Original Research Article

DIALLEL ANALYSIS OF SWEET POTATO [*IPOMOEA BATATUS (*L.) LAM] GENOTYPES FOR COMBINED BETA CAROTENE AND DRY MATTER CONTENT IN SOUTHERN GUINEA SAVANNA, NIGERIA

Abstract

Roots of orange-fleshed sweet potato varieties currently available in Nigeria contain high quantities of β-carotene or pro-vitamin A but have high moisture content. These varieties have been found to be a cheap and crucially important remedy for vitamin A deficiency. The cream or white-fleshed varieties, on the other hand, have a sweet taste with high dry matter content, giving a dry texture, a quality trait preferred in Nigeria. Development of sweet potato genotypes that can combine these two important quality traits is the objective of this breeding work. A diallel experiment using six parental sweet potato genotypes crossed in all possible combinations were carried out and thirty progenies were evaluated for beta carotene (β-carotene) and dry matter content in Landmark University, Omu Aran, Kwara State, Nigeria. The 30 F_1 progenies along with their parental lines were planted in the same field trial. The trial was laid out in 6 x 6 triple lattice in two replications. Highly significant ($P \leq 0.01$) differences were observed among the genotypes for the traits. The average β-carotene content among the progenies was 2.86 (mg/100g.f.w) while the dry matter content had a mean value of 31.89%. The cross progenies 199024.2 x Excel had the highest beta carotene (14.37mg/100g.f.w) content with the highest dry matter content (40.10%) and are therefore recommended for further evaluation.

Key words: Diallel analysis; dry matter; Southern Guinea Savanna; sweet potato; Vitamin A, β-carotene.

INTRODUCTION

Sweet potato [*Ipomoea batatas* (L.) Lam] is the seventh most important crop in the world with an estimated 124 million metric tons produced annually. In the tropics, sweetpotato ranks fifth in terms of caloric contribution after rice, wheat, maize, and cassava [1,2]. In many developing countries, sweet potato is a staple because they are easy to propagate and maintain and yield well under a variety of adverse conditions, including drought. The potential of this crop as a food and a carbohydrate source is widely recognized [3].

Sweet potato is one of the most under exploited of the developing world's major crops [4] as evidenced by its breeding initiatives that are at relatively early stages compared to other crops. The need to identify local germplasm with desirable traits has long been recognised by breeders [4]. It has been long known that many sweetpotato traits are mainly quantitatively inherited [5]. To meet the quality needs there is a need to take into account the farmer and consumer preferences when developing and selecting sweetpotato varieties and in most cases, this can be addressed through participatory variety selection. Fortunately, the attributes considered most important by farmers and consumers were already identified and ranked by [4]. Given the enormous genetic diversity of sweet potato in Uganda [6], the possibility for sweetpotato improvement to accommodate specific uses is expected to be rapid [4]. There is wide genetic variability for vitamin A occurring naturally in sweetpotato. This means conventional breeding techniques can be employed to combine β-carotene and dry matter into sweetpotato varieties.

Diallel mating designs have been widely used in genetic research to investigate the inheritance of important traits in a set of genotypes [7, 8]. Diallel mating designs were devised, specifically to investigate the combining ability of the parental lines for the purpose of identification of superior parents for use in hybrid development programmes. A diallel cross is a set of *p2* possible single crosses and selfs between *p* homozygous [9,10,11,12] or heterozygous [13] parents; it provides a powerful method for investigating the relative genetic properties of these parents. It is possible to partition treatment variation into components due to general combining ability (GCA) and specific combining ability (SCA) [14, 7, 16, 17]. General combining ability (GCA) is the average performance of a genotype in hybrid combination while Specific combining ability (SCA) are those cases in which certain combinations perform relatively better or worse than expected on the average [18]. The estimates of the relative magnitude of the variances of GCA and SCA indicate the type of gene action determining the traits. Variance due to GCA indicates the predominance of additive gene action while that of SCA indicates the predominance of non-additive gene action arising largely from dominance and epistatic deviations [19]. Evaluation of dry matter, starch and beta-carotene content in orange-fleshed sweet potato (*Ipomoea batatas* L.) genotype tested in three agro-ecological zones of Malawi has been described by Kathabwalika et al. [20]. Little, however, appears to have been reported about the relationship between the sensory characteristics and the physical and chemical constituents, such as carotenoids or dry matter. For example, for consumers in Africa, it has been reported that they prefer high dry matter varieties of sweet potato [21-23] . The present research examined the quantitative inheritance of important traits in sweet potato by means of a diallel analysis with a view to estimating the GCA and SCA components of genetic variance, and to determine the associated type of gene action controlling β-carotene content and root dry mass.

2. Materials and Methods

2.1. Description of the Study Area

A field experiment was conducted on six sweet potatoes genotypes (three orange flesh and three white flesh) at the Teaching and Research Farm of Landmark University, Omu Aran, Nigeria. The experimental site is located at the Southern Guinea Savanna agro-ecological zone of Nigeria with district wet and dry seasons. The land had been used continuously for the cultivation of arable crops like maize, melon, cowpea and vegetables for more than three years. Soil samples were collected from the trial site before cropping and were analyzed in the laboratory for physical and chemical properties (Table 2). The soil texture was loamy sand.

2.2. Treatments and Experimental Design

The parent's materials used for the experiment were obtained from the germplasm collection centre of the Department of Agronomy, the University of Ibadan which was originally from the listed sources in Table 1. The parents were selected on the basis of being cross-compatible. Hand crosses were carried out in a 6 x 6 full diallel, excluding selfs from 2010 to 2011 at the Teaching and Research Farm of Landmark University, Omu Aran, Nigeria. Fruits were harvested between 30-50 days after pollination in the early morning to prevent scattering. The fruits were further air dried, shelled, put in a labelled envelope and kept in desiccators. The harvested seeds were soaked in water over night and planted into polythene bags filled with loamy soil. Once the plants were about 30cm tall, they were transplanted to well-prepared ridges for further growth and development. Twenty cuttings of a 25cm length of the sweet potato vines from F_1 progeny were made to represent each cross. The selected 30 F_1 progeny along with their parental lines were planted in the same field trial. The trial was laid out in 6 x 6 triple lattice in two replications. The plot size used was 3m x 1m in two rows. Each plot comprised the 20 cuttings from each progeny of a cross. Each vine was inserted at a slant, with two-third buried below the soil surface. Weeding was done 4, 6 and 8 weeks after planting, using small hoes. No herbicides or fertilizers were applied. Appropriate agronomic practices were followed to raise a good crop.

2.3. Data Collection

All data were recorded on an individual plant basis and then averaged across the 20 progeny of each F_1 cross. The quantitative traits were evaluated as follows: β- carotene content expressed as mg 100 g^{-1} and dry matter content (g) expressed as a percentage of root fresh mass (g).

2.4 Statistical analysis of triple lattice

Data collected on the two traits were subjected to diallel analysis using Griffing (1956) Method II (parents and crosses together), Mixed I (fixed effects). Both general and specific combining abilities were computed using [20] for the parent and crosses.

Diallel analysis

To test the null hypothesis of no genotypic differences among parents and crosses, one-way analysis of variance was performed. Treatment sum of squares was partitioned into three components, parents (P), crosses (C), and parent vs. crosses (P. vs. C.). General Combining Ability and Specific Combining Ability variance components of the cross mean square was computed according to Griffing's (1956) fixed-effects model I. Reciprocals were defined as being below the diagonal, adopting [14] notation the following genetic statistical model for analysis within one environment.

3. Results

3.1 Analysis of variance for β-carotene and dry matter content

β-carotene content and dry matter content means squares were both significant ($p<0.01$) among the parents and their 30F1 families, this shows that there is genetic variation among the parents and their crosses as shown in table 4. Crosses out-performing their parents can be attributed to transgressive segregation which is desirable for improving β-carotene content and dry matter content. The results of average performances of some of the crosses presented in table 5 show that the performances of crosses are significantly higher than the two parents for the traits. Cross 1 x 3 had the highest values in term of β-carotene and dry matter content with means of 14.37 mg 100 g^{-1} and 40.10% respectively followed by 1 x 4 for β-carotene content with means of 12.39 mg 100 g^{-1} and dry matter content with a mean of 30.05% while 2 x 4 had the least β-carotene content and dry matter content with a means square values of 0.03 mg 100 g^{-1} and 31.15%.

3.2 General and specific combining ability analysis for β-carotene content and dry matter content

General combining ability and Specific combining ability mean the sum of squares for β-carotene content and dry matter content were highly significant ($p<0.01$) across the parents, parent x cross and the crosses as presented in Table 6. The mean squares for reciprocals of β-carotene content were significant ($p<0.01$) whereas mean squares for the dry matter for the reciprocal is not significant.

3.3 COMBINING ABILITY EFFECTS

3.3.1 Beta-carotene content

Table 7 presented estimates of GCA effects for β-carotene content and dry matter content of six sweet potato parents. The GCA effects for β-carotene content of parent 1, 2 and 3 were positively and highly significant ($p<0.01$). The GCA effects for parent 5 is significant ($p<0.01$) but negative. The GCA effect for parent 4 and 6 was negative and was not significant. The SCA effects of crosses 1 x 2, 1 x 4,1 x 5 1 x 6, 2 x 3, 2 x 5, 2 x 6 and 3 x 5 were positive and highly significant ($p<0.01$)(Table 8) whereas cross 3 x 6, 4 x 6 is also significant but negative. The rest of the crosses are positive and not significant, apart from 1 x 3 which was negative and is not significant ($p<0.01$). Four reciprocals (5 x 2, 5 x 4, 6 x 5 and 6 x 2) were not significant ($p<0.01$)

and negative except cross 6 x 2 which is positive. Crosses 3 x1 and 3 x 2 were highly significant although they were negative. The rest crosses were positive and highly significant ($p<0.01$) (Table 8).

3.3.2 Dry Matter Content

The GCA effects for parent 2, 4 and 6 were positively and highly significant ($p<0.01$). The GCA effects for parent 1 is also significant ($p<0.01$) but negative. The GCA effect for parent 5 was not significant but positive (Table 7). Crosses 1 x 2 and 3 x 5 were positive although not significant (Table 8). This is against crosses 2 x3, 3 x 4, 4 x 5 and 4 x 6 which were negative and not significant ($p<0.01$). SCA effect for the rest of the crosses was significant ($p<0.01$) and positive (Table 8). For reciprocal, crosses 6 x 1 and 6 x 2 are the only crosses that were positively and highly significant ($p<0.01$).

4 Discussion and conclusion

4 .1 General and specific combining ability for β-carotene content and dry matter content

Both GCA and SCA variances were significantly (Table 5), this suggests that both additive and non-additive gene effects played a major role in the inheritance of β-carotene and dry matter content. The GCA and SCA mean squares for the β-carotene and dry matter content were significant ($p<0.01$). This implies that both additive and non-additive gene action were involved in their expression. This study indicates that additive gene action was relatively more predominant than non-additive gene action in controlling the expression β-carotene content and dry matter content. Hence, predicting progeny performance based on GCA for the traits will be largely successful. The highly significant ($p<0.01$) reciprocal mean squares for β-carotene and dry matter content indicates that maternal effects can play a major role in the inheritance of these traits and consequently the performance of a parent in a cross is dependent on whether it is used as a female or a male.

4.2 β- carotene content

The GCA effects for parent 1 (1.33) and (1.12) were significant ($p<0.01$) and positive indicating that additive gene action contributed positively to the expression β-carotene content consequently, their cross 1 x 2 is positive (3.28) and significant ($p<0.01$) SCA effect. This means that the interaction between the parent for the non-additive gene action resulted in the cross performing above the expectation based on additive effects. The crosses that had positive and significant ($p<0.01$) SCA effects were 1 x 4, 1 x 5, 1 x 6, 2 x 3, 2 x 5, 2 x 6 and 3 x 5 indicating that the non-additive gene action arising from the interaction of the parents contributed positively to the expression of the trait. Parents 5 that had negative GCA effects (- 0.44) produced a cross with a positive (0.022) and highly significant ($p<0.01$) SCA effect (Table 6).This shows that parents cannot be disqualified solely on the basis of negative GCA effects. In other word, parents with high positive GCA effects did not necessarily produce crosses with the desired performance. The parents used in this study, as well as the crosses, generated exhibit different level of significant and desirable crosses were obtained from crossing parents with high GCA effects with parents with low GCA effects that is 1 x 5, 2 x 5 and 3 x 5.

4.3 Dry Matter Content

The GCA and SCA mean squares for dry matter content were significant ($p<0.01$), but the reciprocal mean square was not significant. For the specific combiners for dry matter content parent 3 had a positive GCA and their crosses with parent 1 and 2 given dry matter content of 40.01% and 38.20%.

5. Recommendation

It is, therefore, recommend that:

1. The parent 1 and 3 identified to be good general and specific combiners of β- carotene and dry matter content should be further intrigressed into other proven cultivated in the improvement of β- carotene and dry matter content in sweet potato.
2. The identified crosses with the highest dry matter and β- carotene content could be incorporated into an on-farm trial for proof.

Table 1: Parental genotypes and their traits used in a 6x6 full diallel excluding selfs

No	Genotype	Root flesh colour	Root Dry mass (%)	Source
1	199024.2	Orange	31.02	CIP Kenya
2	440034	Orange	26.92	CIP Kenya
3	Excel	Orange	28.53	South Africa
4	W-151	Yellow	34.29	CIP Kenya
5	TIS 87/0087	White	30.67	IITA Ibadan
6	440168	White	32.31	CIP Kenya

Table 2. Physical and chemical characteristics of the experimental site soil at Landmark University, Omu Aran.

Physical characteristics	**properties**
Texture	Loamy sand
pH 1:1 (H_2O)	5.4
Sand %	84.1
Clay %	8.02
Silt %	6.42
Chemical characteristics	

Exchangeable Ca^{2+} (C. mol kg $^{-1}$)	1.12
Exchangeable Mg^{2+} (C. mol kg $^{-1}$)	1.62
Exchangeable Na^{+} (C. mol kg $^{-1}$)	0.19
Exchangeable K^{+} (C. mol kg $^{-1}$)	0.01
Total acidity H^{+} (C. mol kg $^{-1}$)	0.05
Cation exchange capacity (C. mol kg $^{-1}$)	2.83
% Organic Carbon	0.24
% Soil organic matter	1.03
% Total Nitrogen	0.24
Available Phosphate (mg kg^{-1})	20.31

Table 3 Analysis of variance for Griffing's (1956b) Model I, Method I and the expected mean squares for a full diallel.

Source	Df	sum of squares	mean squares	Expected mean squares	F-ratio
GCA	p-1	S_g	M_g	$\delta^2+2p[1/p-1]\Sigma gi^2$	M_g/M_e
SCA	p(p-1)/2	S_s	M_s	$\delta^{2+1/p(p-1)}\ \Sigma_i\Sigma_j s_{ij}^2$	M_s/M_e
Reciprocal effects	p(p-1)/2	S_v	M_v	$\delta^{2+2[2/p(p-1)]}\ \Sigma_i\Sigma_j r_{ij}^2$	M_r/M_e
Error	M	S_e	M_e	δ^2	

Table 4: ANOVA for six sweet potato parents and their 30 F_1 families evaluated in a triple lattice design

Source		Mean squares	
	Df	**β-carotene content(mg 100 g-1)**	**Dry Matter content (%)**
Rep	1	0.75^{ns}	7.85^{ns}
Treatment	35	38.39**	34.28**
Block within reps	35	14.1	29.60
Intra-block error	70	0.32	5.10
Total	141		

*, ** Significant at ($p<0.05$) and ($p<0.01$) (F-probability) respectively; ns=not significant

Table 5: Block corrected means for six sweet potato parents and their diallel evaluated

Parents/Crosses	β-carotene content (mg 100 g^{-1})	Dry Matter content (%)
1 x 2	1.5	33.00
1 x 3	14.37	40.10
1 x 4	12.39	30.5
1 x 5	1.32	31.88
1 x 6	3.37	28.43
2 x 3	5.49	38.67
2x 4	0.03	31.15
2 x 5	0.03	27.38
2x 6	1.74	27.27
3 x 4	1.5	29.49
3 x 5	0.12	31.67
3 x 6	1.38	35.71
4 x 5	0.02	37.04
4 x 6	0.03	38.89
5 x 6	1.38	34.15
Reciprocal		
2 x 1	11.03	33.82
3 x 1	4.92	31.86
4 x 1	4.41	29.73
5 x 1	0.12	34.00

6 x 1	1.38	34.78
3 x2	4.92	25.86
4 x 2	0.13	35.00
5 x 2	1.66	32.69
6 x 2	1.50	34.72
4 x 3	6.12	32.56
5 x 3	4.92	28.30
6 x 3	0.03	33.33
5 x 4	1.38	24.49
6 x 4	1.5	33.94
6 x 5	0.03	27.47
Parent 1	13.38	36.25
Parent 2	0.15	32.00
Parent 3	5.49	26.47
Parent 4	0.00	25.86
Parent 5	0.03	29.73
Parent 6	0.12	28.30
Mean	2.86	31.89
s.e	0.39	5.38
CV (%)	15.1	7.01
LSD $_{0.05}$	0.85	6.04

Table 6: Combining ability ANOVA for β-carotene content and dry matter content

Source	Df	Mean squares	
		β-carotene content(mg 100 g^{-1})	**Dry Matter content (%)**
Rep	1	0.65**	7.85^{ns}
Parent	5	31.39**	134.28**
Parent x cross	1	11.1**	29.60**
Crosses	11	62.32**	25.10**
GCA	5	83.98**	54.76**
SCA	6	53.76**	10.80**
Reciprocal	12	54.23**	6.9ns
Error	100	0.032	7.63
Total	141		

** Significant at *p*<0.01 (by *F*-probability); ns=not significant; GCA=variation due to general combining ability, SCA=variation due to specific combining ability, reciprocal=variation between reciprocal

Table 7 Estimates of GCA effects for β-carotene content and dry matter content of six sweet potato parents

Parent	β-carotene content	Dry Matter Content
1	1.33**	-3.41**
2	1.12**	4.38**
3	0.50**	- 2.88**
4	-2.13ns	2.05**
5	-0.44**	0.12ns
6	-0.355ns	1.04**

** Significant at $p<0.01$ (by *F*-probability); ns=not significant.

Table 8: Estimates of SCA effects for the Diallel analysis for β-carotene content and dry matter content

Crosses	β-carotene content (mg 100 g-1)	Dry Matter content (%)
1 x 2	3.28**	1.64ns
1 x 3	-2.14ns	3.10**
1 x 4	5.16**	0.78**
1 x 5	0.022**	1.88**
1 x 6	3.37**	3.43**
2 x 3	5.49**	-8.67ns
2x 4	0.03ns	1.15**
2 x 5	4.03**	2.38**
2x 6	1.74**	2.92**
3 x 4	1.27ns	-2.49ns
3 x 5	0.12**	1.67ns
3 x 6	-1.38**	3.76**
4 x 5	-0.02ns	-3.04ns
4 x 6	-7.03**	-3.89ns
5 x 6	-1.38ns	3.15**
Reciprocal		

2 x 1	11.03**	-3.82ns
3 x 1	-4.92**	-1.86**
4 x 1	-6.41**	2.73**
5 x 1	-3.12**	3.00ns
6 x 1	1.38**	3.73**
3 x2	-4.92**	-2.06ns
4 x 2	0.13**	-3.00ns
5 x 2	-1.66ns	2.69Ns
6 x 2	5.50ns	3.72**
4 x 3	6.12**	-3.56
5 x 3	4.92**	2.30ns
6 x 3	0.02**	-3.33
5 x 4	-1.38ns	-2.49
6 x 4	1.5ns	-3.94ns
6 x 5	-5.03ns	2.47ns

*, ** Significant at ($p<0.05$) and ($p<0.01$) (*F*-probability) respectively; ns=not significant

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