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Lead Selection Traits Relationship in Cowpea (*Vigna unguiculata* (L.) Walp.): Is Grain Yield Still Key?

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Authors' contributions

This work was carried out in collaboration between all authors. All authors jointly designed and reported the study and their findings, respectively. All authors read and approved the final manuscript.

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ABSTRACT

A field study was set to highlight the relationships and contributions of yield and yield-related traits to the choice of a superior cowpea variety. Five cowpea varieties, Sampea-7 (IAR 48), Sampea-8 (IAR 452-1), Sampea-10 (IAR 499-35), Sampea-11 (IAR 288) and Sampea-12 (IAR 391) were evaluated under normal growing conditions during the 2011/2012 growing season at the University of Calabar Teaching and Research Farm. The analysis of variance (ANOVA) for a randomized complete block design (RCBD) with three replications did show significant (P = .05) varietal differences for days to 50% flowering (50% FLW), days to 75% maturity (75% MTY), number of pods per plant (NPP), seed size (SDS), total plant biomass (TOB) and grain yield (GRY). The number of branches (NBR), pod length (PDL) and harvest index (HI) were not significantly different. The GRY had a positive correlation with all other yield-related traits except for the flowering traits and breeding for the former traits will be an indirect way to select for high grain yields. However, based on the weighted combined contributions of all the traits, the superiority of the varieties, Sampea-7 and Sampea-8, which were significantly different, followed an order different from their average grain yield order. Apparently, this re-ordered result highlights that the choice of a high performing cowpea variety could not be viewed as a function of high grain yield but a collective contribution of all other yield-related traits. These findings suggest that placing huge emphasis only on the economic yield (in this case, grain yield) as the main selection index could possibly fault the breeding and evaluation of superior cowpea varieties.

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1. INTRODUCTION

Cowpea is an important crop in the tropics and sub-tropics [1,2] and breeding works with various objectives still continue [3]. In cowpea, other pulses and cereals, numerous key traits have been suggested but the emphasis has always been on more grain yield [4,5,6] which, in itself is lacking in explaining the overall performance of the different cowpea genotypes. Additionally, yield is a complex trait resulting from several interacting physiological activities. This fact further informs the breeder of the need to pursue operative and effective ways of selecting superior genotypes in a breeding program. The choice of parent plants in crop improvement therefore becomes an apparently challenging decision-making task [7] and where numerous characters are presented for consideration; there is that utmost need to keenly consider the expected contributions of each character to the final decision about the parent plant and the expected performance and outcomes of the new plant type. Breeders have relied on a range of statistical measures to aid in this process. However, the foundation of yield traits as a basis for selecting for yield has not proven useful because of the existence of offsetting negative correlations where a decrease in one component will produce an increase in another. Understanding such interrelationships will provide interesting insights into the selection of desirable crop varieties. This study was set to highlight the relationships and the individual contributions of lead yield and yield-related characters in the selection of cowpea varieties with overall superior performance.

2. MATERIALS AND METHODS

Five genetically different and morphologically distinct cowpea varieties obtained from the Institute of Agricultural Research (IAR), Samaru, Zaria, Nigeria, were used for the studies. These varieties were Sampea-7 (IAR 48), Sampea-8 (IAR 452-1), Sampea-10 (IAR 499-35), Sampea-11 (IAR 288) and Sampea-12 (IAR 391). The experimental site was the Teaching and Research Farm, University of Calabar, Calabar, Nigeria. Calabar is located at about 39 m above the sea level and experiences a bimodal rainfall distribution with an average annual rainfall ranged from 3 000 mm to 3 500 mm. The annual ambient temperature and relative humidity are 27 – 35ºC and 75 – 85%, respectively. The cowpea varieties were evaluated in the field during the May-October 2011/2012 growing season. The experimental plots were manually cleared and ridged. The ridges measured 8 m long and 1.4 m high. The experiment was laid out in a Randomized Complete Block Design in three blocks (replications). Two viable seeds of each of the cowpea varieties were sown to the depth of 2 cm in the ridges at a planting distance of 75 cm x 20 cm. Each experimental plot had two rows and eight plant stands. Manual weeding was done initially at two weeks after sowing and later when necessary. Insect pests mostly, *Maruca* spp., foliage beetles, flower thrips and pod bugs, were controlled with a mixture of Lambdacyhalothrin (Karate) 25 EC and Cypermethrin (Cymbush) at 0.8 L/ha and 1 L/ha i.e. 80 ml and 100 ml in 20-L knapsack sprayer, respectively. Fertilizer NPK (15:15:15) was applied at 100 kg/ha and incorporated into the soil during planting. The yield and yield-related data collected were as follows, days to 50% flowering – this was observed as the duration (in days) from the date of sowing to when 50% of the plant population bear at least an open flower and days to 75% maturity - the number of days from planting till 75% of the plants in the plot turned yellow, with abscission of the older leaves and lowest pods on the stem.

Five plants at 80% maturity were sampled from each plot to determine the following characters average number of branches and pods, pod length (cm) measured using a meter rule and seed size (mm) measured vertically with the aid of a Vernier callipers, grain yield and the aboveground total biomass (expressed in kg ha^{-1}) weights were taken with a weighing balance. The harvest index was expressed as a percentage of the economic yield over the total biomass (biological yield) [8]. GenStat Software [9] was used for the analysis of variance (ANOVA), bivariate correlation (Pearson's coefficient, r) and overall performance ranking (Kendall's Coefficient of Concordance, W). Fisher's post-ANOVA test [10] was conducted and the significant means were separated using the Least Significant Difference (LSD) approach [11].

3. RESULTS

The variability within each block was less than the variability of the entire sample except for days to 75% maturity (75% MTY) (P = .05) (Table 1). The analysis of variance revealed that the cowpea varieties differed significantly in terms of seed size (SDS) (P = .001) the number of pods per plant (NPP) (P = .05), total biomass (TOB) (P = .05), days to 50% flowering (50% FLW) (P = .01), 75% MTY (P = .01) and grain yield (GRY) (P = .01) (Table 2). The signal-to-noise ratios for NPP, pod length (PDL) and harvest index (HI) of the cowpea varieties were not significantly different. The magnitudes of the coefficient of variation (CV) ranged from 2.62% to 26.46% between the nine characters investigated. The only statistically significant correlation was between GRY and NPP(r = 0.95, P = .013) (Table 3). Ranking based on Kendall's Coefficient of Concordance, W, showed the overall performance of the cowpea varieties following the order (Table 4): Sampea-12 < Sampea-10 < Sampea-7 < Sampea-8 < Sampea-11.

4. DISCUSSION

The variability within each block (replicate) was expected to be less than the variability of the entire sample for an efficient estimate of the varietal effect [12]. The estimate of the varietal effect within each replicate (i.e. block) was less efficient than estimates across the entire plot for all the observations except for 75% MTY (Table 1). The experimental CV was below 10% for 50% FLW, 75% MTY, SDS, GRY and HI. High variations in the number of branches per plant (NBR), TOB, NPP and PDL could partly be described by the quantitative nature of these characters. The 50% FLW, NPP and GRY have been identified as important characters in cowpea selection and breeding [13]. This study also showed that cowpea varieties significantly differed for these characters alongside 75% MTY, SDS and TOB (Table 2). Earliness in cowpea is an important polygenic agronomic trait [14] and an important component for cowpea adaptation in the semi-arid tropics. 50% FLW ranged from 41 days to 57 days with an overall mean of 47.33±1.84 days. These results were in consonance with previous reports [15,16]. The erect and white-seeded Sampea-8 and Sampea-10 were significantly different (P = .05) in 50% FLW. Sampea-7 (erect and brown-seeded), Sampea-11 (spreading and white-seeded) and Sampea-12 (spreading and brown-seeded) were the early maturing cowpea varieties which were also below the overall mean 50% FLW (47.33±1.84). Early flowering has a direct relationship with photoperiodic groupings in cowpea. Cowpea varieties with less than 45 days to 50% FLW were grouped as day neutrals above which they are photoperiodic sensitive [17]. These groupings were found to have a direct influence on days to maturity in cowpea. Sampea-11 was significantly different (P = .05) from Sampea-7 and Sampea-12. Sampea-8 and Sampea-10 varieties mature in 19 days and 20 days, respectively, after the earliest maturing variety, Sampea-12 (59.0 days). The NPP ranged from 8.0 in Sampea-10 to 17.0 in Sampea-11; these varieties had the highest NBR. There was no significant difference between Sample-11 and Sampea-7 in terms of NPP. Sampea-10 differed significantly (P = .05) from Sampea-11 but not statistically different from Sampea-7, Sampea-8 and Sampea-12. The mean PDL was 9.4±1.44 cm and Sampea-11 with the highest NPP recorded the highest PDL (12.0 cm) as well. The combination of fewer NBR, NPP and shorter PDL encourages an effective partitioning of photosynthetic assimilates [18,19] which supports the development of larger seeds in cowpea. The mean seed size was 7.59±0.1 mm. Sampea-10 had the least NPP and PDL but with the largest SDS (9.06 mm) that was significantly different (*P* = .05) from other varieties. Seed size in cowpea is a desirable characteristic that positively influences starch contents useful in industrial production of cowpea flour [20]. Though the mean number of seeds from each of the varieties was not considered in the study, PDL and NPP generally affect the total number of seeds in a pod-bearing plant (peas, beans or lentils) and can serve as important indices for breeding for high number of seeds in cowpea. Longer healthy pods are expected to contain more seeds than shorter pods. It was reported that selecting for higher GRY is an indirect way of selecting for NPP [21]. Higher NPP corresponded with higher TOB which, varied greatly and significantly (*P* = .05) among the cowpea varieties ranging from 3,046.8 kg ha^{-1} (Sampea-11) to 2,579.2 kg ha^{-1} (Sampea-8). Improved GRY is an important selection index in cowpea [22]. The highest and lowest GRYs were obtained from Sampea-11 (1,304.1 kg ha^{-1}) and Sampea-12 (1,069.0 kg ha^{-1}), respectively. Sampea-8 (1,082.7 kg ha^{-1}) and Sampea-10 (1,078.4 kg ha^{-1}) were not significantly different. Sampea-7 had the second highest GRY (1,136.7 kg ha^{-1}) and this was significantly different (*P* = .05) from the rest of the varieties. Slightly different GRYs, 1,792.47 kg ha^{-1} [23] and 1,392 kg ha^{-1} [15], have previously been reported in drier cowpea growing zones of Nigeria. There was no significant varietal difference for HI though the trend corresponded to the GRY. Sampea-11 (42.80%) and Sampea-8 (41.98%) were above the overall mean HI (40.35%) of the cowpea varieties. Their efficiencies in converting over 40% of total photosynthetic assimilates to economic yield (expressed as HI) further highlighted their superior biological and seed-yielding abilities. Both Sampea-11 and Sampea-8 mature after 71 days and 79 days, respectively. This record agreed with Fagwalawa [24] who reported high photosynthetic efficiencies for medium to late maturing cowpea varieties. Understanding these varietal efficiencies will be helpful in the selection of cowpea varieties with improved genetic potentials. Late flowering cowpea varieties produce numerous and longer branches mature late and yield high amounts of fodder due to their distinct photosensitive differences [25]. Generally, crop varieties with shorter vegetative growth phase do have the inherent potential of reduced biomass accumulation at the expense of their reproductive growth [26]. The length of reproductive period has strong influences on photosensitivity [27] and grain yield [28] in cowpea. Generally, we found that the late maturing cowpea varieties had larger seeds. Also, as SDS inversely associated with PDL, cowpea varieties with shorter pod lengths possessed larger seeds. Findings from this study revealed that GRY had a very strong and significantly positive correlation with NPP (Table 3). Thus cowpea varieties with more pods will eventually yield more seeds. Overall, GRY positively correlated with all the traits with the exception of the flowering traits as previously reported [22]. To further address the importance of GRY in assessing agronomic performance in cowpea, the overall performance of the cowpea varieties was then assessed based on the weighted judgments (contributions) of all the yield and yield-related characters. The NBR, 50% FLW, NPP, SDS, TOB and HI were the top traits that jointly contributed to the ranking of Sampea-11 and Sampea-8 as the 'best' performing varieties. The highest contributions of each of the characters to the overall performance of the cowpea varieties (Table 4) could be utilised in the selection of contrasting parents, ranked higher in these characters for cowpea improvement through hybridization. Taken together, these findings do support, with strong recommendations [29], the need to always consider the existing interrelationships between yield and yield-related traits [30, 15] in cowpea selection, breeding and performance assessments.

Table 1. Analysis of variance

Source of variation	Degree of freedom	MSS								
		50% FLW	75% MTY	NBR	NPP	PDL	SDS	TOB	GRY	HI
Block Effect	2	1.07^{ns}	46.67*	0.21^{ns}	14.60^{ns}	0.80^{ns}	0.03^{ns}	354.26^{ns}	0.19^{ns}	2.68^{ns}
Varietal Effect	4	139.83**	259.9**	0.63^{ns}	32.23*	12.9^{ns}	5.43***	891.21*	291.70**	10.85^{ns}
Residual Effect	8	10.23	8.5	0.38	7.41	6.3	0.04	222.91	20.93	13.47

*MSS – mean sums of square; 50% FLW – days to 50% flowering; 75% MTY – days to 75% maturity; NPP – number of pods per plant; PDL – pod length (cm); SDS – seed size (mm); NBR – number of branches per plant; TOB – total biomass (g); GRY – grain yield (kg ha-1); HI – harvest index; ns – non-significant; *, **, *** - significant at the 95%, 99%, >99% confidence level, respectively*

Table 2. Mean yield and yield-related characters in cowpea

Variety	Growth habit	Seed coat colour	Days to 50% flowering	Days to 75% maturity	Number of branches per plant	Number of pods per plant	Pod length (cm)	Seed size (mm)	Total biomass (kg ha^{-1})	Grain Yield (kg ha^{-1})	Harvest index (%)
Sampea–7	Erect	Brown	44.0	61.0	4.53	12.0	8.0	8.23	2,893.5	**1,136.7**	39.28
Sampea–8	Erect	White	57.0	78.0	5.40	11.0	9.0	7.69	2,579.2	1,082.7	41.98
Sampea–10	Erect	White	52.0	79.0	4.26	8.0	7.0	9.06	2,759.6	1,078.4	39.08
Sampea–11	Spreading	White	43.0	71.0	4.80	17.0	12.0	7.58	3,046.8	**1,304.1**	42.80
Sampea–12	Spreading	Brown	41.0	59.0	4.33	9.7	11.0	5.43	2,768.7	1,069.0	38.61
Mean			*47.33*	*69.73*	*4.66*	*11.60*	*9.4*	*7.59*	*2,809.6*	*1,134.2*	*40.35*
±SEM			*1.84*	*1.68*	*1.73*	*1.57*	*1.44*	*0.11*	*8.62*	*2.64*	*1.85*
LSD (0.05)			*6.02*	*5.48*	*ns*	*5.11*	*ns*	*0.37*	*79.5*	*8.61*	*ns*
CV %			*6.75*	*4.18*	*13.20*	*23.46*	*26.59*	*2.62*	*15.03*	*4.03*	*7.90*

SEM – standard error of mean; LSD – least significant difference; CV – coefficient of variation; ns – non-significant at the 95% confidence level

Table 3. The bivariate correlation matrix of yield and yield-related characters in cowpea

Character	Days to 75% maturity	Number of branches per plant	Number of pods per plant	Pod length (cm)	Seed size (mm)	Total biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Days to 50% flowering	**0.847**(.070)	**0.573** (.313)	-0.381 (.527)	**-0.563** (.323)	**0.530** (.358)	**-0.743** (.151)	-0.406 (.498)	0.267 (.664)
Days to 75% maturity	-	0.422 (.479)	-0.115 (.853)	-0.352 (.561)	**0.639** (.246)	-0.365 (.546)	-0.014 (.983)	0.464 (.432)
Number of branches per plant		-	0.371 (.539)	0.178 (.774)	0.046 (.942)	-0.358 (.554)	0.160 (.797)	**0.789** (.112)
Number of pods per plant			-	**0.685** (.202)	-0.057 (.927)	**0.724** (.166)	**0.950*** (.013)	**0.762** (.134)
Pod length (cm)				-	**-0.712** (.178)	0.449 (.449)	**0.597** (.288)	0.475 (.419)
Seed size (mm)					-	0.046 (.941)	0.101 (.872)	0.131 (.833)
Total biomass (kg ha^{-1})						-	**0.845** (.072)	0.190 (.760)
Grain Yield (kg ha^{-1})							-	**0.686** (.201)

*Pearson's correlation coefficients (r) above 0.500 are in bold typefaces; *r is significant at the 95% confidence level; p-value in parenthesis*

Table 4. Overall performance ranking of cowpea varieties based on selected yield and yield-related characters

Variety	Days to 50% flowering	Days to 75% maturity	Number of branches per plant	Number of pods per plant	Pod length (cm)	Seed size (mm)	Total biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)	*Mean
Sampea–7	3	2	4	3	3	4	2	4	4	3.2 (3rd)
Sampea–8	5	4	3	4	5	3	3	3	1	3.4 (2nd)
Sampea–10	4	5	2	2	1	1	1	2	2	2.6 (4th)
Sampea–11	2	3	5	5	4	5	5	5	5	4.0 (1st)
Sampea–12	1	1	1	1	2	2	4	1	3	1.8 (5th)

*Character weighted contribution: 1 – lowest, 5 – highest; Kendall's Coefficient of Concordance, W = 0.294. *Performance rank in parenthesis*

5. CONCLUSIONS

The results obtained from this study were able to speculate that there are striking relationships and contributions of lead agronomic characters useful in the selection, breeding and evaluation of promising high-yielding cowpea varieties. This study further showed that placing extreme emphasis on grain yield alone is not a sufficient basis for cowpea selection as previously reported in numerous studies and this could also be extended to other pod-bearing leguminous crop species. As such, to gain a finer resolution of these results and findings, it is therefore suggested that the cowpea characters mentioned in this study be further investigated with additional cowpea varieties over a variety of growing environments.

COMPETING INTERESTS

The authors report no competing interest in the study.

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