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DETERMINING ALTERNATIVE PATHWAYS TOWARD GRAIN YIELD IN 32 VARIETIES OF COWPEA *(Vigna unguiculata) (L) Walp.)*

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Abstract

Thirty two varieties of cowpea were evaluated for variatioin in seedlng, phenological and grain yield characters over two seasons. Seedling traits contributed only to crop establishment and affected phenological traits but had no effect on yield. Phenological traits affected yield either positively or negatively as prolonged days-to-seed-fill favoured increased grain yield while protracted growth duration favours biomass accumulation but decreases yield.

Twelve varieties had significant high grain yields (above 1000 kg/ha) while six had stable yield in both seasons but five varieties exhibited significant genotype X environment interactions (G x E) for grain yield. Days-to-physiological maturity (DPM) and days-to-harvest maturity (DHM) showed positive significant correlation with grain yield among the high grain yielding varieties while all the phenological traits showed negative effect on the low yielding varieties. All the growth rates measurements contributed significantly to grain yield as they showed positive significant correlation to grain yield on all the 32 varieties of cowpea. Yield growth rate (YGR) had the highest significant association with grain yield both among the high yielding varieties (0.965) and low yielding varieties (0.707).

Path analysis showed that YGR was the most important determinant of grain yield of all the traits investigated.

INTRODUCTION

One of the primary concerns of the crop breeder is to increase grain yield per unit area of land. Yield varies depending on cultivars adaptability to the environment in which it is subjected. Obisesan, (1985) observed that a yield is a representative of the final character which resulted from many developmental processes which must have occured between germination and maturity. Yield in cowpea has been reported to consist of three primary components viz: number of pods/plant, number of seeds/pod and 100 seed weight (Malik and Singh, 1983; Udosen *et al.*, 1984). Apart from these three primary components, Lambers *et al.*, (1990) and Wallace *et al*, (1991) have separately identified three major physiological components of yield. From these studies, it was concluded that cowpea varieties can also attain high yield by having superior rate of yield accumulation, superior rate of biomass accumulation and significant time-to-harvest-maturity.

In Nigeria, considerable attention has been devoted to breeding of improved varieties. Scully *et. al.*, (1991) reported that yield improvement is affected by direct selection due to genetic variance and indirect selection for plant ideotype traits because the two selection strategies enhance the capability of the plant breeder to identify top yielding varieties. Wallace and Masaya (1988) suggested that the ideotype traits which are also referred to as "yield system traits" collectively provide an integrated measure of crop yield. The ideotype traits which have been found to affect yield as basis of indirect selection must have high genetic correlation with final yield (Scully and Wallace, 1990). In order to actualise increased yield, there is need to consider those physiological traits that may enhance efficiency of yield accumulation and to identify likely alternative pathways to yield. A relationship between these traits (primary and physiological components) and grain yield has to be established in order to evaluate them in terms of thier influence on grain yield. Those with significant desirable relationship with yield constitute the alternative pathways.

Phenotype (rp) and genotype (rg) correlations have been used to quantify the relationship between pairs of traits. Multiple regression has also been used to determine the association between some yield components and grain yield (Obisesan, 1985). It has been further observed that simple correlation coefficient which quantitatively measures the bilateral relationship between two variables did not fully account for further complex cause/effect situations which exist among a set of variables (Chuahan and Joshi, 1980; Malik and Singh, 1983). Wright (1921) had suggested among others the technique of path coefficient analysis which is useful in partitioning the correlation coefficient into direct effect through a given causal variable and indirect effects through alternative pathways (other causal variables). The path coefficient analysis has been used by Dewey and Lu (1959), Chauhan and Joshi (1980) and Obisesan (1985) to examine the relative contribution of some yield components to yield and the interaction among them.

The first objective of this investigatioin was to quantify the alternative pathways through which tested cultivars achieved yield. The second objective was to identify among the several traits the trait(s) with superior direct effect on yield.

MATERIALS AND METHODS

The genotype used in this study comprised of foundation lines, improved cowpea varieties undergoing pre-release field evaluation under the Nationality Coordinated Cowpea Research Project (NCRP), one variety introduced from Maiduguri, as well as currently bred varieties obtained from the Department of Plant Science, Obafemi Awolowo University (O.A.U.) Ile-Ife, Nigeria. Field evaluation was conducted at the Teaching and Research farm of the Faculty of Agriculture, of the O.A.U., Ile-Ife. Thirty two lines of different growth habits were evaluated during the early and late seasons of 1991. The experiment was laid out each season using randomized complete block design with three replicates. A plot consisted of 5 rows. Each row was 4m long; inter-and-intra-row spacings were 0.6m and 0.25m, respectively.

Data collection were in two categories: one based on traits measured on a whole-plot basis. These include the seedling traints: (1) emergence (E) determined as total emergence count at 5, 7 and 9 days after planting (DAP); (2) emergence percentage (E%), defined as total emergence 9 DAP expressed as a percentage of total number of seeds planted; (3)

emergence index (EI) expressed as the rate of emergence at 9 DAP; (4) emergence rate index (ERI), determined by EI/E% and phenological traits which include: (5) day of flower node formation (DNF), determined as the day to 50% flower node formation; (6) days to flower formation (DDF), determined as the days from 50% seedling emergence to 50% anthesis (when 50% of plants in the plot had at least one open flower; (7) days to pod maturity (DPM), measured from 50% emergence to the time when 80% of pods had lost their green colour and turned yellow; (8) days to harvest maturity (DHM), measured from 50% emergence to the time 95% of the pods matured and ready for harvest; (9) days to pod fill (DSF), determined from 50% anthesis to 95% pod maturity. The phenological data were taken at each plot every third day.

The other set of data were based on the three middle row per plot: (1) seedling vigour index (VGX) estimated at 21DAP as $^1/_2$ (PHT + CD) where PHT is the plant height from ground level to tip of uppermost leaf and CD is the horizontal measurement at its widest plain; (2) number of pod per plant (NPP), obtained as average number of pods in randomly selected plants; (3) biomass (BM), measure in kg/ha as the aerial portion of the plant; (4) seed yield in kg/ha. Traits calculated from these data include: (1) harvest index (HI) determined as (seed yield/biomass) x 100; (3) seed growth rate (SGR), seed yield/DSF; (4) yield growth rate (economic growth) (YGR), seed yield/DHM; (5) biomas growth rate (BGR) biomass/DHM; (6) hundred seed weight (100SDW). Genotype means average across replication and seasons were used in all statistical analysis.

Data were subjected to analysis of variance (ANOVA), and simple phenotypic linear correlations were calculated between paired variables as outlined by Steel and Torrie (1980); path coefficient analysis was done following the procedure outlined by Wright (1921), Dewey and Lu (1959) and Singh and Chaudhary (1977).

RESULTS AND DISCUSSIONS

Table 1 shows the ANOVA for all the traits measured. Season (S), variety (V) and SXV interation had high significant effect on all the traits except grain yield, NPP and YGR where season had no significant effect. The significant SXV interaction observed on all the traits except NPP confirmed genotype X environment (GXE) interaction and its occurrence has accounted for the non-uniformity of the varieties in their performance over the two seasons on the affected traits.

Table 2 shows the mean biomass accumulation and the grain yield performance of the evaluated varieties. The biomass performance range between 1443.26-4111.18kg\ha in early season while in late season, it ranged between 119.10-4188.72kg/ha with average range of 1604.54 - 3521.14kg/ha and overall mean of 2851.98, 2375.58 and 2613.78kg/ha for early, late and across seasons respectively. Also, grain yield ranged between 4.20 - 1855.33 kg/ha for early season, 302.21- 2479.06kg/ha for late season, with across season range of 343.52 - 1559.91kg/ha and seasonal mean of 935.37, 949.51 and 942.44kg/ha per season respectively. the following varieties exhibited significant GXE interaction for yield: K - 59; OB89(5); H - 113 -14; OB89(1) and Maid - L. Consequently, their performance differed during the growing seasons. Six varieties; IAR48W; IT86D-1010; K-39; IAR-48; IT86D-880 and IT85F-958 recorded stable grain yield in both season. This is a desirable characteristic.

TABLE 1

ANALYSIS OF VARIANCE FOR NINETEEN TRAITS MEASURED ON 32 VARIETIES OF COWPEA IN TWO SEASONS.

S							Mean Square					
Source	df	E	Ex	ERI	VGX	DNF	DFF	DPN	DHM	DSF	YID X 10⁴	BM X 10⁴
Replicatioin	2	1078.65**	1745.72**	187.21*	17.69**	23/77**	29.29**	10.69NS	9.25NS	223.51**	12.63NS	86.54NS
Season(S)	1	478.17*	720.63*	231.47**	1029.9**	145.26**	223.17**	1463.62**	1535.67**	3176.88**	0.95NS	1089.37**
Varieties (V)	31	1057.35**	1647.85**	231.47**	13.02**	74.35**	58.87**	87.14**	116.24**	73.02**	65.29**	141.39**
S x V	31	362.51**	566.72**	95.04**	13.47**	43.41**	61.42**	60.98**	113.98**	61.06**	47.03**	107.05**
Error	126	70.55	108.79	41.60	2.30	4.66	3.21	4.39	10.74	28.78	45.52	40.52

Source	HI	TH%	NPP	SGR	YGR	BGR	100SDW
Replication	0.07NS	7.76NS	252.47NS	1.07NS	14.86NS	197.02NS	3.79**
Seasons (S)	27.18**	1231.25*	638.02NS	775.14**	15.23NS	527.95**	41.48**
Varieties (V)	4.10**	271.82**	434.43*	342.21**	74.34**	217.06**	28.94**
S x V	2.89**	239.43**	294.08NS	241.30**	53.24**	161.57**	5.02**
Error	09.72	42.68	214.74	36.45	7.06	93.00	0.32

*, ** = Significant at P = 0.05 and 0.01 levels of probaility respectively.

NS = not significant

E% = Emergence percentage

VGX = Vigour index

DFF = Days to 50% anthesis

DHM = Days to harvest maturity

YID = Grain yield in kg/ha

HI = Harvest index

WPP = Number of pods per plant

TGR = Yield growth rate

100SW = 100 Seed wight in grams.

E = emergence

ERI = Emergence rate index

DNF = Days to flower node formation

DPM = Days to pod maturity

DSF = Days to pod fill

BM = Biomass in kg/ha

TH% = Threshing percentage

SGR = Seed growth rate

BGR = Biomass growth rate

Table 2: Mean Biomass accumulation and grain yield (kg/ha) of 32 varieties of cowpea evaluated in Ile-Ife, Nigeria.

	SEED YIELD (kg/ha)			BIOMASS (kg/hg)		
Varieties	*Early season*	*Late Season*	*Across season*	*Early Season*	*Late Season*	*Across Season*
K-59	640.66	2479.06	1559.06	2211.13	4188.72	3198.91
IAR-48W	1292.96	1725.24	1509.05	3580.00	3015.65	3297.82
IT86D-1010	1588.01	1381.05	1484.52	4108.90	2933.35	3521.14
IAR-48	1179.43	1742.04	1460.73	2968.95	25000.00	2734.59
K-39	1384.62	1343.33	1364.00	2249.00	3466.76	3150.02
IT83F-958	1151.14	1366.04	1240.56	3077.83	3222.24	3150.02
H-113-4	1855.33	594.61	1225.07	2928.95	2080.00	2504.48
IT86D-880	1168.73	1024.16	1096.42	2653.33	19689.92	2811.14
OB89(5)	877.33	1273.05	1075.22	2824.52	2791.16	2807.86
IT87D-1629	1110.83	994.64	1052.73	2795.67	2804.45	2800.00
IT86D-721	769.53	1333.76	1051.67	2208.96	2782.25	2495.51
IT85D-3577	867.67	1190.79	1029.11	3248.92	2975.63	3112.26
K-28	1183.67	790.79	987.15	3311.16	1884.13	2597.81
OBV5	1223.67	688.41	956.03	2942.27	1902.23	2422.23
L-72	1097.13	811.52	954.33	3595.68	2629.95	31112.33
OB89(4)	889.53	1017.33	935.43	2913.40	2635.60	2774.52
OB89(1)	563.84	1204.75	884.26	2633.38	2862.27	2747.83
OB89X1	1000.26	751.77	875.93	3024.43	2031.14	2527.83
12AK	831.13	912.33	871.73	2539.55	1888.93	2214.27
IF83-1-4(A) 11	777.96	940.33	859.18	2533.34	2408.93	2471.16
IFE BROWN	1011.86	695.24	853.64	2471.16	1901.32	2186,25
IT86D-715	1049.46	641.00	845.26	2966.73	2026.63	2496.63
IT87S-1463-B	1042.56	619.86	831.27	4111.18	2360.02	3235.57
L-80	1120.00	463.11	792.19	2884.46	1842.26	2863.37
IT87S-2246-4	884.33	631.06	757.64	3206.76	2262.26	2734.52
IAR11/48-2	1151.13	302.21	708.77	3237.82	1782.24	2510.00
IT87D-1134	705.25	663.42	684.32	2155.63	1904.42	2030.00
OB89(3)	645.42	559.76	602.58	2861.35	2328.92	2595.19
OB89(312)	593.67	407.17	500.41	2022.28	1191.10	1606.72
MAID-L	4.20	745.92	375.07	1995.63	1999.51	1997.52
IF83-144(A) 21	148.33	599.22	373.86	1560.00	1684.42	1622.26
OB89(2)	194.52	492.55	343.52	1442.26	1766.73	1604.04
MEAN	935.37	94[illegible]	942.44	2851.98	2375.56	2613.78
LSD 5%	402.28	359.12	268.39	1209.50	685.48	728.23

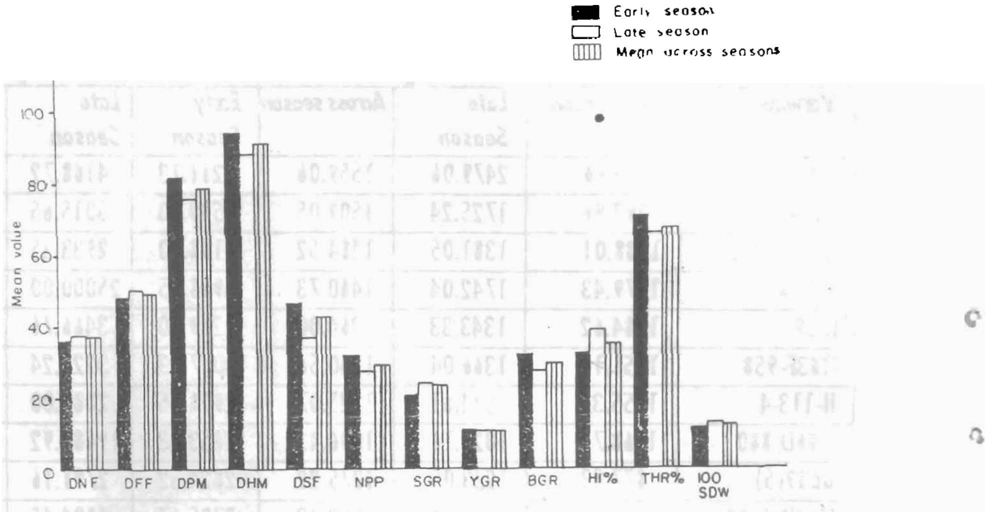

Fig. 1: Seasonal variation in 32 varieties of cowpea evaluated in Ile-Ife, in 1991.

Phenological traits, except DNF and DFF were observed to show prolonged period of expression during the early season than the late season (Fig. 1). This may be due to high moisture and relatively low temperature which seems to promote vegetative growth rather than attainment of anthesis. Similar results have been observed by Rachie *et, al,* (1975) and Udosen *et. al.* (1984), and they suggested that better environment results in better growth. This has accounted largely for the BM accumulation recorded for the varieties investigated in this study. Prolonged phenology influenced the pod fill period, seed yield and biomass accumulation rate.

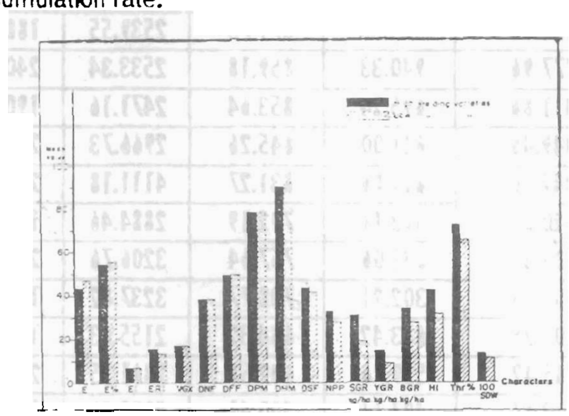

Fig. 2: Variation in the performance of high and low yielding varieties of cowpea for the different characters measured.

Varieties with grain yield above 1000kg/ha were classified as high yielding while those below were grouped as low yielding. Figure 2 shows the graphical representation of all the traits among those varieties classified as high and low yielding varieties. The varieties demonstrated significant diversity for yield components and growth rates measurement (SGR, YGR and BGR). The values for these traits were higher among the high yielding varieties but some low yielders exhibited high BGR (Table 3) / (Fig. 2). It can be suggested that the high yield was influenced by the growth rate traits. Wallace *et. al.* (1993), had make a similar observation. Even though yield components such as NPP, HI% and 100SDW have been identified to influence grain yield, these traits are subsequently influenced by growth rate measurements.

Table 3: Mean values of some yield system output traits and some yield components in 32 varieties of cowpea across seasons.

Varieties	Number of pods per plant (NPP)	Yield per DSF (SGR)	Yield per growth dur. (YGR)	Biomass per growth dur. (BGR)	Harvest Index (HI)	Threshing % (Thr (g)	100 Seeds weight (g) (100 SDW)
K-59	32.83	39.91	17.07	35.16	24.17	77.40	9.67
IAR-48W	32.83	35.81	15.62	34.38	47.83	71.17	14.17
IT86D-1010	25.00	30.85	16.69	39.58	43.50	70.28	14.00
IAR-48	57.33	34.54	15.99	29.56	55.50	72.90	12.00
K-39	33.17	32.26	15.89	38.80	38.83	70.08	12.67
IT83F-958	55.17	34.70	18.70	34.78	39.33	70.48	9.00
H - 113-4	26.83	27.20	12.77	26.89	43.00	73.63	14.00
IT86D-880	22.00	28.81	12.87	32.88	42.67	71.56	12.92
OB89(5)	31.00	23.48	11.42	29.89	39.00	74.39	11.33
1187D-1629	21.33	26.95	12.07	32.11	38.00	72.36	12.00
IT86D-721	23.33	26.02	12.13	29.02	41.17	70.07	12.00
IT85D-3577	27.56	26.16	11.73	35.45	33.67	67.55	18.00
K-28	32.17	22.99	10.79	28.28	38.82	70.63	12.83
OBV5	32.95	21.64	10.73	27.27	38.67	75.91	10.17
L-75	29.00	22.05	10.41	34.00	30.50	67.55	11.92
OB89(4)	25.83	24.09	10.91	31.26	35.50	76.05	10.17
OB89(1)	28.00	19.33	9.13	28.31	31.50	67.3	7.50
OBB9X1	26.83	21.41	9.67	27.83	35.33	70.71	10.08
12AK	30.67	20.57	9.66	24.22	39.33	68.88	8.67
IF83-1-4(A)11	33.50	21.67	8.79	25.40	36.50	69.17	8.67
IFE BROWN	33.67	23.78	9.68	24.91	39.17	64.89	11.83
IT86D 715	22.17	22.15	9.35	27.39	34.00	65.39	10.83
IT875-1463-B	31.00	16.80	8.44	32.97	26.67	67.40	12.50
L-80	34.67	20.24	6.62	31.21	26.50	69.89	10.00
IT875-2246-4	31.00	21.04	9.06	32.76	38.00	66.42	11.50
IAR11/48-2	29.50	18.66	8.40	29.99	26.17	64.95	12.33
IT87D-1134	25.33	16.43	8.08	40.50	33.83	65.95	12.33
OB89(3)	25.67	14.49	6.48	28.10	23.33	62.89	11.33
OB89(312)	10.67	11.81	5 53	17.68	31.67	62.68	10.00
MAID-L	17.33	19.28	4.31	19.86	18.60	40.74	10.50
IP83-144(A)	18.33	9.18	4.23	17.26	23.17	60.85	10.00
OB89(2)	18.82	8.28	3.81	17.09	20.33	64.58	9.67
MEAN	29.14	22.80	10.43	29.51	35.17	67.94	11.37
LSD 50	16.74	6.90	3.04	11.02	9.69	7.46	5.90

The simple linear correlation between grain yield and agronomic traits among the high and low yielding varieties are shown in Tables 4 and 5, respectively. While the phenological traits showed positive significant correlation with each other except DSF among the two yielding groups, only DHM showed positive significant correlation with yield, indicating that the period to maturity highly influenced the final yield in high yielders.Phenological traits were negatively correlated with yield among the low yielders indicating a negative effect on yield.All the growth rate traits were found to show high positive significant correlation with grain yield in both cowpea groups; however values for the high yielders were higher for YGR and BGR with 0.859 and 0.966, as compared to low yielders with 0.679 and 0.707 respectively.This result suggests that growth rate was the most important parameter showing high direct effect on yield.These desirable traits could be considered in addition to already identified yield components when selection for effective breeding is to take place.It has been established by Wallace *et al.*(1993) that superior rates of accumulation enable plants to acquire high harvest index.

Table 4: Linear correalation coefficients between grain yield and some measured yield system traits in high yielding varieties of cowpea

DNF	DNF	DFF	DPM	DHM	DSF	NPP	BM	SGR	YGR	BGR	HI	THr%	100SDW
DFF	0.844**												
DPM	0.745**	0.821**											
DHM	0.565**	0.429**	0.658**										
DSF	-0.321*	-0.503**	0.185	0.385**									
NPP	0.517**	0.502**	0.572**	0.457**	-0.125								
BM	0.197	0.100	0.203	0.142	0.058	0.106							
SGR	0.378*	0.470**	0.531**	0.269**	-0.218	0.545**	0.511**						
YGR	-0.002	0.065	0.131	0.291	0.235	0.360*	0.553*	0.854**					
BGR	-0.220	-0.130	-0.171	-0.120	0.004	-0.026	0.803**	0.408**	0.457**				
HI	6.086	0.104	0.263	0.382**	0.302	0.472**	-0.033	0.519**	0.578**	-0.262			
THr%	0.304	0.11	0.318	0.358*	0.069	0.093	0.132	0.325	0.247	-0.349*	0.367*		
100SDW	-0.125	-0.344	0.413**	-0.126	0.102	0.455**	-0.252	-0.090	0.037	0.226	-0.177	-0.239	
YLD/KG/HA	0.194	0.208	0.544**	0.484**	0.267	0.406**	0.546**	0.859**	0.965**	0.412**	0.647**	0.345	0.383*

*,** *Significantly different from zero at P = 0.05 and 0.01 levels probability respectively.*

Table 5: Linear Correlation between grain yield and some measured yield system traits in low yielding varieties of cowpea.

DNF	DNS	DFF	DPM	DHM	DSF	NPP	BM	SGR	YGR	BGR	HI	THr%	100SDW
DFF	0.935**												
DPM	0.634**	0.536**											
DHM	0.6051**	0.640**	0.635**										
DSF	-0.072	-0.083	0.533**	0.682**									
NPP	-0.310	-0.398*	-0.364*	-0.420**	-0.237								
BM	-0.194	-0.133	-0.189	-0.138	0.495**								
SGR	-0.257	-0.262	-0.410**	-0.485**	0.433**	0.672**	0.667**						
YGR	-0.400**	-0.397*	-0.461**	-0.505**	-0.295	0.677**	0.697**	0.968**					
BGR	-0.622**	-0.485**	-0.493**	-0.507**	-0.182	0.396	0.714**	0.580**	0.644**				
HI	-0.352*	-0.428**	-0.491**	-0.431**	-0.207	0.606**	0.181	0.777**	0.194	0.274			
Thr%	-.0.620**	-0.627	-0.635**	-0.588**	-0.250	0.523**	0.302	0.664**	0.693**	0.362*	0.671**		
100SDE	-0.340**	0.207	-0.452**	-0.427**	-0.289	-0.102	0.241	0.117	0.515**	0.480**	0.056	-0.140	
YLD/KG/HA	-0.369	-0.282	-0.436**	-0.272	-0.113	0.599**	0.567**	0.679**	0.707**	0.488**	0.530**	0.434**	0.235

** ** Siginificantly different from zero at P = 0.05 and 0.01 levels of probability respectively.*

Path coefficient analyses were carried out between grain yield and each of seedling, phenological and growth rates. The traits with superior direct effect on yield from each of the seedling, phenological and growth rate viz: E, DSF, 100SDW and YGR were pooled and subsequently re-assessed to show their relationship with yield (Table 6 and Fig.3). The alternate pathways towards attaining high yield i.e. through optimum emergence index, DSF and 100SDW were not as efficient in enhancing high yield as YGR. Out of the four traits, only YGR showed the highest direct effect of 0.900 on yield. Howevcer, the indirect effect of 100SDW (0.027) was higher than that of YGR (0.084). While yield components and growth rates of cowpea are jointly important for yield improvement, this study showed than one of the physiological components (YGR) was the most important in seed determination. Cowpea genotypes with long days to harvest maturity were generally low yielding and were characterised by high vegetative growth. The activities of photoperiodic genes which appear to control the partitioning of assimialtes to both vegetative and reproductive organs (Wallace and Masya, 1988) are observed to be biased toward more vegetative development in those low yielding varieties. Consequently, much of the assimilate were utilized for vegetative growth with less utilized for reproductive growth. Summerfield *et. al.,* (1974) had earlier observed similar results on cowpea, and they emphasized the negative effect of a protracted growing period on yield.

Table 6

Linear correlation and path coefficients between grain yield and some traits that showed superior direct effects on yields.

	E	DSF	100SW	YGR	Correlation with yield	Indirect effect
E	0.067	0.015 (0.175)	-0.104 (-0.315)	-0.093 (-0.103)	-0.155	-0.182
DSF	0.012	0.086	-0.018 (0.054)	0.059 (0.066)	0.139	0.053
100SDW	-0.021	-0.005	0.329	0.233 (0.259)	0.537**	0.207
YGR	-0.007	0.006	0.085	0.900	0.984**	0.084

* Figures underlined are direct effects of respective traits.

Figures in parenthesis are linear correlation coefficient values between traits measured

* ** Significantly different from zero at P=0.05 and 0.01 levels of probability respectively.

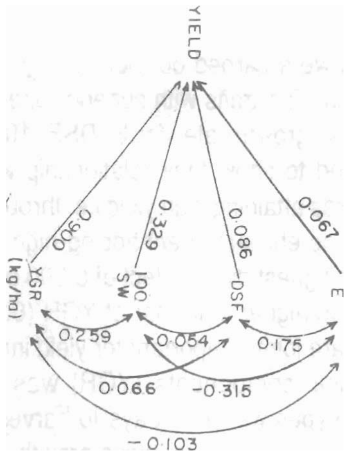

Fig. 3: Path diagram showing the direct effects of traits on grain yield.

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