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ENVIRONMENTAL EFFECTS ON THE HERITABILITY OF QUANTITATIVE TRAITS OF HYBRIDS WHITE GUINEA YAM *(Dioscorea Rotundata)* IN THE RAINFOREST AGRO-ECOLOGICAL ZONE OF SOUTHEAST NIGERIA

Nwankwo, I.I.M., Akinbo, O.K. and Ikoro, A.I.
National Root Crops Research Institute, Umudike, P.M.B 7006, Umuahia. Abia State, Nigeria
Corresponding Authors' email address: nwankwomaxwell@yahoo.com

ABSTRACT
The study was conducted at the western experimental field of National Root Crops Research Institute (NRCRI) Umudike Umuahia Abia State-Nigeria from 2017 to 2018, to determine the environmental effect on the heritability of quantitative characters of the intra-specific hybrids of White yam (Discorea rotundata) in the rainforest agro-zones of Southeastern Nigeria. A total of 13 white yam genotypes were used in the study. The trial was laid out in a two factor factorial in a Randomized Complete Block Design (RCBD). Each plot measured 4.5m2, while each block contained 13 plots replicated six times. Data collected were on three competitive plants on the following plant characters: number of upright shoots, number of leaves, number of lateral branches, leaf area, leaf area index, Stand count at harvest, fresh tuber weight, dry matter of the tuber, tuber shape index, crop growth rate at 4 months after planting and days to physiological maturity. Data collected were subjected to analysis of variance, simple linear correlation, genetic correlation, estimation of the variations of genotypic and phenotypic coefficients in both environments plus Broad sense heritability estimates in both seasons. The result indicated that the physiological maturity of the yam genotypes evaluated had very low coefficient of variability of 0.61% in 2017 and 2018 respectively. This indicated limited scope for further improvement by direct selection of this character. The low heritability estimates of days to physiological maturity (5.07% in 2017 and 0.07% in 2018) and crop growth rate at 4 months after planting (0.02% in 2017 and 0.01% in 2018) indicated that environmental factors played a predominant role in the determination of the expression of these plant characters. If selected, these characters may not be repeated as indicated by its genetic correlation. As a result the yield of tuber dry matter and yield may not be predicted

Keywords: Environment, heritability, yam genotypes and quantitative characters

Introduction

White guinea yam (*Dioscorea rotundata* Poir) is a prestigious and important carbohydrate food especially for the people of West Africa. Nigeria produces three quarters of the global output. FAO (2002) reported the figure to be 33 million metric tonnes annually. White yam yields are sensitive to numerous environmental factors such as water (soil moisture), temperature, light and photoperiod (Orkwor and Asiedu, 1998). Jaimini *et al* (2004), reported that yield is a complex quantitative character, highly influenced by environmental fluctuations and that direct selection for yield could be misleading. Gratius (2010) in his study on barley observed that yield is an end product of multiplicative interaction among yield components and environment. However, Sikka and Jian (2008) stated that the determination of the correlation coefficients of yield and the effect of the environment on the yield components will be helpful in selecting suitable genotypes based on selection of two or more characters that can perform in any environment.

The genotypic variability and the heritability of characters determine to a large extent the rate of environmental effect on the genotypes. Hence, it is essential to partition the overall variability into its heritable and non-heritable components in order to determine the most effective breeding procedures to adopt for selecting crop genotypes stable across the agro-ecological zones (Li, 1981). Ariyo (1995) emphasized that the response of correlated characters can be predicted if genetic correlations and heritability of the characters are known. However, as more characters are involved in the correlation studies, the indirect associations between characters become more complex. In such a complex situation, stepwise multiple regression analysis becomes of great value in identifying and eliminating those characters not contributing significantly to the yield of the crop. The objective of this study therefore, is to examine the "environmental effect on the heritability of quantitative characters of the intra-specific hybrids of White yam (*Discorea rotundata*) in the rainforest agro-zones of Southeast Nigeria".

Materials and Methods

The study was conducted at the western experimental field of National Root Crops Research Institute (NRCRI) Umudike Umuahia Abia State, Nigeria from 2017 to 2018. Ten hybrid white yam genotypes and three landraces (a total of 13 white yam genotypes) were used in the study. The trial was laid out in a two factor factorial in a Randomized Complete Block Design (RCBD) with six replications. Each plot measured $4.5m^2$, while each block contained 13 plots replicated six times giving a total of 78 plots. The yam tubers for the experiments were cut into setts. Each sett size weighed 40g. The seed setts were planted at spacing of 45cm within plants and 100cm between ridges giving a total of 10 stands per plot, 130 yam plants per block and 780 yam plants for the six blocks. Weeding was done manually when necessary. No herbicides and pesticides were used. Data were collected on three competitive plants on the following plant characters: number of upright shoots, number of leaves, number of lateral branches, leaf area, leaf area index [(computed by dividing the leaf area per plant by the planting distance/area covered by the plant following Roderick, (1978)]. Stand count at harvest, fresh tuber weight, dry matter of the tuber (obtained by drying 100g of fresh weight of the tuber from each variety in a ventilated oven at 80^oC for 48 hours), tuber shape index [(calculated by ratio the length of the tuber measured to a ruler by the diameter of the tuber measured with venire calipers (Nwachukwu, 2000)], leaf area [(obtained by using the grid or graph method and multiplied by the number of leaves on the yam plant (Roderick, 1978)], crop growth rate at 4 months after planting and days to physiological maturity.Data collected on competitive yam plants from each genotype in a plot were averaged on single plant basis. The plot means were subjected to analysis of variance. Analysis of variance was used to analyze**:** 1) Tuber yieldand other yield component characteristics. Linear model for the analysis was:Xij = Ui + Bi + Ej + Ti + Tjk + Et**.** Where Xij = value of Observation, Ui = common mean, Bi = block effect,Eji = Varietal effect,Ti = Year effectTjk = Year x varietal effect,Et = error term**.** Mean separation was done using Standard Error of Difference for most of the characters as described by Obi (1986).

Estimation of Genetic Parameters

The estimation of genetic parameters was done using genotypic coefficient of variation, phenotypic coefficient of variation and genetic correlation. The genotypic coefficient of variation and phenotypic coefficient of variation were estimated using the following formulae suggested by Burton (1952) and used by Nwankwo (2008), Warwick and Legate (1981), Kumar *et al* (1985), Sharma (2004), Jawahar (2006) and Rangeswamy (2010).

(i) Estimation of genotypic coefficient of variability

$$GCV = \sqrt{\frac{VG}{X}} \times \frac{100}{1}$$

(ii) Estimation of phenotypic coefficient of variability

$$PCV = \sqrt{\frac{VP}{X}} \times \frac{100}{1}$$

Where,

VG = Genotypic Standard deviation, VP = Phenotypic Standard deviation, X = Grand mean of the character under consideration, Genotypic and phenotypic variations were used to determine real heritable differences and environmental (non-heritable) factors. Estimation of Heritability (in broad sense) according to Warwick and Legate (1981) and Sharma (2004) was used to estimate the heritability of all the characters.

$$h_{bs} = \frac{VG}{VP} \times \frac{100}{1}$$

Where h_{bs} = Heritability in broad sense, VG = Genetic variance, VP = Phenotypic variance

Simple correlation coefficients were computed. Broad Sense heritability estimates were calculated using the formula suggested by Allard (1987), Singh and Chaudary (1979). Genotypic and phenotypic coefficients of the genetic correlation were calculated from the variances and co- variances of the characters according to Falconer (1981), Warwick and Legate (1981).

Results and Discussion

The result of climatic data for the two seasons (Table 1a and 1b) indicate the variation in the weather and this affected the performance of the genotypes. Highly significant differences exhibited by the genotypes based on the quantitative characters measured indicated existence of sufficiently wide base genetic variation for selection. In 2017, the tuber dry matter yield varied from 0.55kg per plant for UYT/20/052 and Nwopoko to 1.02kg per plant for UYT/20/001, while in 2018, tuber dry matter yield varied from 0.44kg per plant for UYT/20/194 and Obiaoturugo to as high as 0.99kg per plant for UYT/20/094 (Table 3). The significant ($P<0.01$) genotype by environmental interactions observed for most of the morphological characters measured except for number of tubers and tuber shape index indicated that different morphological characters of the genotypes behaved differently under varied environmental conditions. For example, the combined result of the F-test on morphological characters for the two seasons in Table 2 indicated that the genotype by environmental interaction varied significantly ($P<0.01$) for number of shoots, vine length, number of leaves, number of lateral branches, leaf area, leaf area index, crop growth rate at 4 months after planting, fresh tuber yield and days to physiological maturity. However, no significant ($P > 0.01$) genotype by environmental interaction was observed in plant characters such as number of tubers per plant and tuber shape index in both years. This indicated that the environmental factors in both years had no influence on number of tubers per plant and this showed that number of tubers per plant were genetically determined and could not be varied by the environment (Table 2).

The thirteen hybrid yam genotypes evaluated for yield indicated wide range of genetic variability in tuber dry matter yield. Variability in tuber dry matter yield of the genotypes revealed that most of the yam genotypes behaved differently under varied environmental conditions. For instance, in 2017, the tuber dry matter yield of UYT/20/053 was 0.95kg per plant, while in 2018 the tuber dry matter yield of the same genotype was 0.61kg per plant (Table 3). This variation in tuber dry matter yield of the genotypes was as a result of environmental factor not genetic. This result confirmed the work of Becker and Leon (1988) in sweetpotato indicating that yield stability refers to a genotype's ability to perform consistently across a wide range of environments. However, before new hybrids are released, extensive multi locational trials have to be conducted in order to test their adaptability and stability across environments. Plant breeders carry out performance test at different locations in different years across target areas and data obtained from the tests are used to determine the magnitude of genotype by environment interactions. The yield component plant characters which contributed to the tuber dry matter yield were also influenced by environmental factors. The environmental influence affected the performance of the tuber dry matter yield of the hybrid yam genotypes.

The plant characters were regressed against tuber dry matter yield. The combined correlation analysis indicated non-significant ($P > 0.05$) correlation of all the plant characters with tuber dry matter yield in 2017. However in 2018, there was positive significant ($P<0.05$) correlation of the following plant characters with tuber dry matter yield: number of leaves ($r = 0.590$*), number of lateral branches ($r = 0.932$*), leaf area ($r = 0.695$*), leaf area index ($r = 0.569$**), number of tubers ($r = 0.647$**), and tuber fresh yield ($r = 0.669$*). The positive significant correction is an indication that these plant characters could be improved simultaneously with plant dry matter yield. This means that the improvement of one character leads to the improvement of the other leading to linear increase in tuber dry matter yield. However, there was negative significant correlation ($r = - 0.606$*) of tuber dry matter yield with days to physiological maturity. This indicated that these two plant characters cannot be improved simultaneously.

Characters which had significant negative correlation with tuber dry matter yield implied that both quantitative characters cannot be improved simultaneously. There was significant negative correlation of tuber dry matter yield with days to physiological maturity ($r = - 606$**). The implication of this observation showed that at the maturity of the yam plant, when all the leaves senescence and dry up, photosynthesis no longer takes place, therefore phosynthates are no longer being translocated to the sink which is the tubers.

This confirms the work of Mba (1995) on yam plants that tuber fresh yield and dry matter content are competing components, and any negative correlation arising between tuber dry matter yield and days to physiological maturity indicated that assimilation by the crop had reached physiological ceiling and any dry matter accumulation becomes limited. He also added that if there is no negative correlation between the two parameters, this suggested that a yield plateau has not been reached. In the present study, the correlation was significantly negative ($r = - 606$**) confirming that a yield plateau has been reached. The resultant yam tuber assumed its physiological shape and characteristics. Again, the non-significant correlation coefficient between the tuber dry matter yield and days to physiological maturity in 2017 and the negative significant correlation between the two traits in 2018 were indications of environmental influence. Therefore, this result implied that environmental factors affected the rate of this character association with tuber dry matter yield and indirectly with one another and this influenced yield.

The considerable influence of the environment on plant characters is an indication that the characters have low heritability estimates (Nwankwo, 2008). This is further proved by heritability estimate. The combined genetic estimates measured for the two years showed that all the plant characters evaluated had moderate to very high heritability estimates except crop growth rate at 4 months after planting (0.02% in 2017 and 0.07% in 2018) and days to physiological maturity which had 5.07% in 2017 and 0.07% in 2018. This was an indication that these two plant characters cannot be inherited for further development. For plant characters to be selected for further improvement, it must have moderate to high percentage genotypic coefficient of variability and high heritability estimate. For the characters to be selected based on eye assessment, it must have high percentage of phenotypic coefficient of variability. Plant characters with very low heritability estimates indicated that the environmental factors had considerable influence on the plant characters. This influence will have either positive or negative influence on the tuber dry matter yield of the hybrid yam genotypes.

Moreso, days to physiological maturity had very low coefficient of variability of 0.61% in 2017 and 2018 respectively. It also had very low heritability estimates of 5.07% in 2017 and 0.07% in 2018 (Table 5). This indicated limited scope for further improvement by direct selection of this character. Its low heritability estimates indicated environmental influence on the expression of this character. If selected, the performance of this plant character in terms of tuber dry matter yield may not be repeatable since it was not genetically determined.

Heritability estimate alone indicated that the effectiveness with which selection of the yam genotypes was made could be based on the phenotypic performance of the yam plants. Also heritability together with genotypic coefficient of variation provides dependable measures of the amount of genetic advance to be expected during selection (Burton, 1952 and Nwankwo, 2008). The low heritability estimates of days to physiological maturity (5.07% in 2017 and 0.07% in 2018) and crop growth rate at 4 months after planting (0.02% at 2017 and 0.01% at 2018) indicate that environmental factors played a predominant role in the determination of the expression of this plant character (Table 5). As a result of this, selection based on phenotypic performance alone may not be reliable. Plant characters that are highly heritable are important to the plant breeder since it enable him to base his selection on the phenotypic performance of the crop (Sharma, 1980). Johnson (1998) reported that heritability estimate shows the effectiveness with which selection of yam genotypes coud be based on the phenotypic performance. The usefulness of heritability estimate is increased when used along with genotypic coefficient of variability (Nwankwo, 2008). This suggested that high heritability estimates and high genotypic coefficient of variability should be used to achieve high selection gain of these characters for each location and based on environmental conditions. Consequent upon the results of this study, the following plant characters: fresh tuber yield, number of tubers, number of lateral branches and leaf area index in both years (2017 and 2018) could be selected to enhance tuber dry matter yield.

For selection to be effective, it must be based on the plant phenotype. That is by eye assessment. The phenotype of a plant character depends on its genetic and environmental correlation (Table 5). This is because the environment plays a tremendous role in plant character expression and selection for further breeding objectives. The significant positive genotypic and phenotypic correlation of these morphological characters with tuber dry matter yield suggested that these plant characters could contribute significantly to tuber dry matter yield per plant in both or either of the seasons. Characters not fully expressed in any of the seasons were due to environmental variation. Any of the morphological characters that are not phenotypically correlated will be difficult to select if selection is based on eye assessment (Ibe, 1998). Excellent yielding capacity alone does not make a variety satisfactory to farmers. An acceptable, stable and marketable variety must be genotypically superior in economic and agronomic traits which can be repeated in all environments. The identification and selection of yam genotypes with suitable genetically correlated quantitative agronomic characters for higher tuber yield would have great potential in terms of human nutrition. The agronomic benefits are such that it will be easy for farmers to adopt the new yam crops with certain yield components as the basis of selection for higher yield.

Conclusion

The results show that low heritability estimates of days to physiological maturity of 5.07% in 2017 and 0.07% in 2018 and crop growth rate at 4 months after planting (0.02% at 2017 and 0.01% at 2018) indicate that environmental factors played a predominant role in the determination of the expression of these plant characters. Their low heritability estimates implies environmental influence on the expression of these characters and therefore could not be used for determination of the tuber dry matter yield performance in the environments. If selected, these characters may not be repeated as indicated by their genetic correlation.

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Table 1a: Agro-metrological data of the experimental site for 2017

Months	Rainfall (mm)	No. of days	Temperature		Humidity %		Sunshine hours	Radiation
			Max.	Min.	0900	1500		
Jan	0.2	0	33	21	63	43	2.4	3.4
Feb	11.9	2	35	23	65	40	4.8	5.1
mar	22.4	4	36	24	66	44	4.0	4.3
April	134.5	9	32	24	78	67	4.6	5.0
May	217.6	11	32	22	76	66	5.7	4.2
June	279.4	18	30	23	83	76	4.1	3.3
July	309.5	18	29	22	85	78	3.6	1.7
Aug	304.3	21	29	22	87	76	1.7	1.8
Sept	324.9	19	30	23	85	72	3.2	2.7
Oct	249.1	16	31	22	82	74	5.0	3.7
Nov	52.5	4	33	22	81	64	4.8	4.8
Dec	5.1	1	33	21	80	57	5.6	3.2
Total	1911.40	123	283	270	934	757	49.5	43.2
Mean	159.28	10.3	31.9	22.5	77.8	63.1	4.1	3.6

Table 1b: Agro-metrological data of the experimental site for 2018

Months	Rainfall (mm)	No. of days	Temperature		Humidity %		Sunshine hours	Radiation
			Max.	Min.	0900	1500		
Jan	17.3	2	33	19	53	39	4.5	3.4
Feb	126.	5	35	23	79	56	5.2	5.4
mar	64.0	6	34	23	80	65	4.2	4.3
April	141.3	11	34	24	77	64	5.4	5.0
May	222.4	17	32	23	81	71	4.8	4.2
June	264.4	18	31	23	90	70	3.7	3.3
July	277.0	24	29	23	88	80	2.1	1.5
Aug	225.0	21	30	22	85	77	3.3	1.8
Sept	339.7	17	31	23	86	77	3.2	2.7
Oct	323.0	18	31	22	84	71	5.7	3.7
Nov	45.4	6	33	23	82	60	5.6	4.8
Dec	8.6	2	32	22	79	56	4.7	3.2
Total	2054.8	147	385	270	964	786	52.2	43.2
Mean	171.2	12.3	32.1	22.5	80.3	65.5	4.4	3.6

Table 2: Combined Results of F-test on the effect of environmentalfactors on the variability of Plant Characters for the two seasons combined

Source of variation	df	No.of shoot	Vine length	No. of leaves	No. of branch	Leaf area (cm)	Leaf area index	Crop growth rate (4MAP)	No. of tuber	Fresh tuber yield	Tuber shape index	Days to physiological maturity	Tuber dry matter yield
Year	1	21.24	38.36	62,91	36.04	7.06	470,54	0.25^{ns}	30.53	6.17	1.30	0.28^{ns}	4.30
Genotype	12	2.33**	5.51**	3.33**	6.52**	1.77*	10.15**	0.98*	1.77	2.61**	0.38^{ns}	0.99**	6.30**
Environment x genotype	12	2.30**	2.5**	11.10*	0.98*	1.47*	2.86**	1.02**	0.58^{ns}	1.32*	0.54ns	1.00*	1.08

* = Significant at 5% level of probability
** = Significant at 1% level of probability
ns = not Significant at either 1% or 5% level of probability

Table 3: Tuber dry matter yield of 13 yam genotypes in 2017 and 2018

Yam genotypes	2017 Tuber matter yield per plot (kg)	2018 Tuber matter yield per plot (kg)
UYT/20/053	0.95a	0.61bc
UYT/20/194	0.63b	0.44b
Obiaoturugo	0.56b	0.44b
UYT/20/001	1.02a	0.90a
UYT/20/095	0.67b	0.55b
UYT/20/006	0.57b	0.54b
Abii	0.59b	0.55b
UYT/20/092A	0.86a	0.92a
UYT/20/052	0.55b	0.91a
UYT/20/044	0.93a	0.77a
UYT/20/094	0.75ab	0.99a
Nwopoko	0.55b	0.47b
UYT/20/085	0.99a	0.88a
Mean	0.76	0.68
LSD (0.05)	0.28	0.33

Table 4: Linear Correlation Coefficient between plant characters and Tuber dry matter yield in 2017 and 2018 combined

			2017	2018
Tuber dry matter yield	x	Plant character	r - coefficients	r - coefficients
Tuber dry matter yield	x	No. of shoots	-0.030	0.030
Tuber dry matter yield	x	Vine length	0.461	0.085
Tuber dry matter yield	x	No. of leaves	-0.213	0.590*
Tuber dry matter yield	x	No. of branches	0.130	0.932*
Tuber dry matter yield	x	Leaf area	-0.265	0.695*
Tuber dry matter yield	x	Leaf area index	0.066	0.569*
Tuber dry matter yield	x	Crop growth rate (4MAP)	-0.482	0.179
Tuber dry matter yield	x	No. of tubers	0.426	0.647**
Tuber dry matter yield	x	Days to physiological maturity	0.304	-0.606*
Tuber dry matter yield	x	Tuber shape index	0.080	-0.202
Tuber dry matter yield	x	Fresh tuber yield	0.627	0.669*

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Table 5: The estimates of phenotypic and genotypic coefficients of variability for characters measured in 2017 and 2018

Plant characters	Year	Mean performance	Phenotypic coefficient of variability (%)	Genotypic coefficient of variability (%)	Heritability (%)
No. of shoots	2017	1.90	28.64	22.50	61.70
	2018	1.23	22.96	12.76	30.00
Vine length (cm)	2017	2.70	15.10	13.47	80.90
	2018	2.31	8.53	6.75	62.53
No. of leaves	2017	315.00	11.97	8.70	52.86
	2018	227.60	19.99	15.72	61.85
No. of branches	2017	26.08	14.77	12.90	76.30
	2018	21.72	15.18	13.66	81.00
Leaf area (cm)	2017	156.85	29.93	16.44	31.86
	2018	9953.0	0.01	0.01	84.87
Leaf area index	2017	3.02	22.56	20.88	85.70
	2018	2.23	35.87	33.01	84.68
Crop growth rate (4MAP)	2017	187.90	731.98	111.11	0.02
	2018	188.10	174.07	187.08	0.01
No. of tubers	2017	1.95	7.79	9.15	131.80
	2018	1.52	16.82	13.50	64.47
Fresh tuber yield (kg)	2017	1.2	19.61	14.81	57.10
	2018	1.08	21.13	12.97	38.00
Tuber shape index	2017	2.41	11.23	13.46	143.90
	2018	2.57	8.43	15.33	50.07
Days to physiological maturity	2017	152.04	1.19	0.61	5.07
	2018	151.77	0.24	0.61	0.07
Tuber dry matter yield (kg)	2017	0.76	23.43	39.48	69.10
	2018	0.68	33.72	29.01	74.03

Table 5: The estimates of phenotypic and genotypic correlation coefficients between morphological characters measured in 2017 and 2018

Plant characters	correlation	1	2	3	4	5	6	7	8	9	10	11
No. of shoots	rg	0.41	0.79	0.92	0.35	0.63	0.82	0.00	-0.85	-0.85	0.30	-0.06
	rp	0.00	0.34	0.61	0.17	0.03	0.36	0.10	-0.62	0.94	0.07	-0.04
Vinelength(cm)	rg		0.78**	0.99**	0.79**	0.61**	0.05	0.63**	0.28	0.80	0.76	0.42*
	rp		0.35	0.34	0.83	0.21	0.15	0.19	-0.45	0.42	0.18	0.46*
No. of leaves	rg			0.93**	0.02	0.89	0.64	0.73**	0.31	0.36	0.52	-0.35
	rp			0.34	0.02	0.78	0.07	0.99	0.76	0.40	0.88	-0.20
No. of branches	rg				0.21	0.71*	0.63	0.78**	0.29	0.16	0.29**	0.22*
	rp				0.18*	0.59	0.06	0.86	0.15	0.81	0.73	0.76*
Leaf area(cm)	rg					0.91	0.67	0.62	0.39	-0.18	0.77	0.59*
	rp					0.92	0.20	0.46	-0.64	0.65	0.43	-0.27*
Leaf area index	rg						0.72	0.88	0.12	0.64	0.63	-0.09*
	rp						0.26	0.95	-0.79	0.60	0.56	0.07*
Crop growth rate (4MAP)	rg							0.08	-0.50	-0.40	0.49	-0.45
	rp							0.07	-0.48	0.54	0.58	0.06
No. of tubers	rg								0.23	-0.64	0.79*	0.45**
	rp								-0.40	0.15	0.80	0.92**
Days to physiological. maturity	rg									0.30	-0.80	0.82*
	rp										0.16	0.71**
Tuber shape index	rg										0.25	0.30**
	rp										-0.48	0.96**
Fresh tuber yield	rg											1.69*