Relationship between yield and its components to detect the direct and indirect effects in some cowpea and guar genotypes

Fadia M. Sultan[1]; Walaa M. E. Mousa[1] and Zeinab E. Ghareeb[2]

[1]Forage Crop Res., Sec., Field Crop Res., Inst., Agric. Res. Center Giza, Egypt
[2]Central Lab. for Design and Stat. Res. Analysis, ARC

DOI: 10.29322/IJSRP.11.01.2021.p10931
http://dx.doi.org/10.29322/IJSRP.11.01.2021.p10931

Abstract- The present investigation was carried out at the experimental farm of Giza Agriculture Research Station, ARC, during 2018 and 2019 summer seasons. Seeds of the ten genotypes of cowpea (as stretched crop) and seven genotypes of guar (as standing crop) were separately sown in a randomized complete block design (RCBD) with three replications to determine the magnitude of variability and the degree of association between the different traits that is important to provide the base for effective selection for yield improvement. Analysis of variance revealed significant differences among both cowpea and guar genotypes for all studied traits. Genotypes P1, P2 and P3 of cowpea and G1, G2 and G3 of guar recorded the highest values of fresh and seed yield over the two seasons, indicating that these genotypes are promising and could be recommended to use among breeding programs. The highest estimates of heritability coupled with high genetic advance % values were observed for plant height, fresh yield/plant, number of pods per plant and pod length traits in cowpea, however, fresh yield, number of seeds per pod and pod length traits in guar, indicating that selection for these traits have more chance for cowpea and guar yield development among the tested genotypes. Correlation coefficient results suggest that selection for higher plant height, number of branches /plant, crude protein, ash% and root length would tend to increase fresh yield in both crops. However, crude fiber (CF %) was in guar only. The fresh yield/plant, number of pods/plant, pod length and 100-seed weight were the effective traits toward in both crops seed yield. However, number of seeds/pod was effective in guar only. Path analysis revealed that number of branches /plant, root length and crude protein (CP %) traits recorded directly and indirectly maximum influence on cowpea fresh yield, meanwhile, ash% trait gave same effects on guar fresh yield. Number of pods per plant recorded the highest direct and indirect contribution to cowpea seed yield; however, fresh yield gave the highest negative effect directly and indirectly on guar seed yield. Hence, these traits could be used in breeding program for the improvement of fresh and seed yield for high yielding cowpea and guar genotypes.

Index Terms- Correlation, Direct effect, Fresh Yield, Forage quality, Genetic Parameters, Heritability and Seed Yield.

I. Introduction

In Egypt, there are several summer forage crops as stretched (Cowpea) or standing (Guar) plants. Those could be used to narrow the gap between the available and required summer forage crops for livestock feeding especially in grass–legume mixtures to increase dry matter yield, protein percent and gave forage of better quality. Cowpea (*Vigna unguiculata* L.) is an important legume widely cultivated for forage, green pods and seeds (**Ali et al., 2004**). It forms an integral part of a sustainable agriculture and land use system **(Ogbonnaya et al., 2003)** and plays a considerable role in the nutritional balance and economy of the rural (**Krasova-Wade et al., 2006)**. Cowpea recipes could also substitute for animal proteins in vegetarian diets because of its rich nutritional value, protein and amino acids (**Boukar et al., 2011**). Some cultivars with seed protein content of about 30% have been reported (**Santos et al., 2012**). Guar (*Cyamopsis tetragonoloba* L.) is a multi-purpose plant, mostly used as a source of fresh yield and seed yield. It is considered as an important source of high quality inexpensive of nutritional quality protein (27-37%). It is an industrial crop and food products, feed for livestock and as a green manure crop (**Gresta et al., 2014**). Guar enhances soil productiveness by fixing atmospheric nitrogen for its own requirements and also for succeeding crop **(Bewal et al., 2009)**. Guar is a versatile and multi-used legume crop, cultivated mostly for vegetable, forage and cover crop **(Arora and Pahuja 2008)**.

In general, selection of promising crops genotypes in breeding program is based on various features, most importantly is final crop yield (grain or seed) and its quality. Relationships among yield and yield-contributing traits also play an important role (**Mohammadi et al., 2003 and Rabiei et al., 2004**). This information can be estimated by correlation analysis which provides associations for yield with other correlated traits. Correlation study is used in selection programs when highly heritable traits are associated with the important trait as yield **(Bizeti et al., 2004).** Consequently, to detect traits having influence on a final trait, path analysis is commonly applied.

In order to have a good choice of yield trait for selection of desirable genotypes under planned breeding program, knowledge of the nature and magnitude of variation existing in available plant breeding materials, the association of component traits with yield and their contribution through direct and indirect effects are very important. Genotypic and different components of variance, heritability and genetic advance have been calculated for different yield traits in cowpea by several workers **(Ubi et al., 2001; Omoigui et al., 2006)** which revealed that selection was effective for a population with broad genetic variability and trait with high heritability. For selection in guar and yield improvement, **Sultan et al. (2012) and Morris 2010** offer possibilities for developing more efficient plants with increased fresh forage yield potential, consequently identifying and quantifying the interrelationships between fresh forage yield and the influencing traits, whereas they were using the most suitable combinations of traits as selection criteria to achieve yield improvement.

These investigate focuses on selection of cowpea and guar genotypes with the most promising traits for agriculture purposes. Therefore, objectives of this study are providing basis for selection to improve fresh and seed yield in both cowpea and guar by: 1) investigating the interrelationships between yield (fresh forage and seed yield) and its components, 2) detect the direct and indirect effects of yield components and 3) estimating the expected genetic advance from selection. The selected genotypes can constitute a valuable initial material for further selection of high-yielding cultivars in plant breeding programs.

II. Materials and Methods

Plant Material and Experimental Design

To study the performance of ten genotypes of cowpea and seven genotypes of guar for yield and its components, this work was carried out at Giza Agriculture Research Station, ARC during 2018 and 2019 summer seasons. Seeds of the ten cowpea and seven guar segregations in size and colure genotypes were inoculated with Rhizobium prior to sowing. The experimental design was a randomized complete block (RCBD) with three replications. All agricultural practices were applied, the experimental plot was consisted of five ridges, 60cm apart and 3.5m long, hills spaced 20 cm and plants thinned to one plant per hill after complete emergence. 150 kg super phosphate (15.5% P_2O_5) was applied before sowing; 45kg/fed of urea (46% N) and 100 kg potassium sulphate (48% k_2O) were applied before live irrigation.

One cutting was taken after 60 days from sowing then the cowpea and guar plants were left for flowering and seed production. Ten guarded plants of each plot were chosen randomly as a sample which separated into their components i.e. leaves, stem and roots for measuring growth traits. The following growth traits were collected:-

- Plant height (cm): it was measured from soil surface up to the top of the plants.
- Number of branches/plant.
- Dry leaf/stem ratio.
- Root length (cm).
- Fresh forage yield (g): at cutting time (60 days from sowing).

At harvest time (according to maturity time for each cowpea and guar genotypes under study), Five individual guarded plants were randomly taken from the central ridge in each plot to determine:

- Pods number/plant
- Pods length/plant (cm)
- Seeds number/pod
- 100 – Seed weight (g)
- Seed yield (kg/fed) was obtained from a central ridges calculation to avoid the border effect.

Forage quality:-

- Plant samples for the first cut were used to determine Crude protein (CP %), Crude fiber (CF %) and Ash percentage (Ash %) according to **A.O.A.C. (1980).**

Statistical analysis

Differences between genotypes were determined for the data in each season/crop. Pooled analysis was carried out when the errors were homogeneous. The homogeneity of variances for each crop in the two seasons was checked by use of **Levene (1960)** test, and then combined across two seasons to test the significant differences among the studied genotypes in each crop, according to the standard statistical procedure described by **Steel and Torrie (1987**).

Genetic parameters (phenotypic and genotypic variance, heritability in broad sense (h_b^2) and the genetic advance percent of mean (GA %) at 5% selection intensity) for each trait/crop were estimated by using variance components method according to **Snedecor and Cochran (1981**).

Relationships between the traits were computed through phenotypic correlation and path coefficient. All simple correlation coefficients were worked out between all possible combinations of traits (**Snedecor and Cochran, 1989**). The path coefficients analysis appeared to provide clue to the contribution of various components of yield to overall fresh or seed yield in the populations under study. It provides an effective way of split up the total phenotypic correlation coefficients into direct and indirect effects of the yield components on fresh or seed yield and helps to understand the relationship among variables based on the general formula of **Duarte and Adams (1972)**.

III. Results and Disussion

Results revealed that the studied genotypes varied significantly for all the traits/crop in each season. The homogeneity of error across the two years was checked by use of **Levene (1960)** test, and then combined across the tested years was performed to test the significant differences among genotypes (G), years (Y), and genotype by years interaction (G x Y) in each crop.

Mean performance

In both cowpea and guar, mean performance indicated the existence of diversity among the all studied genotypes. **Table (1 and 2)** showed highly significant differences among the genotypes for all the studied traits in both crops. These results were in agreement with the findings of **Sultan et al. (2012)** and **Manivannan et al. (2015)** for guar and **Aliyu et al. (2019)** for cowpea.

In cowpea, results revealed significant differences among years (Y) for leaf/stem ratio, number of pod/plant and seed yield, meanwhile, genotype by year interaction (G x Y) significantly affected for plant height, leaf/stem ratio, CP %, root length, fresh yield, 100-seed weight and seed yield. In guar, results showed significant differences among years (Y) for plant height, leaf/stem ratio and 100-seed weight. Genotype by year interaction (G x Y) affected plant height, leaf/stem ratio, CP %, CF %, fresh yield, number of seed /pod, pod length and seed yield.

The differences between the years were not large, which was the result of low differences in weather conditions between the two years in both crops. These results indicates the presence of sufficient genetic variability for fresh and seed yield and its attributes among both cowpea and guar genotypes which selection can be based.

Regarding cowpea data, **Table (1 and 2)** revealed that the P1, P2 and P3 genotypes possessed the profuse number of branches /plant (11.17, 11.50 and 9.83, respectively), highest Ash% (11.77, 11.84 and 11.56, respectively), with tallest root length (38.84, 36.02 and 36.58 cm, respectively), heaviest fresh yield (238.18, 230.90 and 209.47 g, respectively), largest number of pods (45.32, 51.97 and 4.37 pods, respectively), pod length (15.64, 16.28 and 15.83 cm, respectively) and seed yield (499.63, 620.97 and 527.02 kg, respectively) across the two seasons. Genotypes P2, P1 and P4 had the tallest plants (145.58, 142.18 and 139.07 cm, respectively). Meanwhile, P10 and P9 gave profuse leaf/ stem ratio (1.83 and 1.65, respectively). Data revealed that genotypes P1 and P4 had the highest CP% (21.17 and 20.60%, respectively), while P9 and P5 recorded the highest CF% (32.02 and 31.70%, respectively). On the other hand, P3 and P2 possessed the highest number of seeds per pods (20.65 and 18.42 seeds, respectively). However, the heaviest weights of 100-seeds (14.87 and 13.75 g) were recorded by P1 and P2, respectively.

Table 1. Mean performance of some fresh yield traits for the ten cowpea and seven guar genotypes (combined across 2018 and 2019 seasons).

Genotype	Plant height (cm)	Number of branches /plant	Leaf/ stem ratio	Root length (cm)	Fresh yield (g)	CP %	CF %	Ash %
Cowpea genotypes								
P1	142.18	11.17	1.46	38.84	238.18	21.17	26.01	11.77
P2	145.58	11.50	1.29	36.02	230.90	20.25	25.46	11.84
P3	129.70	9.83	1.53	36.58	209.47	19.00	27.41	11.56
P4	139.07	9.00	1.24	24.58	188.52	20.60	29.27	10.78
P5	106.92	6.50	1.41	21.95	180.25	17.62	31.70	10.58
P6	87.80	6.17	1.28	21.09	155.85	16.79	30.88	9.90
P7	110.52	7.00	1.28	16.68	158.63	17.04	31.10	8.70
P8	114.72	8.00	1.44	19.16	139.75	17.54	28.94	8.42
P9	91.50	6.83	1.65	17.70	159.68	17.74	32.02	8.98
P10	114.37	7.17	1.83	27.62	171.40	20.31	29.48	8.93
Years (Y)	NS	NS	0.05	NS	NS	NS	NS	NS
Genotype (G)	6.51	2.19	0.08	1.63	10.68	1.05	1.61	0.74
G*Y	9.20	NS	0.12	2.30	15.10	1.48	NS	NS
Guar genotypes								
G1	134.23	7.67	1.35	7.40	207.63	20.31	30.36	10.82
G2	129.28	9.83	1.31	7.37	224.43	19.06	32.54	11.43
G3	118.37	7.50	1.18	6.75	177.20	20.95	30.09	10.36
G4	123.48	8.67	1.55	5.67	138.67	18.73	28.33	8.60
G5	110.38	6.17	1.54	4.77	108.62	17.67	27.37	7.69
G6	100.20	5.50	1.53	4.42	97.53	17.53	25.24	8.65
G7	94.73	5.83	1.55	4.14	104.40	15.87	26.98	8.13
Years (Y)	3.28	NS	0.06	NS	NS	NS	NS	NS
Genotype (G)	2.76	1.507	0.09	0.44	18.63	1.45	1.20	0.74
G*Y	3.90	NS	0.12	NS	26.35	2.05	1.70	NS

Concerning guar results, **Table (1 and 2)** revealed that genotypes G1, G2 and G3 possessed the highest CP % (20.31, 19.06 and 20.95%, respectively), recording the highest CF % (30.36, 32.54 and 30.09 %, respectively), Ash % (10.82, 11.43 and 10.36, respectively), tallest root length (7.40, 7.37 and 6.75 cm, respectively), with heaviest fresh yield (207.63, 224.43 and 177.20 g, respectively). These G1, G2 and G3 genotypes surpassed for all tested seed yield traits, recorded the highest number of pods per plant (128.88, 134.59 and 124.87 pods, respectively), possessed the highest number of seeds per pods (10.83, 10.33 and 9.33 seeds, respectively), had the tallest pod length (5.95, 4.98 and 6.42 cm, respectively), showed the heaviest weights of 100-seeds (4.66, 4.22 and 4.60 g, respectively) and produced the highest seed yield (409.22, 346.15 and 367.08 kg, respectively) across the two seasons. Meanwhile G1 and G2 had the tallest plants (134.23 and 129.28 cm, respectively). On the other hand, G2 and G4 possessed the highest number of branches/plant (9.83 and 8.67 branches, respectively). The results revealed that the G4 and G7 genotype had the highest leaf/ stem ratio (1.55) across the two seasons.

Table 2. Mean performance of some seed yield traits for the ten cowpea and seven guar genotypes (combined across 2018 and 2019 seasons).

Cowpea Genotype	Number of pod/plant	Number of seed /pod	Pod length (cm)	100-seed weight (g)	Seed yield (Kg/fed)
Cowpea genotypes					
P1	45.32	15.50	15.64	14.87	499.63
P2	51.97	18.42	16.28	13.75	620.97
P3	48.37	20.65	15.83	10.74	527.02
P4	39.71	17.66	13.96	10.91	370.00
P5	34.95	13.83	11.61	9.01	392.95
P6	35.27	11.32	10.53	10.66	379.62
P7	33.11	12.05	9.78	10.39	360.42
P8	27.32	14.94	9.38	9.08	334.15
P9	33.91	16.92	10.49	11.98	274.05
P10	31.57	17.82	14.16	11.02	348.43
Years (Y)	2.298	NS	NS	NS	35.32
Genotype (G)	3.506	1.963	1.439	1.286	10.2
G*Y	NS	NS	NS	1.818	14.43
Guar genotype					
G1	128.88	10.83	5.95	4.66	409.22
G2	134.59	10.33	4.98	4.22	346.15
G3	124.87	9.33	6.42	4.60	367.08
G4	102.18	7.33	3.77	3.91	246.72
G5	101.27	6.33	3.08	3.19	274.63
G6	87.43	6.00	3.38	3.56	282.53
G7	108.18	6.33	2.88	3.32	285.82
Years (Y)	NS	NS	NS	0.251	NS
Genotype (G)	8.28	0.739	0.383	0.412	25.88
G*Y	NS	1.045	0.542	NS	36.61

The highest yielder genotypes combined across the two seasons were P1, P2 and P3 in cowpea and G1, G2 and G3 in guar for fresh and seed yield respectively. Meanwhile, the lowest one was cowpea P8 and guar G6 for fresh yield. On the other hand, cowpea p9 and guar G4 recorded the lowest seed yield. These results are in harmony with those reported by **Davis et al., (1986), Sharawy and El-Fiky (2003)** who found significant differences among tested genotypes for seed yield and its related traits.

IV. Correlation Studies

The correlation coefficients among all pairs of fresh yield studied traits of cowpea and guar over the two seasons are given in Table (3). In cowpea fresh yield, results showed that there was a highly significant positive correlation between fresh yield/plant and each of plant height (0.75**), number of branches/plant (0.79**), crude protein (CP %) (0.71**), Ash % (0.82**) and root length (0.84**). It is suggested that fresh yield/plant of cowpea may be raised through selection for tallness plant, more branches, crude protein, crude fibers, Ash% and tallness root, which is evident in the present study. It is observed that crude fiber (CF %) recorded, highly significant negative correlation with all studied traits except leaf/ stem ratio, meaning crude fiber (CF %) forming decrease other fresh yield studied traits. on the contrary for Ash% was highly significant positive correlation with other studied traits except leaf/ stem ratio, meaning these fresh yield correlated traits increase Ash % forming. Leaf/stem ratio correlation with all studied traits may be independent in their genetic behavior under the tested cowpea genotypes.

Table 3. Correlation coefficients among fresh yield studied traits of cowpea and guar genotypes (data n= 30 and 21, respectively).

Trait	Crop	Plant height	Number of branches /plant	Leaf/ stem ratio	CP %	CF %	Ash %	Root length
Number of branches / plant	Cowpea	0.81**						
	Guar	0.77**						
Leaf/stem ratio	Cowpea	-0.21	-0.16					
	Guar	-0.49	-0.45					
CP %	Cowpea	0.74**	0.58**	0.29				
	Guar	0.79**	0.50	-0.66*				
CF %	Cowpea	-0.72**	-0.83**	0.02	-0.58**			
	Guar	0.78**	0.81**	-0.60*	0.64*			
Ash %	Cowpea	0.65**	0.63**	-0.22	0.53*	-0.64**		
	Guar	0.72**	0.69**	-0.75**	0.61**	0.78**		
Root length	Cowpea	0.73**	0.77**	0.10	0.61	-0.76**	0.75**	
	Guar	0.87**	0.68**	-0.66**	0.70**	0.81**	0.87**	
Fresh yield	Cowpea	0.75**	0.79**	-0.02	0.71**	-0.72**	0.82**	0.84**
	Guar	0.83**	0.79**	-0.73**	0.65*	0.87**	0.92**	0.93**

* and ** indicate significant at 0.05 and 0.01 level of probability, respectively.

In guar fresh yield, plant height (0.83**), number of branches/plant (0.79**), crude fibers (CF %) (0.87**), Ash% (0.92**) and root length (0.93**) were highly significant positive. Crude protein (CP %) had only significant positive association with fresh yield /plant (0.65*). However, highly significant negative association between leaf/ stem ratio and fresh yield/plant (-0.73**) was also observed, indicating that the light leaf/ stem ratio produced more fresh yield/plant. Then, fresh yield /plant may be raised through selection for more tall plant, profuse branches, crude protein, crude fibers, Ash % and tallness root with less leaf/ stem ratio. It is mentioned that crude fibers (CF %) recorded, highly significant and significant positive correlation with all studied traits except leaf/ stem ratio, therefore crude fibers (CF %) considered as a highly important former for fresh yield correlated traits in guar.

The estimates of correlation coefficient between seed yield and some yield related traits were shown in **Table 4**. In cowpea, seed yield components exhibited that there was a highly significant positive association between seed yield trait and each of fresh yield/plant (0.72**), number of pods/plant (0.85**) and pod length (0.67**), and had significant positive correlation with 100-seed weight (0.45*). It is evident that the selection for the previous traits would improve the productivity of cowpea because of their positive and significant association with seed yield. These results concur with those reported by **Aliyu and Makinde (2016) and Aliyu et al. (2019).** Meanwhile, insignificant association between number of seed/pod with 100-seed weight and seed yield was also observed, indicating that these traits may be independent in their genetic behavior under the tested cowpea genotypes. These results were in agreement with **Aliyu and Makinde (2016) and Aliyu et al. (2019),** which suggest available genetic improvement of cowpea seed yield by selection for these traits.

In guar seed yield, results showed that there was a highly significant positive correlation between seed yield and each of plant height (0.78**) and number of branches /plant (0.81**). These findings indicate that selection for each or all of these traits would be accompanied by high guar seed yield. This agrees with **Manivannan et al. (2015)** for number of pods/plant. It is mentioned that fresh yield components exhibited various trends of association among themselves in both cowpea and guar crops, however crude fiber (CF %) was highly for fresh yield trait in guar as standing crop, in contrary cowpea as stretched crop. Therefore, selection for plant height, number of branches /plant, crude protein, Ash% and root length was effective for both guar and cowpea fresh yield trait. Meanwhile, fresh yield/plant, number of pods/plant, pod length and 100-seed weight was the effective both guar and cowpea seed yield trait.

Table 4. Correlation coefficients among seed yield studied traits of cowpea and guar genotypes (data n= 30 and 21, respectively).

Trait	Crop	Fresh yield	Number of pod/plant	Number of seed /pod	Pod length	100-seed weight
Number of pod/plant	**Cowpea**	0.84**				
	Guar	0.85**				
Number of seed/pod	**Cowpea**	0.49*	0.49*			
	Guar	0.91**	0.88**			
Pod length	**Cowpea**	0.88**	0.81**	0.72**		
	Guar	0.78**	0.76**	0.87**		
100-seed weight	**Cowpea**	0.75**	0.60**	0.31	0.62**	
	Guar	0.75**	0.65*	0.79**	0.90**	
Seed yield	**Cowpea**	0.72**	0.85**	0.28	0.67**	0.45*
	Guar	0.67**	0.78**	0.82**	0.84**	0.78**

* and ** indicate significant at 0.05 and 0.01 level of probability, respectively.

It is mentioned that fresh yield components exhibited various trends of association among themselves in both cowpea and guar crops, however crude fiber (CF %) was highly for fresh yield trait in guar as standing crop, in contrary cowpea as stretched crop. Therefore, selection for plant height, number of branches/plant, crude protein, Ash% and root length was effective for both guar and cowpea fresh yield trait. Meanwhile, fresh yield/plant, number of pods/plant, pod length and 100-seed weight was the effective both guar and cowpea seed yield trait.

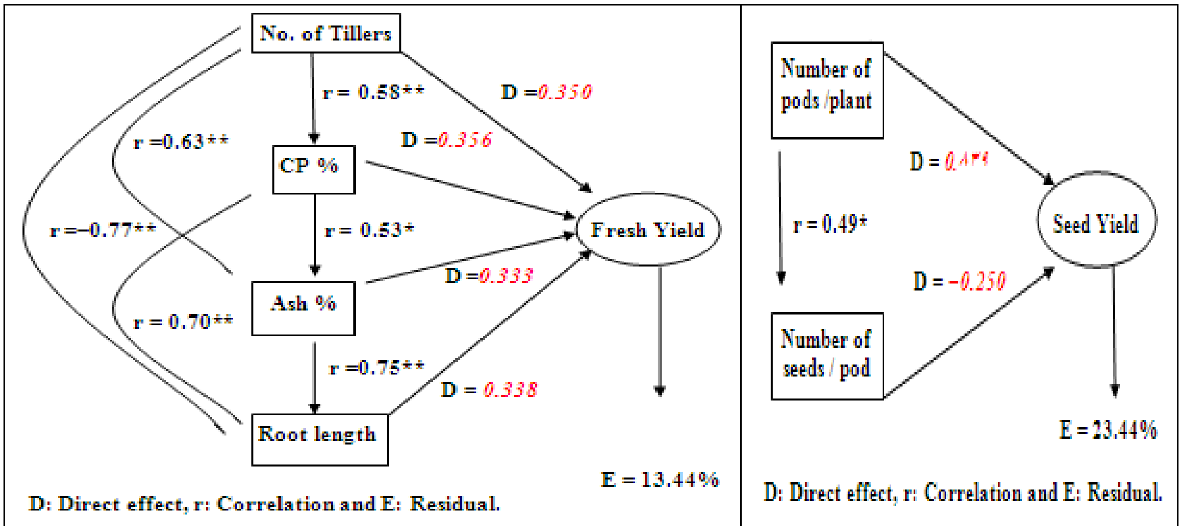
V. Path analysis

The obvious correlation coefficients obtained can be explained by partitioning the correlation coefficients into direct and indirect effects for given set of causal interrelationships. Originally, several symptoms were obtained before path analysis as test the multi-collinearity problem. Direct effects were below one, indicating the absence of multi-collinearity or were minimal for all yields/crop (**Gravois and Helms 1992**). Then, path analysis was performed for all yields-related traits. Direct and indirect effects for different significant seven yield-related traits on cowpea and guar fresh yield are summarized in **Table (5).** In the studied cowpea fresh yield, it is observed that positive direct effects were recorded for all fresh yield traits, except plant height (-0.200) and leaf/stem ratio (-0.076), which were small and negligible, respectively. The results indicated that crude protein (CP %) with (0.356), number of branches per plant (0.350), root length (0.338) and Ash % (0.333) revealed the highest positive direct effect on fresh yield followed by crude fiber (CF %) with (0.102).

Regarding the considerable components of the indirect effects, it is noted that number of plant height had positive large indirect effects on fresh yield through their associations with number of branches (0.282), crude protein (0.262) and root length (0.245). However, the leaf/stem ratio exhibited a considerable positive influence on fresh yield (0.104) through their associations with crude protein (CP %). Meanwhile, a strong negative influence on fresh yield was indirectly recorded by crude fiber (CF %) *via* the number branches per plant (-0.291). **Figure (1)** revealed the effective direct and indirect variables on forage cowpea fresh yield across all genotypes.

The previous observed values had the relative importance for the other direct and indirect effects. The studied seven traits totally explained (86.56 %) of fresh yield variation. In accordance, the residual part may be attributed to unknown variation, committing of errors (13.44 %) during measuring the studied cowpea fresh yield-traits and/or some other traits that were not incorporated in the present investigation. On the basis of obtained results of the cowpea fresh yield-traits, among the components of fresh yield, number of branches /plant, root length and crude protein (CP %) are the most reliable fresh yield components as selection criteria.

In this guar, the matrix of direct and joint effects for the seven related traits on fresh yield/plant is shown in **Table (5)**. Positive direct effects were recorded for all fresh yield traits, except leaf/stem ratio (-0.205) and crude protein (CP %) with (-0.281). The results indicated that Ash% (0.374) exerted the highest positive direct effect on fresh yield followed by plant height (0.301). From the results it can be concluded that fresh yield can be increased by selecting genotypes having more ASH% and plant height. Indirect plant height, number of branches/plant, CP%, CF % and root length affected fresh yield/plant positively and high through their association with Ash % (0.269, 0.256, 0.257, 0.290 and 0.323, respectively). Then, Ash% affected fresh yield positively and indirectly through all the traits except for leaf/stem ratio that recorded negative and high indirect effect on fresh yield (-0.282). However, the indirect effects for the Ash% were more important compared to direct effects in number of branches/plant, leaf/stem ratio, CF % and root length**.** Therefore, there is large scope of simultaneous improvement in guar fresh yield as well as other yield components through selection taking into consideration these pairs of traits. Generally, these studied traits recorded 97.01 % of fresh yield variation. The residual component (2.99 %) may be contributed to unknown variation (other traits that were not considered in this study). **Figure (2)** revealed the effective direct and indirect variables on guar fresh yield across all genotypes.



Fresh yield	**Seed** yield

Fig. 1. Diagrammatic representation of effective direct and indirect variables on forage cowpea yield across all genotypes.

Table 5. Direct (diagonal) and indirect effects of components traits attributing to fresh yield in the studied cowpea and guar genotypes.

Trait	Crop	Plant height	No. of branches / Plant	Leaf /stem ratio	CP %	CF %	Ash %	Root length	Correlation with fresh yield
Plant height	**Cowpea**	***-0.200***	0.282	0.016	0.262	-0.073	0.217	0.245	0.749**
	Guar	***0.301***	0.041	0.100	-0.223	0.142	0.269	0.196	0.83**
No. of branches/plant	**Cowpea**	-0.161	***0.350***	0.012	0.207	-0.085	0.209	0.258	0.791**
	Guar	0.231	***0.054***	0.092	-0.141	0.146	0.256	0.154	0.79**
Leaf/stem ratio	**Cowpea**	0.043	-0.056	***-0.076***	0.104	0.002	-0.074	0.033	-0.024
	Guar	-0.147	-0.024	***-0.205***	0.186	-0.108	-0.282	-0.148	-0.73**
CP %	**Cowpea**	-0.147	0.203	-0.022	***0.356***	-0.059	0.176	0.206	0.713**
	Guar	0.238	0.027	0.136	***-0.281***	0.116	0.257	0.158	0.65*
CF %	**Cowpea**	0.143	-0.291	-0.002	-0.205	***0.102***	-0.214	-0.255	-0.722**
	Guar	0.236	0.043	0.123	-0.181	***0.180***	0.290	0.183	0.87**
Ash %	**Cowpea**	-0.130	0.220	0.017	0.188	-0.065	***0.333***	0.253	0.816**
	Guar	0.216	0.037	0.155	-0.193	0.140	***0.374***	0.195	0.92**
Root length	**Cowpea**	-0.145	0.268	-0.008	0.217	-0.077	0.250	***0.338***	0.843**
	Guar	0.261	0.037	0.135	-0.197	0.146	0.323	***0.226***	0.93**

Cowpea Residuals% 13.44% Guar Residuals% 2.99%

* and ** indicate significant at 0.05 and 0.01 level of probability, respectively.

The direct (diagonal) and indirect contributions of yield attributes to the seed yield of studied cowpea and guar genotypes are presented in **Table (6).** In cowpea, the direct contribution of fresh yield to seed yield was (0.127), whereas the highest indirect contribution came through number of pods per plant. The number of pods per plant direct participation to seed yield was (0.839), while the highest indirect part was exhibited by pod length. Meanwhile, number of seeds per pod and 100-seed weight exhibited low and negative direct contribution (-0.250 and -0.164, respectively). In contrast, its indirect contribution through number of pods per plant was the highest and positive (0.412 and 0.501) for both seeds per pod and 100-seed weight, respectively. Similarly, although the direct contribution of pod length to the seed yield of cowpea was low and positive (0.155), its indirect participation through number of pods per plant was high (0.683). The last studied five traits totally explained (76.56%) of seed yield variation, calculating the residual part from unknown variation as errors (23.44%). The highest direct contribution was exhibited by number of pods per plant, while the indirect contributions via other traits were relatively low. The path coefficient analysis showed that number of pods per plant showed the highest direct contribution and percentage yield contribution to seed yield in cowpea. These findings are in agreement with **Kwaga (2014)** and **Sanganamoni et al. (2016), Neeraj*et al.* (2017) Jonah and Kwaga (2019),** who's established that number of pods/plant was a major contributor to the yield of cowpea. **Figure (1)** revealed the effective direct and indirect variables on forage cowpea seed yield across all genotypes.

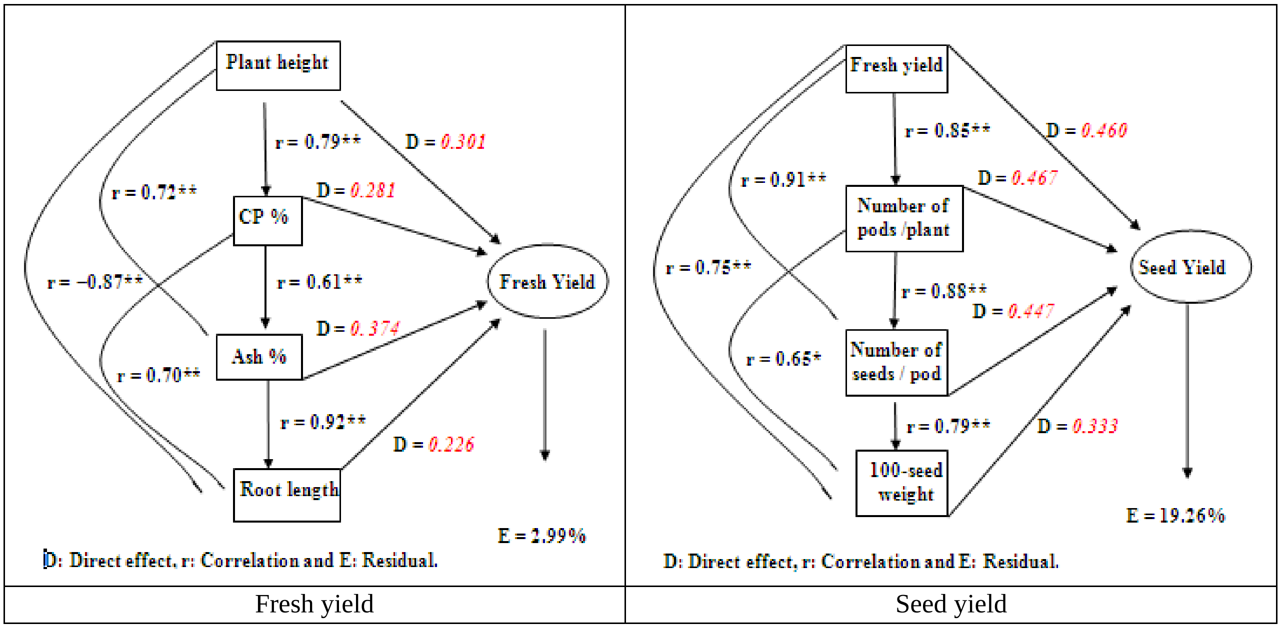


Fig. 2. Diagrammatic representation of effective direct and indirect variables on guar yield across all genotypes.

In guar, the negative direct participation of fresh yield to seed yield was recorded (-0.551), while the highest indirect participation was exhibited by number of seeds per pod (0.406) followed by number of pods per plant (0.390). On the other side, number of pods per plant presented direct positive contribution to seed yield (0.460) while the highest indirect contribution was revealed by fresh yield as negative value (-0.467). Similarly, number of seeds per pod, pod length and 100-seed weight demonstrated direct positive contribution to seed yield (0.447, 0.232 and 0.333, respectively). However, its highest indirect contribution through fresh yield to seed yield exhibited high and negative values (-0.500, -0.432 and -0.411, respectively).

Table 6. Direct (diagonal) and indirect effects of components traits attributing to seed yield in the studied cowpea and guar genotypes.

Trait	Crop	Fresh yield	Pods no. /plant	Seeds no./pod	Pod length	100-seed weight	Correlation with seed yield
Fresh yield	Cowpea	***0.127***	0.703	-0.122	0.136	-0.122	0.722**
	Guar	***-0.551***	0.390	0.406	0.182	0.248	0.674**
Pods no./plant	Cowpea	0.107	***0.839***	-0.123	0.126	-0.098	0.851**
	Guar	-0.467	***0.460***	0.393	0.176	0.216	0.779**
Seeds no./pod	Cowpea	0.062	0.412	***-0.250***	0.111	-0.051	0.284
	Guar	-0.500	0.405	***0.447***	0.203	0.263	0.817**
Pod length	Cowpea	0.112	0.683	-0.180	***0.155***	-0.101	0.669**
	Guar	-0.430	0.350	0.390	***0.232***	0.299	0.840**
100-seed weight	Cowpea	0.095	0.501	-0.078	0.096	***-0.164***	0.450*
	Guar	-0.410	0.298	0.354	0.209	***0.333***	0.783**

Cowpea Residuals% 23.44% Guar Residuals% 19.26%

* and ** indicate significant at 0.05 and 0.01 level of probability, respectively.

Therefore, number of pods per plant and seeds per pod could also be important traits which should be viewed in selection program for guar improvement, since it contributed remarkably to seed yield. These studied traits recorded 80.74% of seed yield variation. The residual component (19.26%) may be contributed to unknown variation. Then, the path coefficient analysis showed that fresh yield exhibited the highest negative direct and indirect contribution to guar seed yield; which was greater than all the contributions of the other traits. **Figure (2)** presented the effective direct and indirect variables on forage cowpea and guar seed yield across all genotypes.

VI. Genetic parameters

Observed highly significant differences for all the traits indicated to the variation was genetic and provides a good chance of improvement in studied cowpea and guar genotypes. The genotypic coefficient of variability (GCV %) and phenotypic coefficient of variability (PCV %), broad sense heritability and expected genetic advance (as percentage of mean) for various studied traits are presented in **Table (7).** Generally, phenotypic coefficient of variability (PCV %) was higher than corresponding genotypic coefficient of variability (GCV %) for all studied traits in both crops which demonstrated the environmental effect upon the traits. The highest estimates of genotypic coefficient of variability (PCV % and GCV %) were observed for root length (32.53 and 31.80%), number of branches (31.77and 20.74%), seed yield (27.62 and 23.48), pod length (22.76 and 20.83) and number of pods/plant (22.07 and 20.67) in cowpea. Meanwhile, fresh yield (36.67and 33.13%), pod length (33.75and 32.50), number of seeds/pod (27.20 and 24.30), number of branches (27.11and 20.21%) and root length (24.78 and 23.89%) exhibited highest PCV % and GCV % values, respectively in guar. That indicates the presence of exploitable genetic variability for root length, number of branches and pod length traits in both two crops.

The estimates of heritability (h^2) in broad sense and expected genetic advance (GA %) for different studied traits/crop were calculated. Across cowpea traits, number of branches per plant, leaf/stem ratio, crude fiber (CF %), ash% and 100-seed weight showed relatively low h^2values (ranged from 39.18 and 59.82%). In contrast, h^2estimates were comparatively high (between 72.31 and 95.52%) for all other fresh and seed yield cowpea traits. Meanwhile, all the guar yield traits had relatively higher h^2values that ranged from (92.94 to 69.35) except number of branches per plant, ash% and crude fiber (CF %) that recorded the relatively lowest h^2values (55.56, 55.93 and 56.15, respectively).

Estimates of GA (as % of the mean) in **Table (7)** ranged from 10.79% for crude fiber (CF %) to 64.01% for root length in cowpea; however in guar GA ranged from 11.49% for crude fiber (CF %) to 64.48% for pod length. Generally, higher estimates of GA % were observed for root length (64.01%), seed yield (41.14%), number of pods per plant (39.87%), pod length (39.28%), fresh yield (32.65%), number of seeds per pod (32.64%) and plant height (31.73%) in cowpea. Meanwhile, traits of pod length (64.48%), fresh yield (61.66%), root length (47.44%), number of seeds per pod (44.71%), number of branches per plant (31.03%) and seed yield (30.75%) recorded the higher estimates in guar. That indicates the presence of exploitable genetic variability for root length, fresh yield per plant, number of seeds per pod, pod length and seed yield traits across both crops (cowpea and guar) and can be improved through selections effectively.

Generally, high heritability estimates coupled with high genetic advance% were observed for plant height, fresh yield, number of pods per plant and pod length traits in cowpea crop, and fresh yield, number of seeds per pod and pod length traits in the guar crop. From the results of both crops, it can be concluded that these traits are controlled by additive type of gene action and could be improved through selection. It is mentioned that number of pods per plant is important in cowpea yield crop improvement by selection; however number of seeds per pod is more important in guar yield crop.

Table 7. Variability coefficient, heritability and expected genetic advance for studied cowpea and guar traits**.**

Trait	**Cowpea**				**Guar**			
	PCV %	**GCV %**	**h^2 %**	**GA %**	**PCV %**	**GCV %**	**h^2 %**	**GA %**
Plant height	18.16	16.73	84.79	31.73	13.14	12.41	89.24	24.15
No. of branches /plant	31.77	20.74	42.63	27.89	27.11	20.21	55.56	31.03
Leaf/stem ratio	16.10	10.08	39.18	13.00	11.72	9.76	69.35	16.74
Crude protein (CP %)	10.64	7.47	95.52	10.79	11.42	8.55	92.94	13.20
Crude fiber (CF %)	9.36	7.24	49.25	11.53	9.97	7.46	56.15	11.49
Ash%	14.48	12.77	59.82	23.20	15.66	13.81	55.93	25.09
Root length	32.53	31.80	77.77	64.01	24.78	23.89	77.80	47.44
Fresh yield	19.24	17.47	82.38	32.65	36.67	33.13	81.63	61.66
Pods no./plant	22.07	20.67	87.69	39.87	16.63	14.84	79.62	27.27
Seeds no./pod	20.72	18.12	76.48	32.64	27.20	24.30	79.79	44.71
Pod length	22.76	20.83	83.77	39.28	33.75	32.50	92.75	64.48
100-seed weight	19.81	14.79	55.76	22.76	17.44	14.40	68.21	24.51
Seed yield	27.62	23.48	72.31	41.14	20.46	17.48	72.95	30.75

VII. Conclusion

The finding of this study indicated that there is some range of variability in both cowpea and guar genotypes. Understanding the magnitude of variability and the degree of association between the different traits is important to provide the base for effective selection for yield improvement in ten genotypes of cowpea (as stretched crop) and seven genotypes of guar (as standing crop). A combined analysis of variance over the two seasons revealed significant differences among both cowpea and guar studied genotypes for all studied traits. Genotypes P1, P2 and P3 in cowpea and G1, G2 and G3 in guar recorded the highest values of fresh and seed yield over the two seasons, indicating that these genotypes are promising and could be recommended for release. Correlation coefficients for fresh yield components exhibited various trends of association among themselves in both cowpea and guar crops and crude fiber (CF %) was highly important for fresh yield trait in guar as standing crop, in contrary cowpea as stretched crop. Therefore, selection for plant height, number of branches /plant, crude protein, Ash% and root length was effective for both guar and cowpea fresh yield trait. Meanwhile, fresh yield/plant, number of pods/plant, pod length and 100-seed weight was the effective in both guar and cowpea seed yield trait, however number of seeds/plant was effective in guar only.

Results of path analysis revealed that the seven studied traits totally explained (86.56%) of fresh yield variation. In accordance, the residual part may be attributed to unknown variation, committing of errors (13.44%). fresh per plant in cowpea showed that number of branches /plant, root length and crude protein (CP %) are the most reliable fresh yield components as selection criteria. On the other hand, traits totally recorded 97.01% of guar fresh yield variation with residual component (2.99%)**,** however Ash% trait gave the maximum influence directly and indirectly. The studied five seed yield traits totally explained (76.56%) of cowpea seed yield variation, recording the number of pods per plant as the highest direct and indirect contribution. Meanwhile, seed yield traits in guar recorded 80.74% of seed yield variation. Therefore, there is large scope of simultaneous improvement in cowpea and guar yield as well as other yield components through selection taking into consideration these traits. High heritability (h^2) estimates coupled with high genetic advance% (GA %) were observed for plant height, fresh yield/plant, number of pods per plant and pod length traits in cowpea crop (as stretched plants). However, fresh yield, number of seeds per pod and pod length traits in the guar crop (as standing plants), indicating that these traits are controlled by additive gene effects and could be improved through selection.

References

[1] A.O.A.C. (1980). Association of official agricultural chemists In (Official Methods of Analysis). 13 Ed . The A.O.A.C., Washington D. C., U.S.A.

[2] Ali, Y., Z. Aslam, F. Hussain and A. Shakur (2004). Genotype and environmental interaction in cowpea (Vigna unguiculata L.) for yield and disease resistance. Inter. J. Environ. Sci. Technol., 1 (2): 119- 123.

[3] Aliyu O. M. and B. O. Makinde (2016). Phenotypic analysis of seed yield and yield components in cowpea (Vigna unguiculata L. Walp). Plant Breed. Biotech. 4: 252-261.

[4] Aliyu, O. M., O. O. Lawal, A. A. Wahab and U. Y. Ibrahim (2019). Evaluation of advanced breeding lines of cowpea (Vigna unguiculata L. Walp) for high seed yield under farmers' field Conditions. Plant Breed. Biotech. 7(1):12-23.

[5] Arora, R. N. and S. K. Pahuja (2008). Mutagenesis in guar (Cyamopsis tetragonoloba L.,Taub.). Plant Mutation Repotrs, 2:1.

[6] Bewal, S., J. Purohit, A. Kumar, R. Khedasana and S. Rama Rao (2009). Cytogenetical investigations in colchicines-induced tetraploids of (Cyamopsis tetragonoloba L.Czech J.Cenet.Plant Breed., 45:143-154.

[7] Bizeti H. S., C. G. P. deCarvalho, J. R. P. deSouza and D. Destro (2004). Path Analysis under Multicollinearity in Soybean. Agron. J., 47(5): 669-676.

[8] Boukar O., F. Massawe, S. Muranaka, J. Franco, B. Maziya-Dixon and B. Singh (2011). Evaluation of cowpea germplasm lines for protein and mineral concentrations in grains. Plant Genet. Resour. 9: 515-522.

[9] Davis, D.W., D. B. Marsh and M.N. Alvarez (1986). MN13 and MN150 cowpea breeding lines. HortScience 2(4):1080-1081.

[10] Duarte, R.A. and M.W. Adams, (1972). A path coefficient analysis of some yield components interrelation infield beans (Phaseoleus vulgaris L.). Crop Sci., 12(5): 579-582.

[11] Gravois, K. A. and R. S. Helms (1992). Path analysis of rice yield and yield components as affected by seeding rate. Agron. J., 84: 1 – 4.

[12] Gresta F., A. I. De Luca, A. Strano, G. Falcone, C. Santonoceto, U. Anastasi and G. Gulisano (2014). Economic and environmental sustainability analysis of guar (Cyamopsis tetragonoloba L.) farming process in a Mediterranean area: two case studies. Ital J Agron. 9 (1):20-24.

[13] Jonah, P.M. and Y.M. Kwaga (2019). Genetic interrelationship among quantitative traits and path analysis of some West African okra (Abelmoschus caillei) genotypes. Agricultural Science and Technology, 11(1):3 – 7.

[14] Krasova-Wade T., O. Diouf, I. Ndaye, C.E. Sall, S. Braconnier and M. Neyra (2006). Water-condition effects on rhizobia competition for cowpea nodule occupancy. Afri. J. Biotechnol. 5 : 1457-1463.

[15] Kwaga Y. M. (2014). Direct and indirect contribution of Yield Attributes to the Kernel yield of Groundnut (Arachis hypogaea L.) grown under Alectra infestation at Samaru, Nigeria. International Journal of Engineering Science (IJRES) 2:9-11.

[16] Levene, H. (1960). Robust tests for equality of variances. In Ingram Olkin, Harold Hotelling, Etalia, Stanford University Press, P. 278-292.

[17] Manivannan, A., C. R. Anandakumar, R. Ushakumari and G. S. Dahiya (2015). Genetic Diversity of Guar Genotypes (Cyamopsis Tetragonoloba (L.) Taub.) Based on Agro-Morphological Traits. Bangladesh J. Bot. 44(1): 59-65.

[18] Mohammadi, S. A., B.M. Prasanna and N. N. Singh (2003). Sequential path model for determining interrelationships among grain yield and related characters in maize. Crop Science 43:1690–1697.

[19] Morris, J.B. 2010. Morphological and reproductive characterization of guar (Cyamopsis tetragonoloba) genetic resources regenerated in Georgia, USA. Genet. Resour. Crop. Evol., 57: 985-993.

[20] Neeraj S, K. S. Dhirendra, P. Pooja, P. Ankit and R. Monisha (2017). Correlation and Path Coefficient Studies in Okra (Abelmoschus esculentus L. Moench). International Journal of Current Microbiology and Applied Sciences 6:1096-1101.

[21] Ogbonnaya C.I., B. Sarr, C. Brou, O. Diouf, N.N. Diop and H. Roy-Macauly (2003). Selection of cowpea in hydroponics, pots and field for drought tolerance. Crop Sci. 43: 1114 – 1120.

[22] Omoigui L. O., M. F. Ishiyaku, A. Y. Kamara, S. O. Alabi and S. G. Mohammed (2006). Genetic variability and heritability studies of some reproductive traits in cowpea [Vigna unguiculata (L.) Walp.]. Afr. J. Biotechnol., 5(13):1191-1195.

[23] Rabiei, B., M. Valizadeh, B. Ghareyazie and M. Moghaddam (2004). Evaluation of selection indices for improving rice grain shape. Field Crops Research 89:359–367.

[24] Sanganamoni M., S. Revanappa, B. P. Shivashankar and K. Muthaiah (2016). Correlation and Path Coefficient studies in okra (Abelmoschus esculentus L. Moench). Research in Environment and Life Sciences, 9:999-101.

[25] Santos, C.A.F., D.C. Campos da Costa, W Roberto da Silva and L.S. Boiteux (2012). Genetic analysis of total seed protein content in two cowpea crosses. Crop Sci., 52: 2501-2506.

[26] Sharawy.Wafaa.M. and Z.A.El-Fiky(2003). Characterization of cowpea (vigna unguiculata (L) walp) grnotypes based on yield traits and RAPD-PCR analyses. Arab J. Biotech. 6(1):67-78.

[27] Snedecor, G.W. and W.G. Cochran (1981). Statistical Methods. 7th ed. Iowa State Univ. Press, Ames., Lowa, USA.

[28] Snedecor, G. W. and W. G. Cochron (1989). Statistical Methods. 8th Ed., Iowa State Univ. Press, Ames Iowa, USA.

[29] Steel, R.G.D. and J.H. Torrie, (1987). Principles and Procedures of Statistics. A Biometrical Approach. 2nd Ed. 6th printing. Mc. Graw. Hill BooK company. USA: 272-277.

[30] Sultan M., Yousaf M. N., Rabbani M. A., Shinwari Z. K. and Masood M. S. (2012). Phenotypic divergence in guar (Cyamopsis tetragonoloba L.) landrace genotypes of Pakistan. Pak. J. Bot. 44: 203-210.

[31] Ubi E. B., H. Mignouna and G. Obigbesan (2001). Segregation for seed weight, pod length and days to flowering following cowpea cross. Afr. Crop Sci. J., 9(3): 463-470.

AUTHORS

First Author – Fadia M. Sultan, Forage Crop Res., Sec., Field Crop Res., Inst., Agric. Res. Center Giza, Egypt
Second Author – Walaa M. E. Mousa, Forage Crop Res., Sec., Field Crop Res., Inst., Agric. Res. Center Giza, Egypt
Third Author – Zeinab E. Ghareeb, Central Lab. for Design and Stat. Res. Analysis, Agric. Res. Center Giza, Egypt