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Correlation Coefficient and Path Analysis of yield and its components for seven cowpea (*Vigna unguiculata* L.) genotypes and its F1 hybrids

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ABSTRACT

The present investigation was carried out in the experimental field of Technical College of Agriculture, University of Halabja, in 2022 summer season to determine correlation coefficient and path analysis results for yield and its components in cowpea. Twenty-eight genotypes of cowpea used in the Completely Randomized Block Design in three replicates to evaluate ten quantitative characters included pods yield/plant, number of pods/plant, pod length, number of seeds/pod, number of branches/plant, 100 grains weight, plant height, average harvest duration, grain index and grain yield/plant. Among the studied traits, pods yield/plant, pod length, number of pods/plant, 100 grains weight, number of branches/plant, plant height and average harvest duration showed highly significant and positively association to grain yield/plant with 0.922, 0.432, 0.787, 0.394, 0.309, 0.515 and 0.560 respectively. Pods yield/plant, with 0.785 recorded the highest value of positive direct effect on the grain yield, followed by the character number of pods/plant with 0.142. The characters number of brunches/plant with -0.060 showed the maximum negative value of direct effect in total grain yield. The pods yield/plant via the number of pods/plant confirmed the highest value of positive indirect effect with 0.654. The highest value of negative indirect effect was -0.033 recorded by the average harvest duration via the character number of brunches/plant. The results of those character association work aid in understanding how various characters contribute to overall yield, breeders can use this knowledge to increase yield-contributing traits directly or indirectly.

معامل الارتباط وتحليل المسار للحاصل ومكوناته لسبعة طرز وراثية من اللوبيا (*Vigna unguiculata* L.) وهجنها *F1*

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الخلاصة

أجري هذا البحث في الحقل التجريبي للكلية الزراعة التقنية ، بجامعة حلبجة، في موسم صيف 2022 لتحديد معامل الارتباط ونتائج تحليل المسار للحاصل ومكوناته في اللوبيا. أستخدم في البحث ثمانية وعشرون نمطًا وراثيًا من اللوبيا مستخدماً تصميم القطاعات العشوائية الكاملة (RCBD) في ثلاث مكررات لتقييم عشرة صفات كمية وهي حاصل القرون/النبات، عدد القرون/النبات، طول القرون، عدد البذور/القرون، العدد الأفرع/النبات ، وزن 100 حبة ، ارتفاع النبات، متوسط مدة الحصاد، وحاصل الحبوب/ النبات. من بين الصفات المدروسة، أظهرت الصفات التالية حاصل القرون/ النبات، طول القرون، عدد القرون/ نبات، وزن 100 حبة، عدد الفروع/ نبات، ارتفاع النبات ومتوسط مدة الحصاد ارتباطًا معنويًا وإيجابيًا مع حاصل الحبوب/ نبات حسب القيم 0.922 ، 0.432 ، 0.787 ، 0.394 ، 0.309 ، 0.515 و 0.560 على التوالي. سجلت حاصل القرون/ النبات أعلى قيمة للتأثير المباشر الإيجابي بقيمة 0.785 على حاصل الحبوب، يليها الصفة عدد القرون/ النبات بقيمة 0.142. ثم أظهرت الصفة عدد الأفرع/ النبات بقيمة 0.060- أعلى قيمة سالبة للتأثير المباشر في إجمالي حاصل الحبوب. وسجلت حاصل القرون/ النبات عن طريق عدد القرون/ النبات أعلى قيمة للتأثير الإيجابي غير المباشر 0.654. وسجلت أعلى قيمة للتأثير السلبي الغير المباشر على حاصل الحبوب 0.033- عن طريق متوسط مدة الحصاد من خلال عدد الأفرع/ النبات. تساعد نتائج عمل ارتباطات هذه الصفات في فهم كيفية مساهمة الصفات المختلفة في العائد الإجمالي؛ يمكن للمربين استخدام هذه المعرفة لزيادة الحاصل عن طريق زيادة الصفات المساهمة في الحاصل بشكل مباشر أو غير مباشر.

الكلمات المفتاحية: معامل الارتباط ،تحليل المسار ، طرز وراثية ، اللوبيا.

INTRODUCTION

Cowpea (Vigna unguiculata L.), is one of the important legume crops cultivated worldwide for its edible seeds, green pods, and nutritious leaves, providing the primary source of calories and protein for millions of people in developing countries (Ali et al., 2004; Silva et al., 2014; Boukar et al., 2019). It is mostly cultivated in the spring and fall, belongs to the Fabaceae family, and has a (2n = 2x = 22) genetic code (Singh, 2005). Due to their high protein content of 25%, cowpea seeds are an economically cheaper and a vital source of protein, vitamins, and minerals in daily diet, and make a healthy source of fodder for cattle (Ali et al., 2004; Giami, 2005; Musvosvi, 2009, and Alpha et al., 2016). Cowpea flowers are usually self-pollinated. After pollination, the plant produces elongated pods, varying in color and size depending on the variety. The pods contain several seeds, commonly referred to as cowpeas or black-eyed peas. Cowpea is produced on 14.13 million hectares worldwide, yielding 4.51 million tons and productivity of 387.45 kg/ha (Malagi, 2005). West Africa alone accounts for over 95% of global output, with Nigeria being the major producer and consumer of

cowpea, generating 3.4 million tons in 2017 (Samireddypalle et al., 2017; FAOSTAT, 2019). Egypt's total cowpea plant cultivation area was estimated to be 1853 hectares, with a mean yield of 7180 tons of dry seeds (FAOSTAT, 2021). A recent study on cowpea in Iraq revealed that the blackeye cultivar had the highest overall seed yields, with 12.92 tons/ha (Rana et al., 2019). Cowpea is known for their tolerance to drought, heat, salt, and poor soil fertility, and their ability to grow well in hot and dry climates. They are classified as a "green manure crop" because it uses symbiotic bacteria (Bradyrhizobium sp.) to fix nitrogen into the soil at a rate of (40-80) kg nitrogen per hectare per year (Das et al., 2020).

The yield, a complex trait, is impacted by several other key yield-contributing traits which are affected by different genes as well as environmental influences (Ehlers & Hall, 1997). The correlation analysis is a tool that is widely used for determining the relationship between grain production and other quantitative traits (Mohammed et al. 2010). Path coefficient analysis as suggested earlier was used to partition the phenotypic correlation coefficients of yield and its component into direct and indirect effects (Dewey & Lu 1959). Path analysis offers information about the size and direction of the direct and indirect influence of yield contributions that correlation does not provide (Bizeti et al., 2004; Chaudhary & Joshi, 2005). As a result, phenotypic correlations of yield and its components, as well as path coefficient analysis, have become valuable techniques for crop development programs to choose desired characteristics (Shahid, 2013).

The aim of the study was to increase and improve crop production by selecting and developing cowpea strains that are drought-tolerant, disease and insect resistant, and acceptable to farmers. The current investigation aims to study and evaluate the relationship between the total yield and its contributing characteristics using the correlation coefficient, then to identify the direct and indirect factors that contribute to enhancing and improving the final yield by path coefficient analysis.

MATERIAL AND METHODS

The experiment was conducted at the Technical College of Agriculture, University of Halabja's experimental field, which is located at an altitude of 634 meters above sea level in the Halabja governorate, Kurdistan Region of Iraq (Lat 35º 21‾ 64 N; Long 45º 95‾ 7 E). Twenty-eight cowpea genotypes were used for this study (including seven parents and twenty-one ***F1*** hybrids) in the breeding program of half-diallel analysis. On April 2, 2022, the field soil was plowed twice and leveled as needed, and it was prepared in accordance with the proposed design. The experiment was designed with three replicates (blocks) using Randomized Completely Block Design (RCBD). There are 28 plots in each block. Each genotype was planted in a plot, which had three rows of three meters each, a row-to-row distance of 0.50 meters, and a plant-to-plant distance of 20 centimeters. The distances between the plots and the blocks were 0.5 meters and 1 meter, respectively. Before planting

cowpea plants, soil samples were gathered from the sites at a depth of 0-30 cm to find out the physical and chemical characteristics of the soil, as it was shown in (Table 1). And (Table 2), showed the Agro-meteorological data of Halbja during 2022. The area of the experimental unit was 4.5 m^2. On April 12, 2022, the seeds were sown in rows. All recommended agronomic techniques were followed, to grow a suitable crop.

Studied Characteristics

Five competitive plants from each genotype were randomly chosen to collect data on yield and its components. A number of measurements were made, including pod yield/plant (g), pod length (cm), the number of pods/plant, the number of seeds/pod, 100 grains weight (g), the number of branches/plant, plant height (cm), average harvest duration, grain index and grain yield/plant (g).

Table (1), lists the soil's physical and chemical characteristics in Halbja.

Soil characteristics	**Value %**
Sand	13.55
Silt	27.15
Clay	59.30
Texture class	Clay
Chemical properties	
pH	7.3
EC ds/m^{-1}	0.59
Organic matter	1.16
Available nutrient (mg/ kg^{-1})	
Nitrogen (N)	0.13
Phosphor (P)	5..98
Potassium (K)	5.28
Boron (B)	0.89
Fe	12.90
Zn	0.60
Cu	2.04
Mn	13

Table (2): Agro-meteorological data of Halbja during 2022

months	Air Temperature (°C)			Air Humidity		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
April	28.36	14.36	21.36	43.81	19.25	31.53
May	31.89	18.36	25.12	35.91	14.76	25.33
Jun	40.88	24.65	32.76	20.43	11.36	15.89
July	40.66	24.75	32.70	18.93	12.19	15.56
August	44.74	27.42	36.03	18.16	11.45	14.80
September	40.00	22.92	31.46	20.83	12.40	16.61
October	32.92	17.72	25.32	31.03	17.00	24.01
November	20.92	10.30	15.61	52.64	24.51	38.57

Statistical Analysis

Each plot contained data on ten quantitative characters, from which mean values were generated for statistical analysis (Al-Jibouri *et al*., 1958). The correlation coefficient was used to assess the degree of the characters' interconnectedness as well as their relationship to the yield, by using the formula given by (Singh and Chaudhary, 1985).

A simple correlation coefficient among traits will be estimated depending on the trait mean of the genotypes as follows:

$$r = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{n}}{\sqrt{\left[\sum X^2 - \frac{(\sum X)^2}{n}\right]\left[\sum Y^2 - \frac{(\sum Y^2)}{n}\right]}}$$

$$t_{Cal.}(n-2) = \frac{r}{\sqrt{\frac{1-r^2}{n-2}}}$$

n = number of the treatments. r = correlation factor value.

Path coefficient analysis between grain yield and its constituent attributes will be done to partition the phenotypic correlation coefficients of yield and its component into direct and indirect effects as suggested earlier by (Dewey and Lu, 1959; Singh and Chaudhary, 1985). The scientific website was used on the World Wide Web “OPSTAT Home Page” to do the phenotypic correlations between the different characteristics of production, as well as find direct and indirect factors of the characteristics that contribute to a significant increase in yield. The website address is mentioned below: http://14.139.232.166/opstat/

RESULTS AND DISCUSSION

The correlation coefficient is defined as the measure of a two-variable linear relationship, and it indicates the strength of the association between two or more independent variables. The correlation coefficient, a single value, is commonly required to describe this link. It helps the breeder in developing an effective seed yield selection strategy, which is governed by a large number of genes and is exceedingly complex.

To find out the association between yield and yield contributing characters, the phenotypic correlation coefficients were estimated between 10 characters for 28 genotypes (as mentioned before), through the software on OPSTAT Home Page, the software analyzed the row data in the first step to the phenotypic correlation coefficient. The software automatically refers to the status of all correlations between the two transactions, whether they are significant or non-significant. The results of the analysis are presented in Table 3, it shows that there is a positive and negative association between all of the analyzed features.

1. Pod yield/plant (g):

As indicated in the table, pod yield/plant associated highly significantly and positively with each of the characters pod length, the number of pods/plant, 100 grains weight, the number of brunches/plant, plant height, average harvest duration, and grain yield/plant, even though it was associated significant and positively with the grain index, whereas the number of seeds/pod was not significant. (Nguyen *et al*., 2019) reported similar findings. By the way, this characteristic significantly contributes to cowpea genotype seed yield improvement.

2. Pod length (cm):

Pod length was positively and highly significantly correlated with each of the characters the number of pods/plant, the number of seeds/pod, plant height, and grain yield/plant, while it was correlated significant and negatively with grain index. In a genetic investigation, it was discovered that pod length significantly increased seed yield (Kumar *et al*., 2016), and prior investigations by (Kutty *et al*., 2003; Anbumalarmathi *et al*., 2005; and Suganthi & Murugan, 2008) found similar results, which were consistent with the current study. It is possible to increase grain output by enhancing this trait.

3. Number of pods/plant:

The results shown in (Table 3), indicate the presence of highly significant and positively association between number of pods/plant with each of the characters 100 grains weight, number of brunches/plant, plant height, average harvest duration and grain yield/plant. These outcomes are consistent with what (Matos Filho *et al.*, 2009 and Santos *et al*., 2014) found, showing that selection for a greater number of pods per plant can directly boost grain yield.

4. Number of seeds/pod:

The findings in Table 3, show that there is a highly significant association between the number of seeds/pod with plant height and highly significant and negative association with the character 100 grains weight.

5. 100 grains weight (g):

The data in (Table 3), revealed that there is a highly significant and positive association between 100 grains weight with the characters average harvest duration, grain index, and grain yield/plant. According to (Anbumalarmathi *et al*., 2005 and Nwofia *et al*., 2012) similar results have been found and showed that 100 grains weight correlated significantly and positively with grain yield/plant.

Table (3): Correlation coefficient among the studied characters for Cowpea genotypes

	PY/Plant	Pod length	NP/ Plant	NS/ Pod	100 Gr.Wt	NB/ Plant	Plant Height	AHD	Grain Index
PY/Plant									
Pod length	0.467**								
NP/ Plant	0.832**	0.385**							
NS/ Pod	0.190 ^{NS}	0.487**	0.120 ^{NS}						
100 Gr.Wt	0.407**	0.170 ^{NS}	0.334**	-0.443**					
NB/ Plant	0.361**	0.209 ^{NS}	0.404**	0.167 ^{NS}	-0.077 ^{NS}				
Plant Height	0.513**	0.554**	0.376**	0.311**	0.067^{NS}	0.405**			
AHD	0.616**	0.169 ^{NS}	0.782**	0.009 ^{NS}	0.350**	0.249*	0.065 ^{NS}		
Grain Index	0.245*	-0.221*	0.174^{NS}	-0.173^{NS}	0.419**	-0.036^{NS}	-0.191^{NS}	0.243*	
Gr.Yield/Plant	0.922**	0.432**	0.787**	0.159^{NS}	0.394**	0.309**	0.515**	0.560**	0.266*

* . Correlation is significant at 5% probability level **. Correlation is significant at 1% probability level

PY/plant (g) = pod yield/plant (g),Pod length (cm), NP/Plant = Number of pods/plant , NS/Pod = Number of Seeds/pod
100 Gr.Wt. = 100 grains weight (g), NB/Plant = Number of branches/plant , Plant Height (cm) AHD = Average Harvest Duration

Grain Index , Gr. Yield/Plant = Grain yield/plant (g)

6. Number of brunches/plant:

In the same table, a highly significant and positive association was discovered between number of brunches/plant with two characters, plant height and grain yield/plant, while significantly and positive correlated was observed with average harvest duration. In a previous study the researcher showed that number of primary and secondary branches correlated highly significant and positively with grain yield (Lingaraj, 2009 and Kumawat & Raje, 2005) showed comparable findings. As a result, increasing the number of branches /plant can enhance grain yield.

7. Plant height (cm):

Highly significant and positive association was estimated between the plant height and grain yield/plant. Similar findings were reported by (Kumar *et al*., 2016; Mathivathana *et al*., 2015 and Kebede, 2016).

8. Average harvest duration:

The data in the same table revealed that the character average harvest duration was highly significant and positively correlated with grain yield/plant, and associated significantly and positively with grain index.

9. Grain Index:

Data represented in (Table 3), showed that grain index correlated significant and positively with grain yield/plant.

10. Grain yield/plant (g):

Data revealed in (Table 3), indicated that the grain yield/plant correlated highly significantly and positively with all characters with the exception of number of seeds/pod, which is not significant, and grain index which is only significant. The same outcomes have been reported by (Nguyen *et al*., 2019) which obtained that the largest positive significant association was found between grain yield/plant with number of pods/plant, number of seeds/pod, and number of branches/plant. The similar results are observed by (Kumar *et al*., 2016 and Lingaraj, 2009). According to the correlation study results, increasing pod yield/plant, pod length, the number of pods/plant, 100 grains weight, the number of branches/plant, the plant height, average harvest duration, and grain index can boost grain yield.

Path coefficient analysis:

For cowpea genotypes, Table 4 demonstrated the existence of path coefficient analysis between grain yield and its constituent attributes. Data showed that among yield component traits pod yield/plant is a significant yield component trait that has a high positive direct effect (0.785) in grain yield, and the number of pods/plant followed it with (0.142), indicating the positive contribution of this trait on grain yield. The results found by (Nguyen *et al*. 2019; Tikka *et al*., 1978; and Kana & Kwon-Ndung, 2019) indicated that pod yield/plant, the number of pods/plant, the number of branches /plant, and 100 grain weight had a high positive direct effect in grain yield/plant. These findings support the current research. The increase in grain yield could be accomplished if any of these factors are chosen. Data in (Table 4) revealed that the character's number of brunches/plant, average harvest duration, number of seeds/pod, and the 100 grains weight recorded negative direct effects on grain yield with (-0.060, -0.042, -0.023, and -0.014) respectively, indicating the negative contribution of these characters in total grain yield. The results found by (Santos *et al*., 2014 and Ullah *et al*., 2011), which obtained direct negative effect of the number of seeds /pod with the grain yield, are consistent with the results of the present study. As it was shown in the same table maximum positive indirect

effect was (0.654) recorded by pod yield/plant via the number of pods/plant, followed by the value of (0.484) revealed by the character pod yield/plant via the average harvest duration. The highest negative indirect effect on grain yield was (-0.033) exhibited by the character average harvest duration via number of pods/plant. In a genetic study on yield and its component traits in Cowpea, the number of pods/plant showed heist direct effect to yield with (0.889), followed by the number of secondary branches/plant with (0.479) (Kumar *et al*., 2016). Path coefficient analysis reveals how several characters contribute to overall yield, and breeders can use path coefficient analysis to increase yield by enhancing directly or indirectly yield-contributing qualities. The results of these character association studies help to understand how various characters contribute to overall yield, breeders can use this knowledge to increase yield by increasing directly or indirectly yield-contributing traits.

Table (4): Path coefficient analysis among the studied character for Cowpea genotypes

	PY/Plant	Pod length	NP/ Plant	NS/ Pod	100 Gr.Wt	NB/ Plant	Plant Height	AHD	Grain Index	Gr.Yield Correlation
PY/Plant	0.785	0.001	0.118	-0.004	-0.006	-0.022	0.056	-0.026	0.020	0.922**
Pod length	0.367	0.001	0.055	-0.011	-0.002	-0.013	0.060	-0.007	-0.018	0.432**
NP/ Plant	0.654	0.001	0.142	-0.003	-0.005	-0.024	0.041	-0.033	0.014	0.787**
NS/ Pod	0.149	0.001	0.017	-0.023	0.006	-0.010	0.034	-0.001	-0.014	0.159^{NS}
100 Gr.Wt	0.319	0.001	0.048	0.010	-0.014	0.005	0.007	-0.015	0.033	0.394**
NB/ Plant	0.284	0.001	0.057	-0.004	0.001	-0.060	0.044	-0.011	-0.003	0.309**
Plant Height	0.402	0.001	0.053	-0.007	-0.001	-0.024	0.109	-0.003	-0.015	0.515**
AHD	0.484	0.001	0.111	-0.001	-0.005	-0.015	0.007	-0.042	0.020	0.560**
Grain Index	0.193	-0.001	0.025	0.004	-0.006	0.002	-0.021	-0.010	0.080	0.266*

PY/plant (g) = pod yield/plant (g),Pod length (cm), NP/Plant = Number of pods/plant , NS/Pod = Number of Seeds/pod
100 Gr.Wt. = 100 grains weight (g), NB/Plant = Number of branches/plant , Plant Height (cm) AHD = Average Harvest Duration
Grain Index , Gr. Yield/Plant = Grain yield/plant (g)

CONCLUSION

The possibility of creating new varieties of cowpea using plant breeding techniques is revealed by this study and others like it. Cowpea seed yield could be improved by selecting various characters such as pod yield/plant, number of pods/plant, number of seeds/pod, number of branches/plant, and grain index, which were all positively correlated with grain yield/plant. In addition, the results of path analysis showed that pod yield/plant is a significant yield component trait that has a high positive direct effect on grain yield, followed by the number of pods/plant. But the character's number of brunches/plant, average harvest duration, number of seeds/pod, and 100 grains weight recorded negative direct effects on grain yield. The maximum positive indirect effect recorded by pod

yield/plant via the number of pods/plant. The highest negative indirect effect on grain yield exhibited by the character average harvest duration via number of pods/plant. To obtain a high grain yield, these characteristics should be considered in the cowpea breeding program.

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