondary Branches), PH (Plant Height), PPCP (Percentage of Pegs Converted into Pods), MPP⁻¹ (Mature Pods per Plant), PPCMP (Percentage of Pegs Converted into Mature Pods), PMP (Percentage of Mature Pods), PWP (Pods Weight per Plant), SP (Shelling Percentage), APL (Average Pod Length), HSW (Hundred Seed Weight).

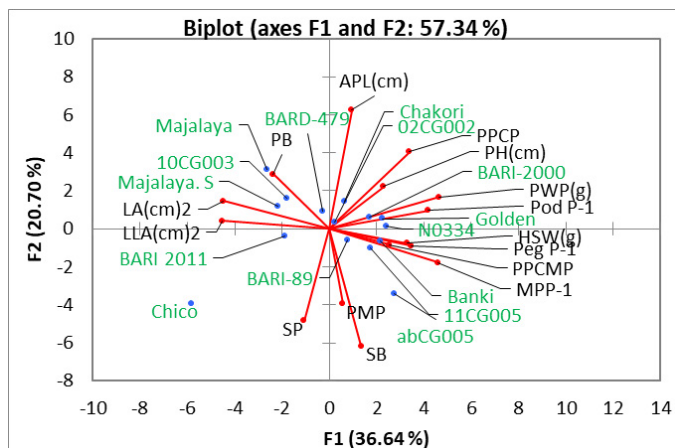


Figure1: Biplot (Principal component analysis) indicating overall variability in 15 genotypes for traits variables, LA (Leaf Area), LLA (Leaflet Area), PB (Primary Branches), SB (Secondary Branches), PH (Plant Height), PPCP (Percentage of Pegs Converted into Pods), MPP⁻¹ (Mature Pods per Plant), PPCMP (Percentage of Pegs Converted into Mature Pods), PMP (Percentage of Mature Pods), PWP (Pods Weight per Plant), SP (Shelling Percentage), APL (Average Pod Length) and HSW (Hundred Seed Weight).

in Table 4. According to path analysis study, it was shown that the number of Pods⁻¹ (3.99), PPCP (0.63), PPCMP (0.31), PMP (1.19), SP (0.63), APL (1.07) and HSW (1.53) had important direct and positive contribution towards pod yield. Whereas, LA (-6.28), PB (-0.68), SB (-0.45), PH (-0.29), number of Pegs⁻¹

(-0.59), and MPP⁻¹ (-4.10) also appeared to influence the yield negatively and directly (Table 4).

Variation among yield and yield related traits in peanut genotypes

Principal component analysis (PCA) biplot has been demonstrated in (Figure 1) to check the variability among genotypes for selected traits. Biplot indicates overall variability of 57.34% among genotypes. It has been observed that APL, SB and SP have shown more significant variability for peanut genotypes overall. The most important yield contributing trait, PPCP, also had greater variability in genotypes Chakori, 02CG002, BARI-2000, and Golden and also closely associated with Pod⁻¹ and PWP.

Genotypes Majalaya, 10CG003 and Majalaya. Sare showing variability for Leaf area (LA) and Primary branches (PB), while genotypes BARI 2011, BARI 89, and Chico have shown variation for shelling percentage with large vector. Genotypes including Chakori, 02CG002, BARI-2000 and Golden depicted considerable variation in Plant Height and pod-1 while greater variation for Average pod length showed a larger vector. Percentage of pegs converted into pods and pod weight per plant have shown considerably less variation than APL, PH and Pod-1 for these genotypes. Genotypes N0334, Banki, 11CG005 and abCG005 had a greater variation for

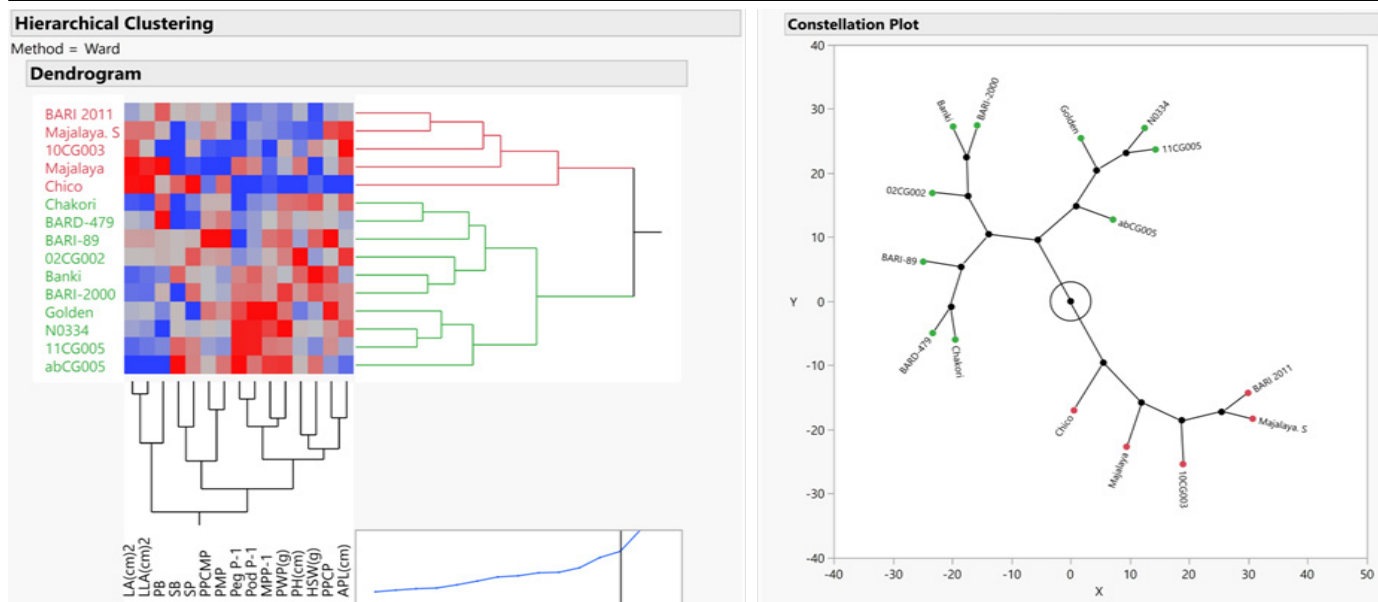


Figure 2: Cluster analysis indicates the degree of genetic diversity. Cluster diagram using WARD's method revealed three clusters. Cluster I comprise of five genotypes, cluster II contains six genotypes and cluster III contains four genotypes.

secondary branches (SB), whereas, PMP and MPP-1 have shown considerably greater variation for these genotypes, whereas PPCMP, Peg-1 and HSW have shown less variation for these genotypes. It was observed that, HSW, Pegs-1 and PPCMP had less variation in genotypes, but in genotypes Banki, 11CG005 and abCG005 a considerable magnitude of variability has been observed for these traits.

As indicated in the biplot, genotypes in cluster I are showing closer association of leaf area, leftlet area and primary braches. Moreover, results have also shown that genotypes falling in cluster II have shown a maximum number of Pods⁻¹, which is the most economically important character. Whereas genotypes falling in cluster III were also important regarding producing maximum number of pegs and hundred seed weight. The maximum number of pegs must be converted into mature pods from the total number of pegs produced; genotypes falling in cluster III have shown this property.

Regarding the association between parameters, there are also three clusters (Figure 2). In cluster I, there are three parameters LA, LLA, PB and there are four parameters in cluster II including SB, SP, PPCMP and PMP, while seven parameters such as Peg-1, Pods -1, MPP-1, PWP, PH, HSW, PPCP and ALP in cluster III have shown closer relation. The results are shown bycorrelation analyses also have shown the closer association of the above-mentioned arameters.

Genotypes were holding a significant variation for considered traits suggesting the importance of these candidate traits for the selection of genotypes regarding yield. Results provide the information of the amount of association of characters in correlation and splitting the correlation value into indirect and direct effects of characters to yield is useful for selection of traits in a breeding program.

The recorded percentage of pegs converted into pods in genotype BARI-89 was 83.20. Similarly, in Chico minimum of 52.83 percent pegs were converted into pods. Yadava *et al.* (1981) reported that an increased number of pods are not always the trait in favor of increased yield. An increase in number may decrease the seed size. Viability of pegs and time is also very important in relation to pods converted into proper pod. Sometime pegs cannot reach the soil till the proper time; this phenomenon is not in favors of high yield related to pegs. Similar findings were exhibited by Luz *et al.* (2011).

Number of mature pods determines the actual pod yield. According to percentage of pegs conversion in mature pods maximum percentage was seen in BARI-89 with 69.85%, whereas, Majalaya had a minimum percentage of pegs converted into mature pods of 30.58%. Attributes of mature pods are hard ls, filled and not shrunken. These features also favor quality and safety from fungal attack. Many previous researchers, Kumar (2004) and Mahalaksmi *et al.*

(2005) emphasized mature pods for the improvement of groundnut yield. It is evident that a number of pegs present at the lower portion of the groundnut plant penetrate well in the soil and can easily reach to the soil surface and the possibility of the number of pegs conversion into mature pods is increased (Godoy *et al.*, 1999 and Santose *et al.*, 2000; Jahanzaib *et al.*, 2020).

The maximum recorded shelling percentage was in genotype Chico with 71.10%, whereas genotype Golden showed a minimum shelling percentage with 61.38%. Effects of shelling percentage and mature kernels and shelling percentage through 100 seed weight exhibit positive results towards yield. Higher 100 seed weight in genotypes like Banki (58.17g), Chakori (52.1g) and BARI-2000 (52.1g) was recorded. Thus higher 100 seed weight can be attributed to high vigor of seeds of different peanut genotypes. These results are following the findings of Alam *et al.* (2014); Jeyaramraja *et al.* (2014).

(*Arachis hypogaea* L.), pod yield is a complex trait and depends upon the interaction between number of components traits. In this way, a correlation study helps understand each component's contribution to yield.

Association among the yield and yield related traits

Several important yield contributing characters were associated with each other and with yield, showing significant and highly significant genotypic correlation such as the number of pegs per plant (pegs-1), percentage of pegs converted into pods (PPCP), mature pods per plant (MPP-1) and average pod length (APL) showed positive and significant correlation with yield. These results could be proved helpful in the plan of improvement of character components of yield by taking these characters simultaneously in the next breeding program (Shukla *et al.*, 2014; Kumara *et al.*, 2015; Jain *et al.*, 2016; Ramakrishnan *et al.*, 2017; Trivikrama *et al.*, 2017; Rajarathinam *et al.*, 2017; Venkataravana *et al.*, 2020).

Information of extent of relationship between various characters is important for plant breeding researchers, to accomplish the goal of increased production by enhancing the yield potential of crop. In case of groundnut (*Arachis hypogaea* L.) pod yield is a complex trait and depends upon the interaction between numbers of components traits. In this way correlation

study helps in understanding the contribution of each component on yield.

LA and LLA were negative and highly significantly correlated with pod yield, indicating that increased vegetative growth may cause a decrease in pod yield. PB and SB had non-significant and negative genotypic correlation; similar results were reported by (Kumar *et al.*, 2014). Similarly, the results of other characters like PH, number of Pegs⁻¹ and MPP⁻¹ were positive and significant among themselves and with pod yield found in conformity with (Sadeghi *et al.*, 2012; Zaman *et al.*, 2011; Luz *et al.*, 2011). MPP⁻¹, number of Pods⁻¹, HSW, PH were significantly and positively associated with pod yield which directed that these components are important for improving pod yield in groundnut crops. Similar results have been reported by Ofori *et al.* (1996) regarding no. of mature pods per plant and total pods per plant respectively. Due to the pleiotropic effect and tight linkage between different characters, correlation arises. Thus, an association of yield-related characters is considered important in selecting preferred genotypes (Hampannavar *et al.*, 2018).

Direct and indirect effect of yield related traits

The correlation only provides the amount of relationship of characters, whereas at the same time, path analysis measures the direct effect of one variable upon another and enables the splitting of correlation coefficients into components of direct and indirect effects (Dewey *et al.*, 1959).

The Pegs-1, Pods-1, HSW, APL, PPCMP and MPP-1 are important traits under path analysis for taking in the improvement of yield. Hampannavar *et al.* (2018); Kumar *et al.* (2014) also observed that MPP⁻¹ effect on pod yield greatly but indirectly through kernel yield indicating the significance of these traits in the enhancement of seed yield.

LA, number of Pegs⁻¹, PPCP and MPP-1 had a positive direct effect greater than the genotypic correlation coefficient. Similarly No. of Pods⁻¹ and PPCMP have shown negative direct and greater effect than correlation coefficient which indicated that correlation is due to direct effect. While, PB, SB and SP had lesser negative direct effect and PH, APL and HSW demonstrated positive direct effect lesser than correlation coefficient which indicated that correlation is due to indirect effects (Shoba *et al.* (2012), (Thiruma-

la Rao. (2016); Rajarathinam *et al.* (2017); Trivikrama Reddy *et al.*, 2017).

These results were in agreement with those of Durga Rani *et al.* (1987) for the number of pods, shelling percentage and 100- seed weight and Ofori (1996) for the number of pods per plant, Vasnathi (1998) for 100-pod weight and Arjunan *et al.* (1999) for leaf area.

Conclusion and Recommendations

The mean values for genotypes N0334, abCG005 and BARI-2000 had maximum pod yield per plant among all the genotypes. In correlation studies yield related important parameters e.g No. of Pegs-1, No. of pods-1, MPP-1 demonstrated very highly significant and positive correlation with pod yield. The results of this correlation study can provide information for future breeding plans. No. of Pegs⁻¹, PH, PPCP and HSW were directly associated with yield. Path coefficient analysis results can be proved helpful in following careful restricted simultaneous selection model in case of higher direct effect and case of a lesser direct effect than correlation coefficient then it indicated that correlation is due to indirect effects. In Biplot analysis 02CG002, BARI-2000 and Golden have shown variation for Pod⁻¹ and PWP and N0334, Banki, 11CG005 and abCG005 abCG005 had a considerably greater variation for PMP and MPP⁻¹ whereas, PPCMP, Peg⁻¹ and HSW have also shown variation but in less amount. This analysis has indicated the genotypes showing variation for different traits. Genotypes clustered in groups have shown their closer association regarding parameters selected. Parameters clustered in groups have also demonstrated this relationship in correlation analysis which can be proved helpful in selection in further evaluation.

Novelty Statement

The mean values for genotypes N0334, abCG005 and BARI-2000 had maximum pod yield per plant among all the genotypes. In correlation studies yield related important parameters e.g No. of Pegs-1, No. of pods-1, MPP-1 demonstrated very highly significant and positive correlation with pod yield.

Author's Contribution

Shiguftah Khalid: Execute research plan.

Muhammad Jahanzaib: Wrote manuscript and logistics.

Haris Khurshid: Statistical analysis.

Rabia Khalid, Sundas Waqar and Faiza Siddique: Collected data.

Fazal Yazdan Saleem Marwat: Agronomic management.

Zahid Akram: Plan and supervise research.

Conflict of interest

The authors have declared no conflict of interest.

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