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Some Comparative Morpho-Physical Features of Kola (Cola spp.)

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The embryo length, moisture content and some other physical features of the nuts of both *Cola acuminata* (P. Beauv) Schott and Endlicher and *Cola nitida* (Vent.) Schott and Endlicher were examined. Fresh and dry weights, nut length and width, embryo and embryo-groove lengths increased with nut size in both species. Nut moisture content decreased with increase in nut size in both species, especially in *C. acuminata*. Generally, embryos were longer in *C. acuminata* than in *C. nitida*. Embryo length relative to nut width was much higher in *C. acuminata* than in *C. nitida*.

Correlations between these morpho-physical factors and rates of germination in both species showed that germination response in *C. nitida* was mainly determined by nut size-related factors such as class midpoint, nut fresh and dry weights and nut length and width. Embryo length and embryo-groove length were critical for germination of both species but they were much more so for germination of *C. nitida* than of *C. acuminata* . Germination in *C. acuminata* was negatively correlated with nut moisture content compared with *C. nitida* where there was no significant relationship. On nut cotyledon basis, both cotyledon number and embryo length positively influenced germination in *C. acuminata* . These relationships show that embryo and embryo-groove lengths, nut moisture content and nut cotyledon number are both jointly and severally responsible for the differential rates of germination in the two kola species.

Keywords: *Cola acuminata, Cola nitida,* embryo length, moisture content, morpho-physical features, nut weight.

In *C. nitida*, post-harvest dormancy is operative such that stored nuts have been found to germinate better and faster than freshly harvested ones (Ashiru, 1969; Ibikunle and MacKenzie, 1974). However, this post-harvest dormancy is not known in *C. acuminata* which has been found to germinate within 14 days of sowing (Ibikunle, 1975; Oladokun, 1982a) and even under storage conditions (Oladokun, 1986).

C. nitida nuts have two cotyledons while *C. acuminata* nuts have two to six, sometimes one or seven cotyledons (Oladokun, 1982b) (Fig. 1). Germination studies in *C. acuminata* showed that cotyledon number significantly influenced germination of the nuts; that is, germination increased as cotyledon number increased from two to five (Oladokun, 1985a).

van Eijnatten (1966) observed differences in position and length of the embryo in *C. nitida* nuts obtained from four different locations. In addition, he found that embryo and embryo-groove lengths increased with increase in nut size. Ibikunle (1975) and Oladokun (1985a) found that variations in the speed of germination of *C. acuminata* were related to nut size and cotyledon number. The factors causing differences in germination of kola are not yet clearly understood. Therefore, the objective of this study was to examine, in the same set of studies, some physical features of both the nuts and embryos in *C. acuminata* and *C. nitida*, and to relate them to the rate of nut germination in both species.

MATERIALS AND METHODS

Thirty nuts were selected from each pre-determined nut size (class interval of 5g size) (Fig. 2) and cotyledon number of *C. acuminata* and *C. nitida* (Oladokun, 1982a). The length, breadth at the widest point and fresh weight of the nuts were recorded. The embryo of each nut was then excised and its length measured. The components of each nut were dried at 105°C to constant weight and recorded. Similarly, germination trials were carried out using nuts from the same batches of *C. acuminata* (at various nut sizes and cotyledon number) and *C. nitida* (at various nut sizes). Four replicates were used for each germination trial. Each replicate had 10 nuts sown per nut size for each cotyledon number for *C. acuminata* and 10 nuts/nut size for *C. nitida*. Germination rate was determined by taking the reciprocal of the number of days required to achieve 50% germination in each treatment/subtreatment. Data were subjected to correlation and regression analyses according to Little and Hills (1975) using the nut size and cotyledon number as

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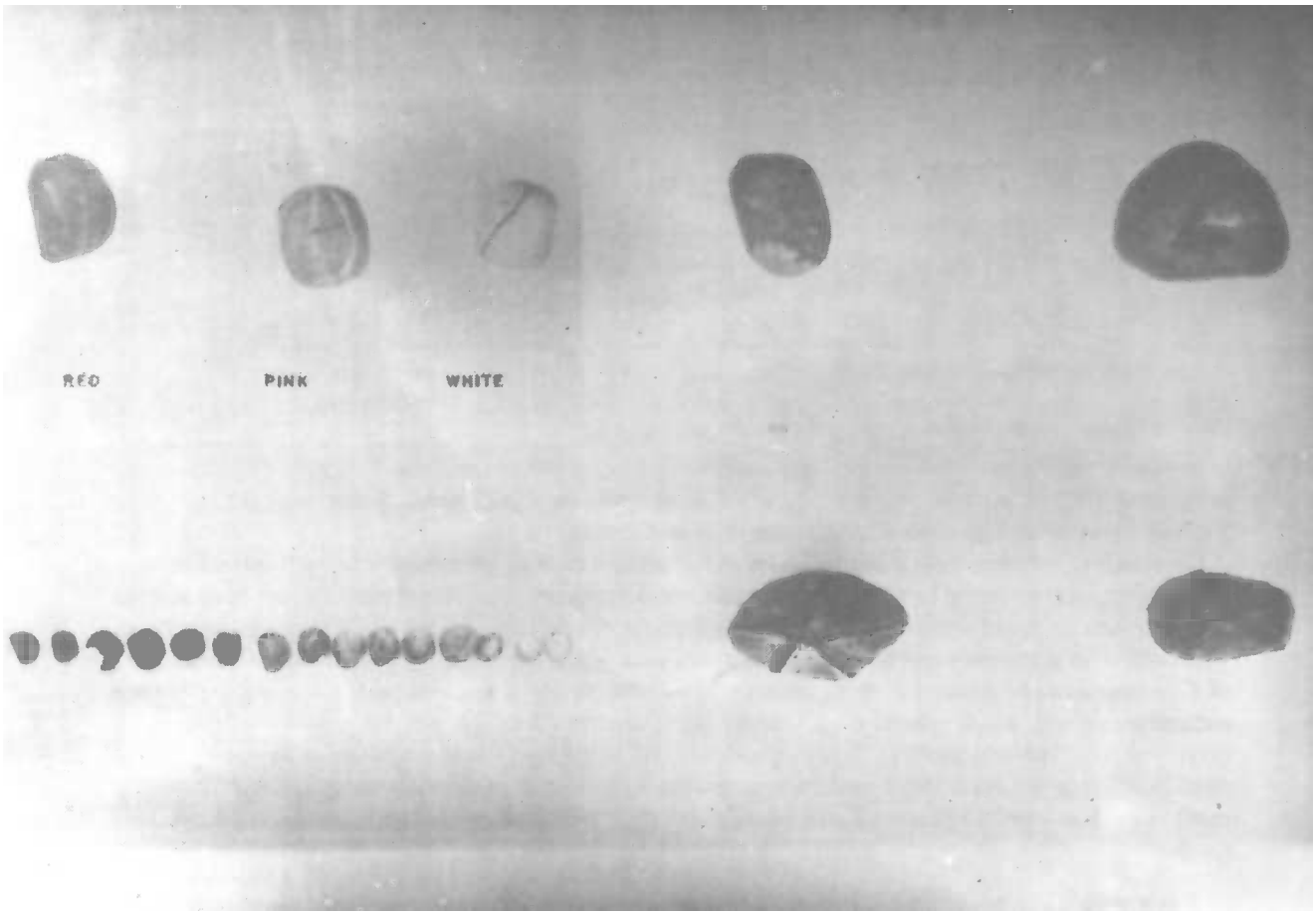

Fig. 1. Nut color and cotyledon number in *Cola acuminata*. (Top left) Three principal color gradations; (bottom left) Color diversity; (top right) One-cotyledon nuts; (bottom right) Seven-cotyledon nuts.

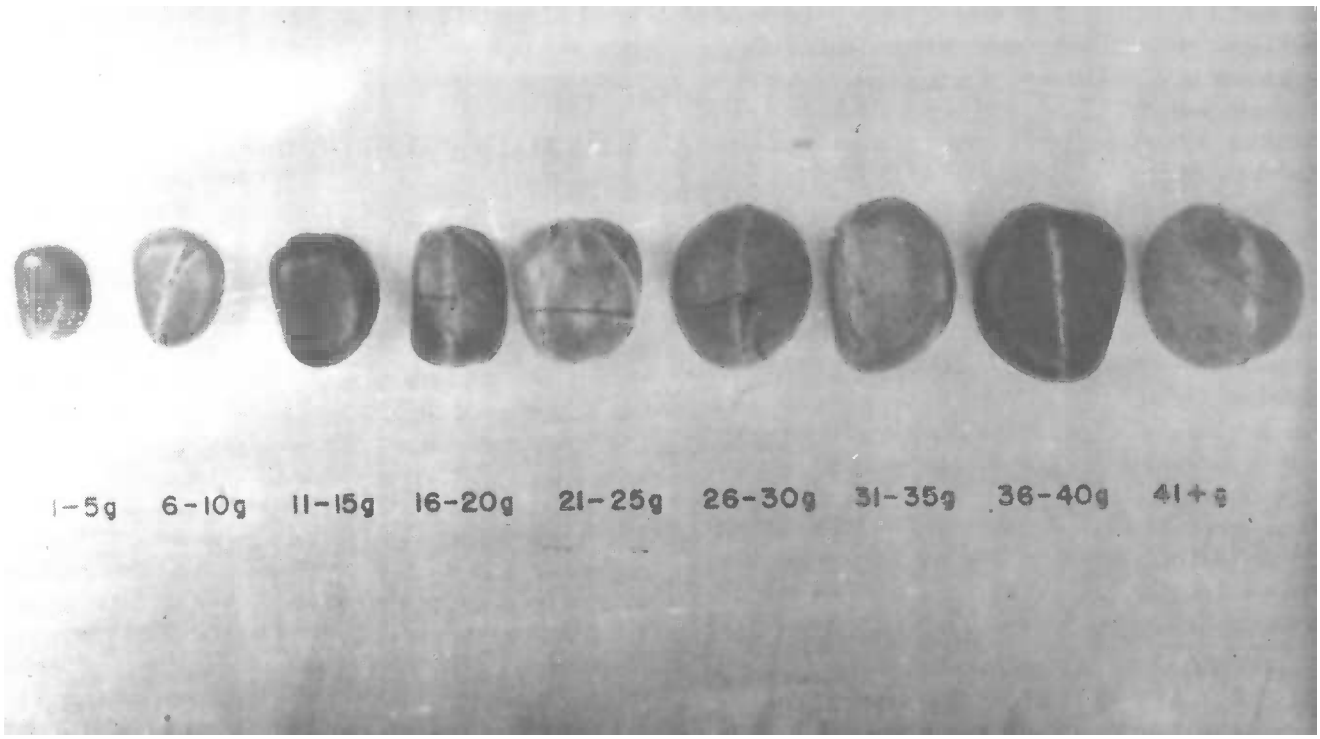

Fig. 2. Nut size variation in *Cola acuminata*.

independent variables. The germination rates were correlated with the morpho-physical factors in both species to determine which of them are the most important factors for germination.

RESULTS

In *C. acuminata* , parameters such as fresh and dry weights, nut length and width, embryo and embryo-groove lengths significantly increased with increase in nut size (Table 1; Figs. 3 and 4). However, nut mositure content as percentage of nut fresh weight significantly decreased with increase in nut size (Table 1; Fig. 5).

Among the ratios of the physical characters considered, embryo length to embryo-groove length correlated positively with nut size and some other parameters. These were, however, negatively correlated with percent moisture content. Cotyledon number was positively correlated with nut fresh weight, nut dry weight, nut length, embryo and embryo-groove lengths (Table 2; Fig. 6). Similarly to nut size, % moisture content correlated negatively with cotyledon number.

The ratios of nut length to nut width and embryo length to nut fresh weight correlated positively with cotyledon number, while those of nut length to embryo length, nut width to embryo length, nut dry weight to nut cotyledon number were generally negatively correlated with nut cotyledon number (Table 2).

In *C. nitida*, nut fresh weight, nut dry weight, nut length, nut width, embryo and embryo-groove lengths positively correlated with nut size. The reverse was, however, the case for % mositure content with nut size (Table 3). These factors also regressed significantly with nut size (Figs. 3, 4 and 5).

The ratios of some of the physical features such as nut length to embryo length, nut width to embryo length and the product of nut length and nut width correlated positively with nut size (Table 3). Other ratios, nut length to nut width, embryo length to embryo-groove length, nut dry weight to class midpoint, embryo length to nut dry weight and % moisture content to embryo length correlated negatively with nut size. The correlation between percent moisture content and embryo length was highly significant.

Correlation coefficients between morpho-physical factors and the rates of germination in both *C. acuminata* and *C. nitida* are shown in Table 4. Nut size-related morpho-physical features such as class midpoint, nut fresh and dry weights, nut length and width as well as the product of nut length and width significantly and positively correlated with germination in *C. nitida*. In *C. acuminata* correlations between nut length, nut width as well as the product of the two and germination rate were just positively significant at P=0.05. Embryo groove length was highly positively correlated with germination rate in *C. acuminata* while correlation between the embryo length and germination rate was just significant (P=0.05). Moisture content increase in *C. acuminata* nuts led to lower rate of germination, a situation similar to what obtained between the ratio of moisture content to embryo length and germination rate.

Increase in nut cotyledon number and embryo length led to increase in germination rate in *C. acuminata* (Table 5). Increase in the ratio of nut width to embryo length significantly led to decrease in germination rate in *C. acuminata*.

Comparisons of the morpho-physical features of *C. acuminata* with *C. nitida* are shown in Table 6. While the mean nut weight of *C. nitida* was higher than that of *C.*

Table 1. Linear correlation coefficients of some characteristics of *Cola acuminata* nuts (nut weight).

	Class midpoint	Fresh Weight	Dry Weight	Moisture Content	Nut Length	Nut Width	Embryo Groove Length	Embryo Length	Nut Length / Embryo Length	Nut Width / Embryo Length	Nut Length / Nut Width	Embryo Length / Embryo Groove Length	Dry Weight / Class Mid-point	Nut Length × Nut Width	Embryo Length / Dry Weight	Moisture Content / Embryo Length
Class midpoint	-	0.99***	0.99***	-0.96***	0.97***	0.97***	0.87*	0.97***	0.32	0.39	-0.34	0.82*	-0.33	0.99***	-0.92***	-0.94***
Fresh Weight		-	0.99***	-0.96***	0.97***	0.97***	0.86*	0.97***	0.33	0.41	-0.35	0.82*	-0.32	0.99***	-0.91***	-0.94***
Dry Weight			-	-0.96***	0.95***	0.95***	0.82*	0.95***	0.33	0.42	-0.38	0.86*	-0.26	0.99***	-0.88**	-0.92***
Moisture Content				-	-0.94***	-0.96***	-0.82*	-0.92***	-0.40	-0.60	0.58	-0.80*	0.20	-0.90***	0.88**	0.91***
Nut Length					-	0.99***	0.95***	0.99***	0.35	0.38	-0.31	0.66	-0.50	0.99***	-0.98***	-0.99***
Nut Width						-	0.94***	0.98***	0.37	0.47	-0.41	0.68	-0.43	0.99***	-0.97***	-0.98***
Embryo Groove Length							-	0.96***	0.25	0.25	-0.20	0.43	-0.70	0.90***	-0.98***	-0.98***
Embryo Length / Nut Length								-	0.25	0.31	-0.29	0.67	-0.53	0.96***	-0.98***	-0.99***
Embryo Length / Nut Width									-	0.74*	-0.29	0.14	0.09	-0.27	-0.28	-0.26
Embryo Length / Nut Length										-	-0.84*	0.37	0.36	-0.17	-0.30	-0.32
Nut Width / Embryo Length											-	-0.45	-0.41	-0.57	0.24	0.29
Embryo Groove Length / Dry Weight												-	-0.19	0.30	-0.54	-0.60
Class Midpoint / Nut Length × Nut Width													-	0.92	0.64	0.58
Embryo Length / Dry Weight														-	0.91	0.98
Moisture Content / Embryo Length															-	0.99***
																-

***Significant at 0.1% **Significant at 1.0% *Significant at 5.0%

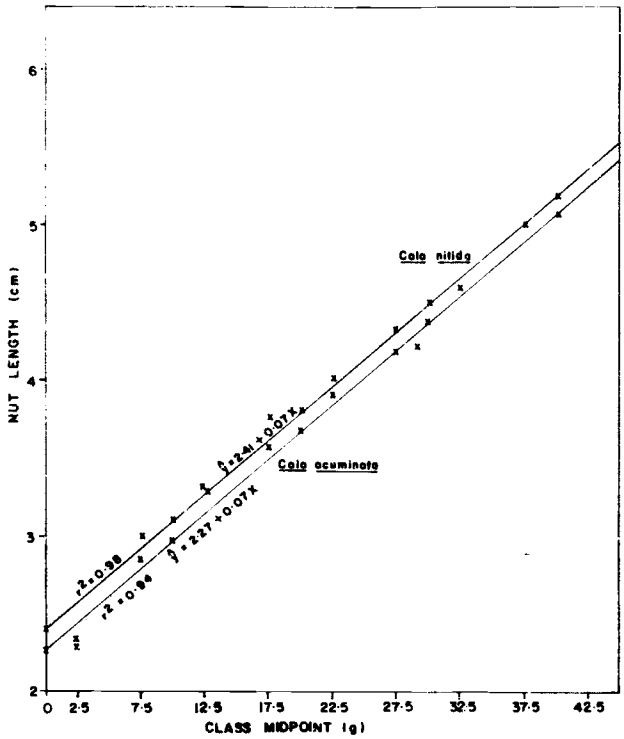

Fig. 3. Regression curves of nut length with class midpoint in *Cola acuminata* and *Cola nitida*.

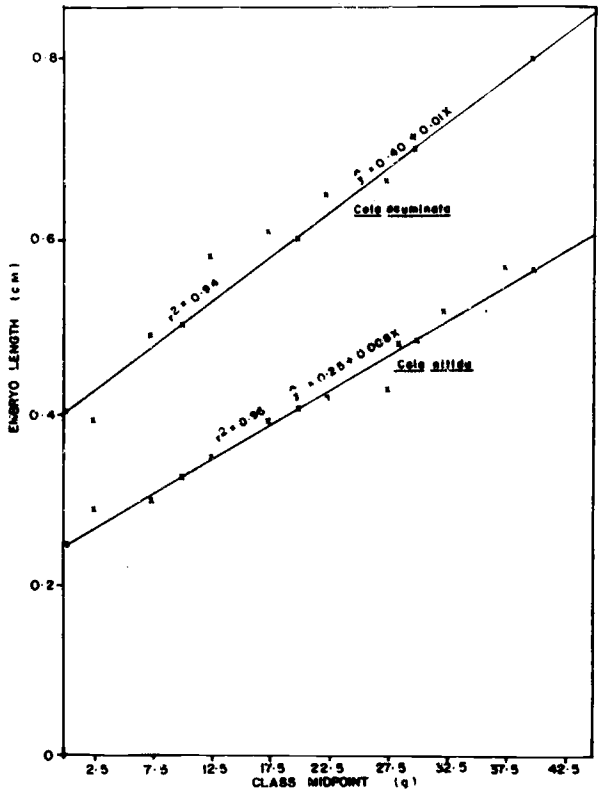

Fig. 4. Regression curves of embryo length with class midpoint in *Cola acuminata* and *Cola nitida*.

acuminata, the latter's embryo length was greater. *C. acuminata* nuts had higher moisture content while the ratio of nut length to nut width was 1.3 in both species.

DISCUSSION

The significant positive correlation recorded for increase in nut dry weight, nut length and width, embryo and embryo-groove lengths with increase in nut size in both *C. nitida* and *C. acuminata* not only agree with, but supplement, the findings of van Eijnatten (1966) that embryo and embryo-groove lengths increased with nut size in *C. nitida*. It is noteworthy that moisture content decreased with increase in nut size of both species. Mean moisture content for *C. acuminata* was 60.29% while that of *C. nitida* was 55.06%. These values compare favorably with those of Ogutuga (1975) on *C. nitida*.

The fact that embryos were longer in *C. acuminata* than in *C. nitida* (0.6 cm for *C. acuminata* as againsst 0.4 cm for *C. nitida*) while the values of the ratio of embryo length to embryo-groove length were much higher in *C. acuminata* than in *C. nitida*, may account for the differential rate of germination of the nuts of the two species. van Eijnatten (1967) observed that the embryos of stored *C. nitida* nuts were much more developed than those of the freshly harvested nuts and that this accounted for stored nuts germinating faster than freshly harvested nuts.

Correlating the germination rates with these morpho-physical factors in both species, it was observed that whereas nut size related morpho-physical factors positively influenced germination more in *C. nitida* than in *C. acuminata*, it was the embryo and embryo-groove lengths which

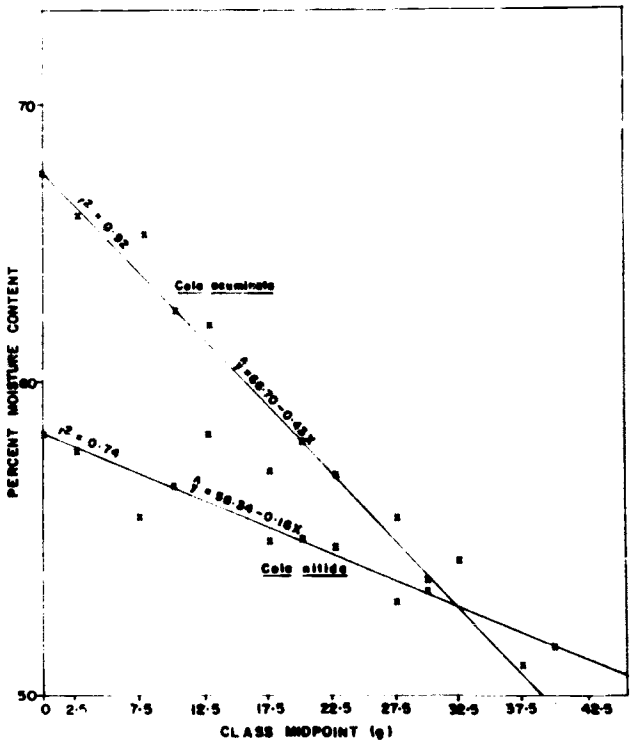

Fig. 5. Regression curves of percent moisture content with class midpoint in *Cola acuminata* and *Cola nitida*.

apparently influenced germination in the latter. This is because both the embryo length and embryo-groove length are much more dependent on nut size in *C. nitida* than in *C.*

Table 2. Linear correlation coefficients of some characteristics of *Cola acuminata* nuts (nut cotyledon number).

	Cotyledon Number	Fresh Weight	Dry Weight	Moisture Content	Nut Length	Nut Width	Embryo Groove Length	Embryo Length	Nut Length Embryo Length	Nut Width Embryo Length	Nut Length Nut Width	Embryo Length Embryo Groove Length	Dry Weight Cotyledon Number	Nut Length × Nut Width	Embryo Length Dry Weight	Moisture Content Embryo Length
Cotyledon Number	-	0.86	-0.87	-0.77	0.78	0.25	0.72	-0.99***	-0.99***	-0.97*	0.18	0.83	-0.97*	0.40	0.94*	-0.96*
Fresh Weight		-	-0.93	-0.96*	0.97*	0.64	0.97*	0.90*	-0.85	-0.76	-0.25	0.42	-0.72	0.76	0.96*	-0.74
Dry Weight			-	-0.97*	-0.97*	0.68	-0.85	-0.89	0.84	0.74	0.31	-0.52	0.79	-0.78	-0.90	0.71
Moisture Content				-	0.97*	-0.80	-0.93*	-0.81	0.74	0.62	0.47	-0.32	0.64	-0.89	-0.87	0.59
Nut Length					-	0.80	0.93*	0.81	-0.74	-0.62	-0.49	0.33	-0.64	0.89	0.87	-0.58
Nut Width						-	0.70	0.30	-0.20	-0.03	-0.90*	-0.24	-0.09	0.99***	0.42	0.01
Embryo Groove Length							-	0.77	-0.71	-0.61	-0.37	0.20	-0.53	0.79	0.90*	-0.60
Embryo Length								-	0.99***	-0.96*	0.13	0.77	-0.95*	0.45	0.97*	-0.95*
Nut Length / Embryo Length									-	0.98**	-0.23	-0.83	0.97*	-0.35	-0.94*	0.97
Nut Width / Embryo Length										-	-0.40	-0.89	0.97*	-0.19	-0.89	0.99**
Nut Length / Nut Width											-	0.59	-0.32	-0.82	0	-0.43
Embryo Length / Embryo Groove Length												-	-0.93	-0.10	0.60	-0.88
Dry Weight / Cotyledon number													-	-0.24	-0.84	0.95*
Nut Length × Nut Width / Embryo Length														-	0.56	-0.15
Dry Weight / Moisture Content Embryo Length															-	-0.89
																-

***Significant at 0.1% **Significant at 1.0% *Significant at 5%

Table 3. Linear correlation coefficients of some characteristics of *Cola nitida* nuts.

	Class Midpoint	Fresh Weight	Dry Weight	Moisture Content	Nut Length	Nut Width	Embryo Groove Length	Embryo Length	Nut Length Embryo Length	Nut Width Embryo Length	Nut Length Nut Width	Embryo Length Embryo Groove Length	Dry Weight Class Midpoint	Nut Length × Nut Weight	Embryo Length Dry Weight	Moisture Content Embryo Length
Class Midpoint	-	0.99***	0.99***	-0.86**	0.99***	0.99***	0.96***	0.98***	0.13	0.35	-0.82**	-0.07	-0.50	0.99***	-0.84**	-0.99***
Fresh Weight		-	0.99***	-0.87**	0.99***	0.98***	0.96***	0.98***	0.14	0.33	-0.81**	-0.06	-0.48	0.99***	-0.82**	-0.99***
Dry weight			-	0.89***	0.98***	0.97***	0.97***	0.98***	0.12	0.30	-0.78*	-0.07	-0.45	0.99***	-0.80**	-0.98***
Moisture Content				-	-0.86**	-0.84**	-0.89***	-0.84**	0.14	-0.32	0.62*	0.31	0.31	-0.87**	0.71*	0.85**
Nut Length					-	0.99***	0.96***	0.96***	0.11	0.42	-0.82**	-0.15	-0.60	0.99***	-0.89***	-0.99***
Nut Width						-	0.94***	0.94***	0.08	0.43	-0.88**	-0.13	-0.59	0.99***	-0.89***	-0.98***
Embryo Groove Length							-	0.96***	0.24	0.27	-0.72*	-0.27	-0.47	0.96***	-0.80**	-0.97***
Embryo Length								-	0.27	0.17	-0.72*	0.01	-0.41	0.97***	-0.75*	-0.98***
Nut Length / Embryo Length									-	-0.48	0.03	0.05	-0.01	0.10	0.02	-0.21
Nut Width / Embryo Length										-	-0.68*	-0.46	-0.75	0.38	-0.73*	-0.35
Nut Length / Nut Width											-	0.13	0.55	-0.83**	0.81**	0.82**
Embryo Length / Embryo Groove Length												-	0.38	-0.08	0.35	0.14
Dry Weight / Class Midpoint													-	-0.51	0.87**	0.53
Nut Length × Nut Width / Embryo Length														-	-0.84**	-0.99***
Dry Weight / Moisture Content Embryo Length															-	0.85**
																-

***Significant at 0.1% **Significant at 1.0% *Significant at 5.0%

acuminata. The size of the embryo is much more critical to germination in *C.nitida* than in *C. acuminata* because it is much smaller in the former than in the latter and will need to develop to the required size before germination can take place; hence this condition is apparently satisfied under storage conditions as observed by van Eijnatten (1967). For *C. acuminata*, most of the embryos are fully developed and hence commence germination immediately even under storage (Oladokun, 1986). Embryo-groove length was much more size dependent in *C. nitida* than in *C. acuminata* and since it provides room for further growth and development of the embryo, it is no surprise, therefore, that it was highly significantly and positively correlated with germination rate.

Increase in nut moisture content was much more detrimental to germination in *C. acuminata* than in *C. nitida* as this factor was much more negatively correlated with those factors that critically lead to increase in germination, such as the embryo length, in *C. acuminata* than in *C. nitida*. Also, *C. acuminata* nuts contained more moisture than *C. nitida* to the extent that it became detrimental to germination. Oladokun (1986) found that percentage germination in *C. acuminata* increased with nut size under storage conditions while in the present study, nut moisture content correlated

Table 4. Correlation coefficients between some morphophysical factors and rates of germination in *Cola acuminata* and *Cola nitida*.

Characteristics	*Cola acuminata*	*Cola nitida*
Class Midpoint	+0.71	+0.98***
Nut Fresh Weight	+0.72	+0.97***
Nut Dry Weight	+0.70	+0.95***
Moisture Content (%)	-0.80*	+0.09
Nut Length	+0.81*	+0.96***
Nut Width	+0.80*	+0.97***
Embryo Groove Length	+0.86**	+0.90**
Embryo Length	+0.79*	+0.92**
Nut Length		
Embryo Length	-0.55	+0.38
Nut Width		
Embryo Length	+0.54	+0.85*
Nut Length		
Nut Width	+0.09	-0.76
Embryo Length		
Embryo Groove Length	+0.32	-0.74
Nut Dry Weight		
Class Midpoint	-0.19	-0.68
Nut Length × Nut Width	+0.80*	+0.97***
Embryo Length		
Nut Dry Weight	-0.62	-0.89**
Moisture Content		
Embryo Length	-0.81*	-0.89**

***Significant at 0.1%
**Significant at 1.0%
*Significant at 5.0%
Correlations obtained by correlating germination rates (Oladokun, 1982a) with morpho-physical factors.

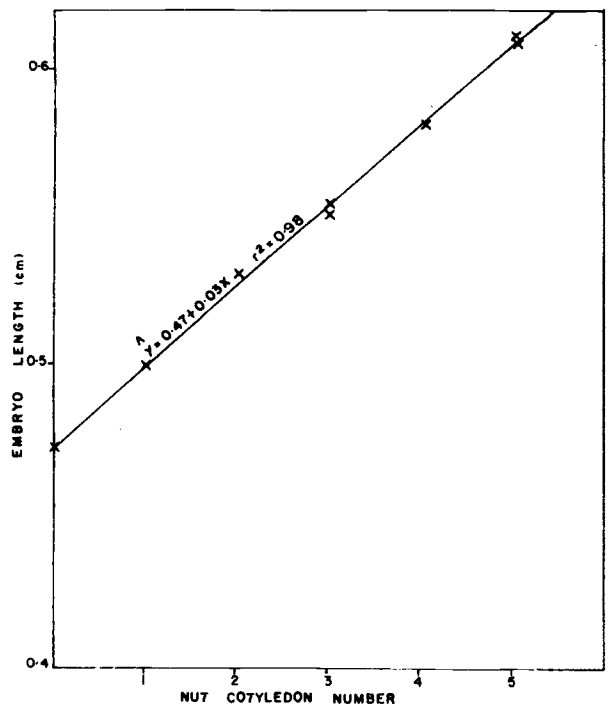

Fig. 6. Regression curve of embryo length with nut cotyledon number in *Cola acuminata*.

Table 5. Correlation coefficients between some morpho-physical factors and rate of germination in *Cola acuminata* (nut cotyledon number)

Characteristics	*Cola acuminata*
Cotyledon number	+0.85
Nut Fresh Weight	-0.36
Nut Dry Weight	-0.40
Moisture Content (%)	+0.16
Nut Length	-0.22
Nut Width	-0.39
Embryo Groove Length	-0.45
Embryo Length	+0.63
Nut Length	
Embryo Length	-0.72
Nut Width	
Embryo Length	-0.96*
Nut Length	
Nut Width	+0.42
Embryo Length	
Embryo Groove Length	+0.86
Nut Dry Weight	
Cotyledon Number	-0.82
Nut Length × Nut Width	-0.38
Embryo Length	
Nut Dry Weight	+0.62
Moisture Content	
Embryo Length	-0.84

*Significant at 5%.
Correlations obtained by correlating germination rates (Oladokun, 1982a) with morpho-physical factors.

Table 6. *Mean values of some morpho-physical factors of *Cola acuminata* and *Cola nitida* nuts

Characteristics	*Cola acuminata*	*Cola nitida*
Nut Fresh Weight	15.28 ± 8.63	20.00 ± 11.61
Nut Dry Weight	6.41 ± 4.13	9.21 ± 5.68
Moisture Content (%)	60.29 ± 4.17	55.06 ± 2.33
Nut Length	3.30 ± 0.66	3.81 ± 0.87
Nut Width	2.60 ± 0.54	3.00 ± 0.77
Embryo Groove Length	0.60 ± 0.10	1.02 ± 0.25
Embryo Length	0.57 ± 0.11	0.41 ± 0.10
Nut Length		
Embryo Length	5.80 ± 0.12	7.09 ± 3.76
Nut Width		
Embryo Length	4.56 ± 0.17	7.01 ± 0.68
Nut Length		
Nut Width	1.27 ± 0.03	1.28 ± 0.06
Embryo Length		
Embryo Groove Length	0.95 ± 0.05	0.40 ± 0.03
Nut Dry Weight		
Class Midpoint	0.44 ± 0.06	0.48 ± 0.08
Nut Length × Nut Width	8.88 ± 3.36	12.01 ± 5.38
Embryo Length		
Nut Dry Weight	0.13 ± 0.08	0.06 ± 0.05
Moisture Content		
Embryo Length	111.35 ± 32.65	142.69 ± 38.59

Each figure is the mean of 720 nuts for *Cola acuminata* and 480 nuts for *Cola nitida*, plus or minus the standard error.
*Weight and Length measurements are in gram and centimeters respectively.

negatively with nut size. However, the relative humidity under the prevailing storage conditions is a factor to be recognized in relation to the nut moisture content.

The fact that, on nut cotyledon number basis, germination increased with increase in cotyledon number and embryo length but decreased with embryo-groove length shows that both nut size and cotyledon number jointly influence germination of *C. acuminata* nuts as heavier nuts have bigger embryos, less moisture content and, when combined with higher number of cotyledons, the cotyledons are held together by lower adhesive force leading to easier splitting of the cotyledons and emergence of the radicles (Oladokun, 1985b). At this point in time, increase in the embryo-groove length is not particularly necessary to influence germination as the embryos have apparently attained the peak of pre-germination growth and development. This is where the importance of the ratio of the embryo length to that of embryo-groove length becomes significant. Where there is difficulty in splitting, the possible ameliorative role of hormones and plant growth substances needs to be investigated (Adedipe, 1975; Ashiru, 1969).

Apparently, it is not necessarily the nut length or the embryo-groove length per se which determines germination differences between the two species. The length of the embryo relative to that of the nut, as well as embryo length relative to nut width appear to be important factors in nut germination as they are indicators of their developmental status. These values were 100% and 60% (respectively) higher in *C. acuminata* than in *C. nitida*, hence the widely observed faster germination in *C. acuminata* than in *C. nitida*. More comparative studies will, however, be needed along these lines for better understanding of the basis of differential germination in kola species.

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