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Variability and Inter- Relationships Between Yield and Associated Traits in Cowpea (*Vigna unguiculata* (L.) Walp as Influenced by Plant Populations

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Abstract: Selection of genotypes with adequate combination of traits with high relationship and direct effect on yield at the appropriate density level increased the productivity in cowpea. The study was therefore undertaken to estimate genetic attributes of different cowpea genotypes and do path analysis of yield traits to yield to identify and select genotypes with adequate trait combination for improvement in yield. Correlation and path coefficient analysis were used to study yield and yield components. Six out of the nine traits measured in 2010 showed highly significant differences among the genotypes while all the traits were significantly different in the genotypes in 2011. The genotypic variances were lower than the phenotypic variances in all the traits indicating their interaction with the environment. Principal component analysis (PCA) could be used to delineate the genotypes into two groups. One group could be the bushy and dwarf types caused by high number of leaves and dwarfiness. The second group being the non-bushy and non-dwarf types caused by low number of leaves and high elongation of stems. Seed yield was positively and significantly correlated to number of leaves/plant, seed weight/pod, dry matter yield/plant in 2010 and number of pods/plant in 2011. Seed weight/pod and number of leaves/plant had positive direct effects of 0.611 and 0.549 on seed yield in 2010. Number of pods/plant, number of leaves/plant and pod length had positive direct effects of varying magnitude to seed yield (0.367, 0.087 and 0.016, respectively) in 2011. The consistent positive direct effect of number of leaves on yield in both years and high magnitude direct effect of seed weight in 2010 and number of pods/plant in 2011 suggests that the traits have high direct positive influence on seed yield. Hence, selection of genotypes with adequate combination of the three traits in combination with other traits will improve yield in cowpea at 40,000 plants/ha in the agro ecology as the traits are complementary in action.

Key words: Cowpea · Selection · Path analysis · Yield · Traits plant population

INTRODUCTION

Grain legumes are an important source of human dietary protein and calories in many parts of the world. Their high protein and lysine content make them a natural supplement to staple diets of cereals, tubers and fruits [1]. Cowpea (*Vigna unguiculata* (L) walp is one of the most important food and forage legume in the semi-arid tropics. It is a valuable and dependable commodity crop for farmers and grain traders with approximately 8.4 million ha grown worldwide and an annual production of over 3.05 million Mt [2,3]. It is grown mostly by poor farmers in developing countries with over 80% of production occurring in the dry savannas of tropical West Africa [2] but advances in crop development have opened opportunities for its production in wetter agro ecologies [4]. Cowpea grain yields have been low typically ranging from 0.1 to 0.4 mg ha^{-1} in the traditional systems compared to ~3.0 mg ha^{-1} in experimental plots [5]. Part of the reason for this low yield have been attributed to insect pests and diseases, use of low yielding varieties and plant population density.

Selection of high yielding crops with wider adaptability shall not be only very useful but shall induce increasing productivity. Genetic improvement of seed yield, alone, is not possible through phenotypic selection because of polygenic nature and low heritability. Hence selection through correlated response entailing several contributing factors which influence seed production both directly and indirectly shall be most appropriate.

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Therefore, an understanding of relationship between yield and its components is fundamental for selection process and its relationship can be explained by means of correlation and path analysis [6-8]. Correlation enables breeders to estimate the strength of the relationships among various characters as well as direction of changes expected during selection. Path coefficient analysis provides a more realistic understanding of the relationship as it partitions the correlation coefficients into the direct as well as the indirect effects of the variables [9]. Path analysis provides information on the path through which the component characters influences the expression of an economic character like yield and have been used extensively in the improvement of many crops by many workers [8,10-12].

Cowpea production in the humid forest fringes is a recent development and hence studies on variability and selection indices under optimum plant population densities is a prelude for developing suitable cultivars for this agro-ecology. This study therefore was undertaken to estimate genetic variability, heritability, character association and the direct and indirect contributions of some yield characters towards seed yield of some cowpea genotypes under varying plant population densities.

MATERIALS AND METHODS

Twelve cowpea genotypes namely IT960-610,IT90K-277-1,Danillo IT89KD-374-57,IT91K-506-1,IT88D-867-11, Borno local, IT89KD-288, IT86D-719, IT89KD-391, IAR48 and IT81D-985 obtained from the International Institute of Tropical Agriculture, (IITA) Ibadan were used in this study. The experiment was carried out in the Research farm of the National Cereals Research Institute, Amakama, Umuahia (Lat. 05°29'N, long. 07° 32' E,Alt.122m a.s.l.) in 2010 and 2011 cropping seasons. The soil was a sandy loam ultisol [13] and the monthly rainfall distribution is presented in Figure 1. The experimental design used was a split-plot in a randomized complete block design replicated three times. The main plot was the three plant population densities : 40,000, 53,333 and 80,000 plants/ hectare while the twelve cowpea genotypes were placed in the sub plots. The subplot size was 2 x 3 m with 1m between subplots and replications.

Three seeds of each cowpea genotype were sown per hole and later thinned to one plant per stand at two weeks after planting (2WAP).Weed control was achieved by hoe-weeding at 4 WAP and 8 WAP while insects were controlled with the insecticide cypermethrin EC at the rate

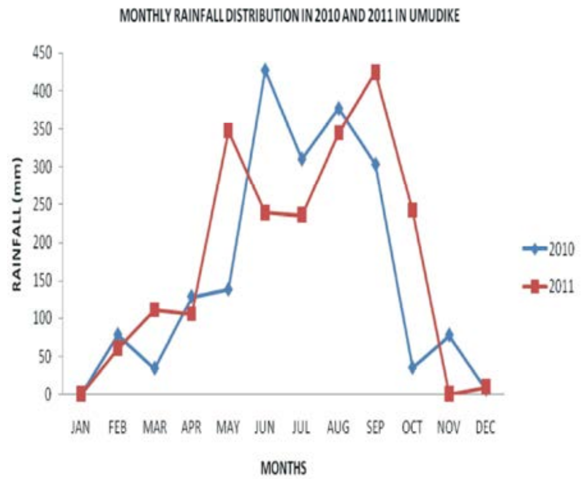

Fig. 1: Monthly Rainfall Distribution in 2010 and 2011 in Umudike

of 2.5 ml/litre of water using a knap sack sprayer at 2 weekly intervals from 21 DAP. Four randomly selected plants were assessed for plant height, number of branches, leaves, pods and dry matter per plant. Pod length, number of seeds/pod and seed weight/pod were recorded from 10 randomly selected pods from each genotype while seed yield/hectare was estimated from seed yield/ plot.

Data obtained were subjected to analysis of variance using the GenStat Discovery Edition 3 Software [14]. The Phenotypic variation for each trait was partitioned into genetic and non-genetic factors and estimated according to Wricke and Weber [15] and Prasad *et al.* [16].

$$VG = \frac{MSG-MSE}{r}, \quad VP = \frac{MSG}{r}, \quad VE = \frac{MSE}{r}$$

where: MSG, MSE and r are the mean squares genotypes, mean squares error and number of replications respectively. The phenotypic (PCV) and genotypic (GCV) coefficients of variations were estimated by the methods of Burton [17] and Johnson *et al.* [18] as:

$$PCV = \frac{\sqrt{VP \times 100}}{\bar{x}} \quad GCV = \frac{\sqrt{VG \times 100}}{\bar{x}}$$

Where: VP, VG and X are phenotypic and genotypic variances and grand mean respectively for the traits under consideration. Broad sense heritability (h^2B) was expressed as the percentage of the ratio of VG to VP and was estimated on genotypic mean basis as described by Allard [19].

Genetic advance (GA) was estimated by the methods of Fehr [20] as GA = k(Sp) h^2B where k is a constant (2.06 at 5% selection pressure), sp is the phenotypic standard deviation vVP, h^2B is heritability ratio. GA was also calculated as a percentage of the mean.

Principal component analysis (PCA) was also used to evaluate the traits contributing to the phenotypic variation among the genotypes. Correlations were estimated to examine inter character relationships among the traits using SPSS for Windows version 16.0 while path coefficient analyses were done to determine the direct and indirect effects of each trait to yield according to the procedure of Dewey and Lu [21].

RESULTS AND DISCUSSION

Analyses of variance showed that six out of the nine attributes studied in 2010 showed highly significant ($p<0.01$) differences among the genotypes while in 2011 all the attributes were highly significant ($p<0.01$) except seed weight/pod that was significant at 5% (Table 1). This suggests the possibility of improving the traits through genotypic selection. The error variances was smaller than the genotypic variances for all the traits studied in both years (Table 2). This is an indication that the genotypic component was the major contributor to the total variation for these attributes, hence the variations observed had more genetic than non-genetic components. The variability due to genotypic variances indicates that there is considerable scope for selections of superior genotypes. Similar results have been reported by Singh and Yadawa [22] on Sunflower, Baye,[23] on *Vernonia galamensis*, Nwofia *et al.* [24]on cowpea, Nwofia and Ojimelukwe [25] on *Carica papaya* and Aruah *et al*. [19] on *Cucurbita* spp.

The phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all the traits (Table 3). This indicated that all the attributes interacted with the environment to some degrees. High PCV values was observed for yield (kg/ha) in both years indicating that selection based solely on such character will not be effective. Similar results are in agreement with those obtained by Gupta and Godawat [26] on linseed, Okoye and Ene-Obong [27] on *Sphenostylis sternocarpa* and Baye [23] on *Vernonia galamensis*. GCV provides information on the genetic variability present in quantitative traits but the determination of the amount of variation heritable is not possible from GCV alone. Improvement efficiency is related to the magnitude of GCV, heritability and genetic

Table 1: Mean squares and variance ratios of yield and associated traits of twelve genotypes of cowpea as influenced by plant population in 2010 and 2011 cropping seasons.

	Mean squares		
Attribute	Genotype	Error	Variance ratios
2010			
No of seeds/pod	9.209	1.578	5.83***
No of pods/plant	35.26	44.50	0.79^{ns}
Dry matter(g)	335.70	227.70	1.47^{ns}
Seed weight/pod(g)	0.79631	0.04018	19.82***
Pod length (cm)	7.395	1.094	6.76***
No branches/plant	1.7870	0.5825	3.07**
Plant height (cm)	221.70	128.80	1.72^{ns}
No of leaves/plant	229.36	29.44	7.79***
Yield(kg/ha)	202903	32870	6.17***
2011			
No of seeds/pod	13.388	1.739	7.70***
No of pods/plant	34.766	8.393	4.14***
Dry matter(g)	120.28	30.34	3.96***
Seed weight/pod(g)	0.06806	0.03075	2.21*
Pod length (cm)	22.029	1.467	15.01***
No branches/plant	1.4687	0.3646	4.03***
Plant height (cm)	2488.00	179.20	13.89***
No of leaves/plant	206.44	27.12	7.61***
Yield(kg/ha)	318680.00	8165.00	39.03***

ns = not significant *= $p<0.05$ ** = $p< 0.01$ *** = $p<0.001$

Table 2: Phenotypic (VP), Genotypic (VG) and error (Ve) variances for yield and associated of twelve cowpea genotypes as influences by plant population in 2010 and 2011 cropping seasons.

Attribute	VP	VG	Ve
2010			
Seeds/pod	3.0697	2.5437	0.526
Pods/plant	-----	-----	------
Dry matter(g)	-----	-------	-------
Seed weight/pod(g)	0.265437	0.252043	0.013359
Pod length (cm)	2.465	2.10033	0.36467
Branches/plant	0.59567	0.4015	0.194167
Plant height (cm)	---------	--------	------
Leaves/plant	76.4533	66.64	9.8133
Yield (kg/ha)	67634	56677.67	10956.67
2011			
Seeds/pod	4.46267	3.883	0.57967
Pods/plant	11.58867	8.791	2.79767
Dry matter(g)	40.09333	29.9467	10.1133
Seed weight/pod(g)	0.022687	0.0124367	0.01025
Pod length (cm)	7.343	6.854	0.489
Branches/plant	0.489567	0.36803	0.12153
Plant height (cm)	829.333	769.60	59.733
Leaves/plant	68.1333	59.7733	9.04
Yield (kg/ha)	106226.6667	103505.00	2721.667

Table 3: Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), Mean, heritability in the broad sense and Genetic advance for yield and associated traits if twelve cowpea genotypes as influenced by plant population in 2010 and 2011 cropping seasons.

Attributes	Mean	PCV	GCV	h^2Bs	GA
2010					
Seeds/pod	10.43	16.79	15.29	82.86	28.67
Pods/plant	15.10	------	-----	-------	-----
Dry matter(g)	31.07	------	------	------	-----
Seed weight/pod(g)	1.39	37.07	36.12	94.95	72.50
Pod length (cm)	12.53	12.53	11.57	85.27	22.03
Branches/plant	3.82	20.20	16.59	67.40	28.05
Plant height (cm)	77.09	-------	------	------	------
Leaves/plant	33.71	25.94	24.22	87.16	46.57
Yield (kg/ha)	362.70	71.70	65.64	83.83	123.78
2011					
Seeds/pod	8.55	24.71	23.05	87.01	47.29
Pods/plant	7.34	46.38	40.39	75.86	35.18
Dry matter(g)	9.21	68.75	59.42	74.69	105.78
Seed weight/pod(g)	1.32	11.41	8.42	54.82	12.89
Pod length (cm)	10.71	25.30	24.44	93.34	48.65
Branches/plant	3.14	22.28	19.32	75.17	34.51
Plant height (cm)	55.60	51.80	49.90	92.79	99.01
Leaves/plant	29.67	27.82	26.06	87.73	50.28
Yield (kg/ha)	175.30	185.92	183.531	97.44	373.19

Table 4: Eigenvector values for principal components using yield traits for twelve genotypes of cowpea as influenced by plant population in 2010.

Attributes	PC1	PC2	PC3	PC4	PC5
Dry matter	- 0.1394	- 0.3660	0.1433	0.06676	0.2836
Number of branches	0.2575	- 0.3098	0.2080	0.0358	- 0.6531
Number of leaves	0.4501	- 0.2947	- 0.2208	- 0.1568	- 0.1543
Number of pods/plant	- 0.1220	- 0.1339	- 0.6436	0.4404	- 0.3795
Number of seeds/pod	- 0.4528	- 0.4383	- 0.0379	-0.1676	- 0.1040
Plant height	0.2045	- 0.2100	- 0.6131	- 0.2817	0.4209
Pod length	- 0.1548	- 0.4970	0.2032	- 0.4208	- 0.0108
Seed weight/pod	0.5774	- 0.0691	- 0.1116	- 0.1152	0.0216
Yield (kg/ha)	- 0.3042	0.4194	- 0.2053	- 0.1913	- 0.3614
Eigenvalues	2.18558	1.71896	1.08980	0.99459	0.9789
Percentage variation	24.30	19.10	12.10	11.10	10.90
Cumulative	24.30	43.40	55.50	66.50	77.40

Table 5: Eigenvector values for principal components using yield traits for twelve genotypes of cowpea as influenced by plant population in 2011.

Attributes	PC1	PC2	PC3	PC4	PC5
Dry matter	0.1211	0.0225	- 0.3255	- 0.6949	0.5252
Number of branches	0.2421	0.3802	0.0090	- 0.2120	- 0.5708
Number of leaves	- 0.4288	- 0.0466	0.1010	- 0.5109	- 0.3800
Number of pods/plant	- 0.3881	0.3550	- 0.2003	0.2943	- 0.0051
Number of seeds/pod	- 0.3296	- 0.4961	- 0.0663	0.2819	0.1190
Plant height	0.4138	- 0.3443	- 0.2664	- 0.1196	0.0907
Pod length	- 0.3109	- 0.4781	- 0.1976	- 0.0532	- 0.4623
Seed weight/pod	0.3004	- 0.0423	- 0.7146	0.1096	- 0.1310
Yield (kg/ha)	- 0.3542	0.3628	- 0.4675	0.1264	- 0.0261
Eigenvalues	1.92161	1.73068	1.17266	1.04725	0.93767
Percentage variation	21.40	19.20	13.00	11.60	10.40
Cumulative	21.40	40.60	53.60	65.20	75.70

Table 6: Correlation coefficients of yield and yield traits in twelve genotypes cowpea as influenced by plant population densities in 2010 and 2011.

	2010				
	Number of leaves	Pod length	Seed weight/pod	Dry matter	1Seed yield
Leaves/plant	------	0.078	- 0.388**	- 0.055	0.300**
Pod length		------	0.141	0.114	- 0.168
Seed weight/pod			----	0.146	0.329**
Dry matter				-----	0.219*
Seed yield					-----

Table 6: Continue

	2011				
	Plant height	Number of leaves	Pod length	Pods/plant	Yield
Plant height	------	-0.195	0.073	0.319**	-0.292**
Leaves/plant		------	0.312	0.095	0.163
Podlength			------	0.017	0.038
Pods/plant				------	0.420
Yield					------

Table 7: Direct and indirect effect of yield components on the yield of twelve cowpea genotypes as influenced by plant population in 2010 and 2011 cropping seasons.

	2010				
Attributes	Number of leaves	Pod length	Seed weight/pod	Dry matter	Correlation with seed yield
Number of leaves	0.549	- 0.0205	- 0.237	0.0135	0.305
Pod length	0.04282	- 0.263	0.0862	- 0.0282	- 0.162
Seed weight/pod	- 0.2130	- 0.03708	0.611	- 0.03606	0.325
Dry matter	- 0.030195	- 0.02998	0.0892	- 0.247	- 0.218
Residual					0.536
	2011				
Attributes	Plant height	Number of leaves	Pod length	Pods/plant	Correlation with seed yield
Plant height	- 0.161	- 0.016965	0.00112	0.114871	- 0.292
Number of leaves	0.031395	0.087	0.004992	0.034865	0.163
Pod length	- 0.01127	0.027144	0.016	0.006239	0.038
Pods/plant	0.050393	0.008265	0.000272	0.367	0.426
Residual					0.884

advance [18]. Traits with high GCV,h^2B and GA can be improved through selection. Such traits as seed weight/pod, number of leaves/plant and yield (kg/ha) in 2010 and number of seeds/pod, dry matter, plant height, number of leaves/plant and yield (kg/ha) in 2011 can be improved upon through direct selection.

The eigenvector values for principal components using traits of the twelve genotypes of cowpea as influenced by plant population density in 2010 and 2011 are shown in Tables 4 and 5. The first five components contributed 77.40% of the variability among the twelve cowpea genotypes in 2010. PC_1, PC_2, PC_3, PC_4 and PC_5 accounted for 24.30%, 19.10%, 12.10%, 11.10% and 10.90% of the total variations respectively. The PC_1 with eigen value of 2.18558 has high loading for number of leaves/plant, seed weight/pod and yield in 2010.

PC_2 with eigen value of 1.71896 had dry matter, number of branches/plant, seeds/pod, pod length and yield (kg/ha) as the main contributing attributes. PC_3 had number of pods/plant and plant height as the main contributing attributes and had an eigen value of 1.08980. PC4 with an eigen value of 0.99459 had number of pods/plant and pod length as the contributing factors.PC5 with an eigen value of 0.97889 had number of branches/plant, number of pods/plant, plant height and yield as the main contributing attributes. Number of pods/plant and yield was important in three PCs while number of branches, plant height and number of seeds occurred twice in three PCs.

In 2011,the first five PCs were important and accounted for 75.70% of the total variation. PC1 with eigen value of 1.92161 accounted for 21.40% of the variation and had high loadings for number of leaves per plant, number of pods/plant, number of seeds/pod, plant height, pod length, seed weight/pod and yield (kg/ha). PC2 had eigen value of 1.73068 and accounts for 19.40% of the total variation. It had high loading for number of leaves/plant, pods/plant, seeds/pod, plant height, pod length and yield (kg/ha). The eigen value for PC3 was 1.17266 and this accounts for 13% of the total variation and had high loading for three traits- Dry matter, seed weight/pod and yield (kg/ha).

PC_4 had an eigen value of 1.04725 and accounts for 11.60% of the total variation and had dry matter and number of leaves as the main contributing factors. PC5 had eigen value less than one indicating that dry matter, number of branches, pods/plant and pod length was contributing here.

Number of leaves/plant, dry matter, pod length and yield (kg/ha) was important in three PCs while the other traits occurred in two PCs indicating their relative importance in variability of these genotypes. PCA is a tool for identifying and expressing data in such a way as to highlight their similarities and differences [28]. It has been used to examine associations among traits [29]. The traits that occurred in 3 PCs are the major contributors to variability in these genotypes.

The results of the correlation coefficients among the twelve genotypes of cowpea as influenced by plant population densities in 2010 and 2011 are shown in Table 6. Seed yield was positively and significantly correlated with number of leaves/plant, seed weight/ pod and dry matter yield/plant in 2010 and number of pods/ plant in 2011. Plant height was negatively and significantly correlated with seed yield (r = -0.292**) in 2011. Number of leaves/plant was negatively and significantly correlated to seed weight/pod in 2010. The 2011 result further showed that plant height was negatively and significantly correlated with number of pods/plant (r = -0.319**) while number of leaves /plant was significantly and positively correlated with pod length (r = 0.312**). The significant positive correlations between yield and number of leaves/plant, seed weight/pod, dry matter, pods/plant suggests that these characters contributed positively towards yield and should be considered when selecting for grain yield in cowpea. Similar results were reported by Ombakho and Tyagi [30] and Nakawuka and Adipala [31] on cowpea.

The vagaries in rainfall data (Fig. 1) as it appeared in 2010 and 2011 could be the cause of differential response of the traits of the genotypes in both years. Hence, the seed weight/pod and dry matter yield/plant showed that positive and significant correlation with yield in 2010 showed significant height and number of pods/plant with non significant effects in the previous year became highly significant. The rainfall pattern (Fig. 1) showed that it peaked in June and August in 2010 but in 2011 it peaked in May and September. This could have had significant effect on these attributes as the resulted in the variation.

The direct and indirect effects of the yield components on the yield of twelve cowpea genotypes as influenced by plant population in 2010 and 2011 cropping seasons are shown in Table 7. In 2010, seed weight per pod with direct effect of 0.611 had highest positive direct effect on seed yield and was followed by number of leaves/plant (0.549). Pod length and dry matter yield had negative direct effect on seed yield. Pod length had positive indirect effect in both years except through dry matter/plant and plant height that was negative. Pods/plants had positive indirect effect with all the attributes in 2011 while plant height in the same year had negative indirect effect with number of leaves. This implies that taller plants with more leaves can lead to dissipation of stored/photosynthates to satisfy the plant needs due to effects of shading as against the need for seed production.

The main traits that had high direct effects on seed yield in these cow pea genotypes were seed weight/pod, number of leaves/plant and number of pods/plant. Incidentally, the three attributes had moderate heritability, genetic advances and also had high loading in PC_1 of the PCA in the two years of this study. This implies that they are the main contributors to seed yield and should be selected for in this agro ecology to improve yield. Earlier reports have implicated number of pods/plant, seeds per pod, seed size and number of branches/plant as the major determinants of seed yield in cowpea [31-33].

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