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INHERITANCE OF FRUIT COLOUR IN NIGERIAN LOCAL OKRA, *ABELMOSCHUS ESCULENTUS* (L.) MOENCH, CULTIVARS.

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ABSTRACT

As part of an ongoing breeding programme aimed at improving the mucilage content of high yielding local okra cultivars, crosses were made using three local okra Abelmoschus esculentus (L) Moench cultivars to work out the pattern of inheritance of fruit skin colour in some Nigerian local okra cultivars. Okra with deep green skin colour are considered more mucilaginous than others and okra consumers show appreciable preference for them. The results confirmed that fruit skin colour in okra is monogenically controlled and the recessive genes involved form a multiple allelic series. The genotypes of the genes involved are suggested as well as their dominance hierarchy. Therefore transferring the deep green colour from Awgu early, an elite cultivar, to other identified cultivars will be quite easy and fast. The results also failed to agree with some of the reports on the inheritance of okra fruit skin colour involving some exotic okra cultivars, thereby contributing to the resolution of some of the existing controversies on the pattern of inheritance of this trait.

Key words: Local Okra**,** ***Abelmoschus esculentus*****,** fruit skin colour, inheritance.

INTRODUCTION

Though a good number of reports exist on the inheritance of fruit skin colour in okra, such reports come from studies done with exotic okra types in different parts of the world where the criteria for selection of ideal okra fruits, to meet consumers expectations, differ markedly from the ones in Nigeria and indeed West Africa. In West Africa, okra is utilized essentially because of its high mucilage content which is used in the thickening of soup (Irvine 1952; Purseglove 1968; Wolfe *et a1*1977; Vickery and Vickery 1979; Fatokun *et al* 1979; Fatokun and Chheda 1980; Uzo and Ojiakor 1980). Udengwu (1999) noted that in the improvement of exotic okra cultivars, selection is strictly against high mucilage content, a quality very much sought after in West African countries where swallowed food occupies a premier position in the people's menu. Soups with high mucilaginous character greatly facilitate the swallowing of molded balls of food usually prepared from tuber crops or cereals or a mixture of both. Okra soup exhibiting high mucilaginous character is the delight of the average Nigerian, especially those from the Southern part of the country.

Okra fruits considered to be of good quality in the Nigerian context, must be smooth, green coloured, short and highly mucilaginous (Fatokun *et al* 1979). Deep green coloured fruits are popularly believed to also have high mucilaginous character; hence they have better market value than fruits of other colours. Fruit skin colour is therefore a very important agronomic trait of okra in Nigeria.

Work done on the inheritance pattern of this trait in other parts of the world apart from being conflicting also somehow involved different fruit skin colours when compared with the local cultivars. Kalia and Padda (1962) reported that in inter- varietal crosses between three varieties of okra having purple, green and creamy fruits, a multiple allelic series appeared to control fruit colour, green being dominant over cream while purple was dominant over both green and cream. Kolhe and D'Cruz (1966) indicated that pigmentation on the fruit of okra was monogenically controlled with reddish pigmentation being completely dominant over non pigmentation of fruits. They observed no new recombinants with respect to pigment in stem, fruit, leaf veins, petal veins and calyx and suggested that the genes causing colour in these plant parts of okra is most probably pleiotropic in action. White skin was reported by Jassim (1967) to be dominant over green with a pair of genes involved. Nath and Dutta(1970) on the other hand stated that fruit skin

colour was controlled digenically, with light cream colour and pink shading both being dominant over green colour.

This report is part of the breeding programme for high mucilage content in local okra cultivars. No other known work is known to be currently going on in the country or any other part of West Africa that is geared towards breeding for high mucilaginous character in okra. The report by Uzo and Orjiakor (1980) was based on a physical method for the determination of okra fruit quality based on "apparent" kinematic viscosity of okra fluid. Wolfe *et al* (1977) did a chemical extraction of the mucilage of okra after boiling and precipitation to estimate the yield of mucilage per kilogram of okra fruit. They also studied the properties of the extracted mucilage.

Pertinent studies already carried out in this very important area of breeding for high mucilage content include, Udengwu (1999), which reported on fruit quantitative characters and apparent kinematic viscosities of mucilage of okra cultivars as well as Udengwu (2008), which reported on the effects of temperature changes on the apparent kinematic viscosity of fruit mucilage of *Abelmoschus esculentus* and *A. callei* cultivars. From these two studies, one *Abelmoschus esculentus* cultivar, Awgu early, known for its characteristic green colour was identified as the most mucilaginous in that group while Ebi Ogwu also known for its green colour was identified as the most mucilaginous okra among the *A. callei* group.

This present study as part of the ongoing high mucilage content breeding programme is aimed at understanding the pattern of inheritance of fruit skin colour in the Nigerian local okra cultivars. This is with a view to quickly transferring the genes responsible for greenish fruit skin colour, which is one of the most acceptable okra fruit qualities in the country and which may also be involved in the control of the mucilage character, into high yielding local cultivars that lack both the green fruit skin colour as well as high mucilage character. This report also attempts to resolve the existing conflict about the dominance hierarchy in okra fruit skin inheritance as well as the number and kind of genes involved.

MATERIALS AND METHODS

Three local early okra cultivars namely "Ogbu Oge", Awgu early and "Mpi ele" were used in the three separate crosses. They are briefly described as in Table 1.

Table 1. Fruit skin colour characteristics of the 3 okra cultivars

"Ogbu Oge"	"Awgu Early"	"Mpi ele"
A very late-early flowering okra that produces **reddish green** fruits that are shaped like cocoa pod.	A very early flowering okra type which produces short fat fruits that are **deep greenish** in Colour	A moderately late-early flowering okra which produces very long, slender, **faint greenish-milky white** fruits

In October 1990, three pre-germinated seeds of each of the three parents were sown in medium sized black polythene bags measuring 12cm in diameter and 25cm deep, filled with a mixture of top garden soil, poultry manure and river sand in the ratio of (3:1:1). The bags were placed on wooden benches in the screen house in the Botanical garden, University of Nigeria, Nsukka. Ten days after the emergence of the two cotyledon-like leaves, the seedlings were thinned down to one plant per bag. Watering was done twice daily, morning and evening. When the plants flowered, non destructive emasculation technique (DET), based on the methods reported by Udengwu(2007), was used to effect emasculation, since planting was done during the harmattan harsh period.The following direct and reciprocal crosses were made:

(a) "Ogbu Oge" (Reddish green fruit) x Awgu early (Deep greenish fruit) **Direct Cross(DC)**
Awgu early (Deep greenish fruit) x "Ogbu Oge" (Reddish green fruit) **Reciprocal Cross(RC)**

(b) "Ogbu Oge" (Reddish green fruit) x "Mpi ele" (Faint greenish- milky white) **DC**
"Mpi ele"(Faint greenish- milky white) x "Ogbu Oge"(Reddish green fruit) **RC**

(c) Awgu early (Deep greenish fruit) x "Mpi ele" (Faint greenish- milky white).**DC**
"Mpi ele" (Faint greenish- milky white).x Awgu early (Deep greenish fruit) **RC**

When the hybrid seeds were dry they were harvested and stored in desiccators, using anhydrous Calcium chloride pellets as dehydrant.

In April 1991, three pre-germinated seeds, from the stored F_1 hybrid seeds, as well as the parental seeds, were planted per stand, in holes about 1cm deep in the Botanical garden on flat beds measuring 3mx3m with 15cm as the within row spacing and 30cm as the between row spacing, following standard cultural practices. The hybrids were completely randomized and there were three replicates with the three parents serving as guard rows. Chicken manure was applied at the rate of

10.75kg per plot. Ten days after the emergence of the two cotyledon-like leaves, the seedlings were thinned down to one per stand. The plants were rain fed. When the plants were in bloom, the hybrid plants were selfed to obtain the F_2 seeds. The F_1 hybrid plants were also backcrossed to the recessive parents to study the segregation in the backcross generations. The selfed and backcross flowers were tagged. The F_2 plants were counted to study the segregation of the traits under study. Counts were made after thorough observations. All the replicates were treated as a single population with regards to counts of the expression of fruit skin colour. Other data obtained from the replications which were subjected to analysis of variance, based on the experimental design, and do not form part of this report. The following F_1 selfings and backcrosses were made:

"Ogbu Oge"(Reddish green fruit) x Awgu early (Deep greenish fruit), **F_1 Selfed**
Awgu early (Deep greenish fruit) x "Ogbu Oge"(Reddish green fruit), **F_1 Selfed**
Awgu early x ("Ogbu Oge"x Awgu Early), **F_1 Backcrossed**
Awgu early x (Awgu Early x "Ogbu Oge"), **F_1 Backcrossed**

"Ogbu Oge" (Reddish green fruit) x "Mpi ele" (Faint greenish- milky white), **F_1 Selfed**
"Mpi ele" (Faint greenish- milky white) x "Ogbu Oge" (Reddish green fruit), **F_1 Selfed**
"Mpi ele" x ("Ogbu Oge"x "Mpi ele"), **F_1 Backcrossed**
"Mpi ele" x ("Mpi ele"x "Ogbu Oge"), **F_1 Backcrossed**

Awgu early (Deep greenish fruit) x "Mpi ele" (Faint greenish- milky white), **F_1 Selfed**
"Mpi ele"(Faint greenish-milky white) x Awgu Early (Deep greenish fruit),**F_1 Selfed**
"Mpi ele"x (Awgu Early x "Mpi ele"), **F_1 Backcrossed**
"Mpi ele"x ("Mpi ele"xAwgu Early), **F_1 Backcrossed**

In September 1991, the F_2 were also planted in the Botanical garden. The beds for the backcross were similar to that of the F_1 while that for the F_2 measured 10mx2m with plant spacing similar to that of the F_1. There were three replicates in a randomized complete block design. When the first fruits produced attained the age of 25 days, counts were made with respect to fruit colour expression, treating the replicates as a single population as already explained for the April 1991 planting. Chi-square test was used in the analyses of the data. However as a result of the small population size of the experimental plants, Yates Correction for small numbers and continuity was introduced. The formula used was:-

$$\chi^2 = \sum (| O - E | - 0.5)^2 / E$$

where O = Observed
and E = Expected

RESULTS AND DISCUSSIONS

The results showed that there were no striking morphological differences between the F_1 plants from the direct and reciprocal crosses. Table 2 gives the summary of the results of the various crosses and their tests for significance using the (χ^2) Chi-square statistic. The F_1 in the first cross "Ogbu Oge" (**Reddish green fruit**) x Awgu early (**Deep greenish fruit**) showed that the fruits of all the progenies had Reddish green fruits irrespective of the cultivar used as the maternal parent. The segregation of the F_2 plants showed a ratio of 3 Reddish green fruits: 1 deep greenish. The backcrosses of the Reddish green hybrid parents (from both the direct and reciprocal crosses) to the Deep green recessive parent gave a ratio of 1Reddish green : 1Deep green in each case.

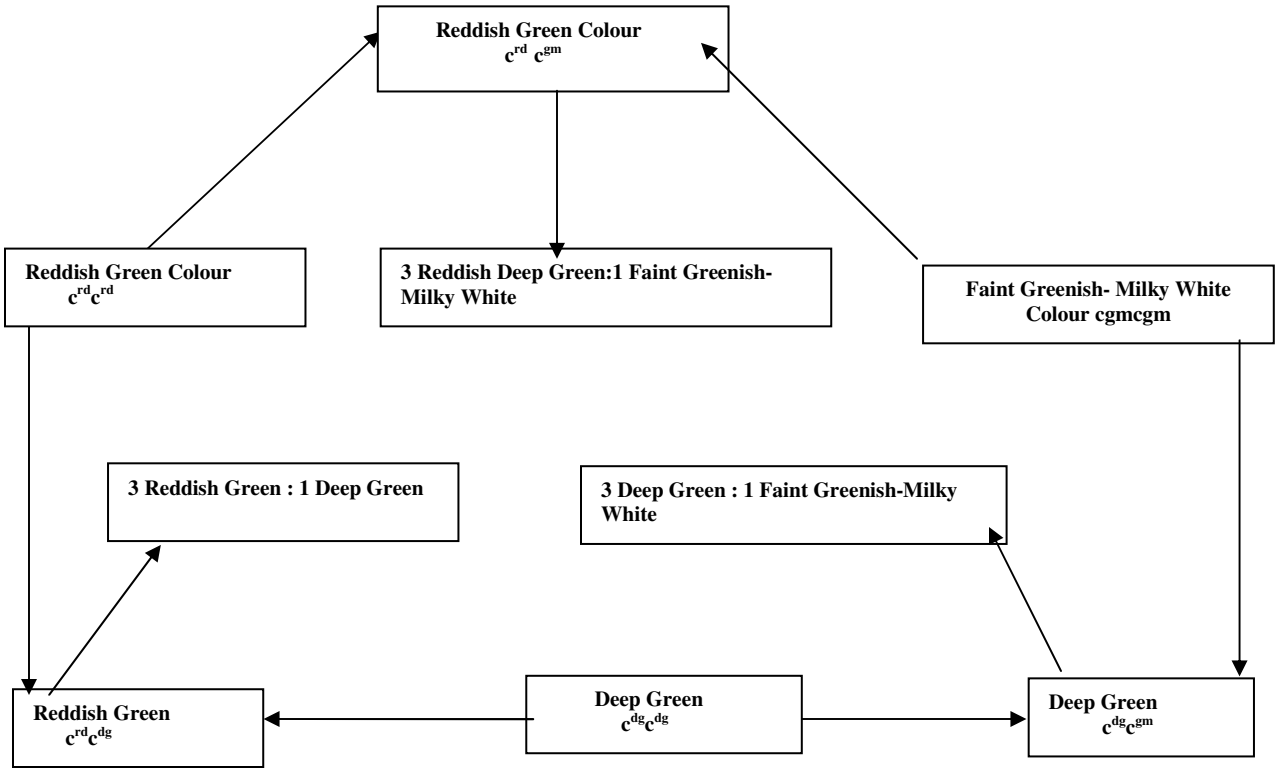
For the second cross "Ogbu Oge" (**Reddish green fruit**) x "Mpi ele" (**Faint greenish- milky white**), all the F_1 plants produced Reddish green fruits, for both the direct and reciprocal crosses. The segregation of the F_2 gave a ratio of 3 Reddish green fruits : 1 Faint greenish-milky white. For the backcross of the Reddish green hybrid parent to the recessive Faint greenish-milky white parent, a ratio of 1Reddish green:1 Faint greenish milky white was produced for both the direct and reciprocal backcrosses.

Similarly for the third cross, Awgu early (**Deep greenish fruit**) x "Mpi ele" (**Faint greenish- milky white**), all the F_1 hybrids produced Deep greenish fruits, for the direct and reciprocal crosses. The F_2 segregated into 3 Deep green : 1 Faint greenish-milky white while the backcross of the Deep green hybrid parent to the recessive Faint greenish- milky white parent gave a ratio of 1 Deep green : 1 Faint greenish-milky white for both the direct and reciprocal backcrosses. The (χ^2) Chi-square tests showed no significant differences between the observed and the expected values, for all the crosses analysed, as can be seen from the probabilities in table 2. No intermediate colours were observed in any of the generations

Table. 2: Phenotypic expression of fruit skin colour in Parents, F1, F2 and backcross generations in okra

Parents and Crosses	Plants with Reddish Green colour	Plants with Deep Green colour	Plants with faint greenish milky white colour	Total population	Expected phenotypic ratio	χ^2	Probability
"Ogbu Oge"	27	--	--	27			
Awgu Early	--	29	--	29			
"Mpi Ele"	--	--	24	24			
i) "Ogbu Oge" x Awgu Early, F1	30	--	--	30			
Awgu Early x "Ogbu Oge", F1	32	--	--	32			
"Ogbu Oge" x Awgu Early, F2	155	47	--	202	3:1	0.3233	.70-.50
Awgu Early x "Ogbu Oge" F2	142	39	--	181	3:1	1.1510	.30-.20
Awgu Early x ("Ogbu Oge" x Awgu Early) BC1	27	35	--	62	1:1	0.0322	.50-.30
Awgu Early x (Awgu Early x "Ogbu Oge") BC1	33	23	--	56	1:1	1.7857	.20-.10
ii) "Ogbu Oge" x "Mpi Ele", F1	23	--	--	23			
"Mpi Ele" x "Ogbu Oge", F1	27	--	--	27			
"Ogbu Oge" x "Mpi Ele", F2	143	_	54	197	3:1	0.6108	.50-.30
"Mpi Ele" x "Ogbu Oge" F2	132	--	35	167	3:1	1.4550	.30-.20
"Mpi Ele" x ("Ogbu Oge" x "Mpi Ele") BC1	24	_	31	55	1:1	0.8909	.50-.30
"Mpi Ele" x ("Mpi Ele" x "Ogbu Oge") BC1	32	--	27	59	1:1	0.4237	.70-.50
iii) "Awgu Early x "Mpi Ele", F1	--	21	--	21			
"Mpi Ele" x Awgu Early , F1	--	23	--	23			
Awgu Early x "Mpi Ele" F2	--	134	54	188	3:1	1.3900	.30-.20
"Mpi Ele" x Awgu Early F2	--	135	58	193	3:1	2.6269	.20-.10
"Mpi Ele" x (Awgu Early x "Mpi Ele") BC1	--	18	26	44	1:1	1.4545	.30-.20
"Mpi Ele" x("Mpi Ele" x Awgu Early) BC1	--	15	22	37	1:1	1.3243	.30-.20

Fig.1 **Schematic Representation of Multiple Allelism in the Inheritance of Okra Fruit Skin Colour**



Inheritance of fruit colour in nigerian local okra. *abelmoschus esculentus* (l.) Moench. cultivars**.**

The report by Jassim (1967) that white skin was dominant over green with a pair of genes involved differ from this report if the faint greenish-milky white colour of this report is equated to his white colour but if his white colour is seen as a distinct colour from the faint milky-white colour then it needed to be involved alongside other shades of colours of okra fruit skin for a better and broader understanding of the dominance hierarchy in fruit skin colour in okra. The faint greenish-milky white colour in this report is quite close to the light cream colour Nath and Dutta(1970) used in their studies which they incidentally reported was dominant over green colour. This again differs from this finding where green colour is dominant over faint greenish milky white colour. On the other hand just as was observed in the case of white colour if their light cream colour is seen as a distinct colour then it could also be involved in this wider study involving many more shades of okra fruit skin colour. Additionally since no intermediate colours were observed in any of the generations and the colours studied found to be monogenically controlled, this report again differs from that of Nath and Dutta (1970) which indicated that fruit skin colour was controlled digenically with light cream colour and pink shading both being dominant over green colour.

Though the colour of fruits Kalia and Padda (1962) studied differed slightly from the ones reported here, the present study essentially confirmed their findings especially with respect to a multiple allelic series controlling the inheritance of fruit skin colour in okra and fruit skin colour in okra being monogenically controlled.

The suggested genotypes for the genes controlling the three fruit skin colours from this study are: $c^{rg}c^{rg}$ for reddish green fruit, $c^{dg}c^{dg}$ for deep greenish fruit and $c^{gm}c^{gm}$ for faint greenish-milky white. The dominance hierarchy in the

multiple allelic series is given as $c^{rg}c^{rg} > c^{dg}c^{dg} > c^{gm}c^{gm}$ (fig 1). It is suggested that a much broader inheritance study involving many more diverse fruit skin colours in okra need to be carried out for a more comprehensive dominance hierarchy in this trait. The existence of diverse fruit colour types in okra is indicative of the existence of very wide recombination potentials in the plant and most interestingly the inheritance pattern of several traits studied in okra show that the traits are governed by simple Mendelian genes. Erickson and Couto (1963) found okra to be extremely variable phenotypically and they observed that this plant-plant variability is suggestive of an excellent source of diverse genetic material. They concluded that okra is evidently a polyploid. In their review of variation in okra varieties, Martin *et al* (1981) noted that a surprisingly large number of characteristics are inherited in a simple fashion and have high heritabilities, which suggested that they are controlled by relatively few genes. They opined that the large chromosome number of okra (2n=130) provides an excellent opportunity for very wide recombination. Morakinyo and Adeyemi (2007) noted that all the accessions of okra they studied differed significantly in all the eighteen characters considered. All these attributes auger well for the rapid in situ improvement of local okra cultivars to meet local needs as suggested by Okonkwo (1984).

What is urgently needed is serious and sustained effort to retrieve the remaining local okra germplasm which are still under the custody of subsistent local farmers with a view to establishing a comprehensive national okra gene bank. In fact in their analysis of the variation patterns in okra germplasm, Fatokun *et al* (1979) observed significant differences between the exotic and locally collected materials, with the range of variability among the local collections being higher. This according to them provided further evidence to support Harlan's (1971) assertion that West Africa is a centre of diversity for okra.

Having established the pattern of inheritance of fruit skin colour in the three local okra cultivar used for this study, the next stage is to carry out wider two way crosses involving Awgu early as donor parent and other identified high yielding okra cultivars that require both the green fruit skin colour as well as high mucilage content to meet consumers demand in the country.

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